Estimating the size of the resident populations living at a proximity linked to exposure risks to emissions from petrochemical production facilities in the virgin plastics value chain in 11 countries across Asia, Europe, and North America

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Executive Summary

Plastics are produced by extracting crude oil or fossil gas, which is purified, polymerised into resins, and then converted into plastic nurdles. These plastic nurdles are the feedstock for the production of plastic products. The processes of purification and polymerization, which is referred to as the midstream stage of the virgin plastics value chain, take place in petrochemical production facilities and are collectively referred to as the production of plastics-linked petrochemicals. Specifically, the midstream stage denotes the processes involved in transforming hydrocarbon feedstock from refineries into plastic nurdles.

This study uses geospatial analysis to estimate on a country-level the resident population size that lives within 5 or 10 km of a petrochemical production facility involved in the midstream stage of the virgin plastics value chain across 11 countries. Living in proximity to a petrochemical production site of this midstream stage has been associated with negative health effects. Possible causes of these effects include exposure to air pollutants emitted during plastic production processes. Thus, proximity to these plants is a risk factor for exposure and a cause for concern.

While the chemicals emitted and the concentrations of pollutants can vary across facilities, there is a well-established body of evidence—supported by scientific literature and documented cases—linking elevated rates of illness to air pollution emissions from nearby petrochemical production sites. A number of studies in the literature link living within 10 km of a petrochemical production facility with a risk of exposure to emitted air pollutants and an increased risk of health impacts, with populations living within 5 km facing the most pronounced exposure risk.

This study estimates that over **16 million people** across the 11 countries analysed reside within 5 km of a midstream stage petrochemical production facility associated with plastics manufacturing, in areas that this study refers to as 'elevated risk-of-exposure zones'. Estimates of the affected population size increase to more than **51 million people** when considering a 10 km proximity zone, which this study refers to as ‘extended risk-of-exposure zones’.

Country	**Estimated national and transboundary resident population living within within 5 km of a petrochemical production facility**	**Estimated national and transboundary resident population living within within 10 km of a petrochemical production facility**
Canada	765,000	2,312,000
Germany	1,320,000	3,962,000
Indonesia	2,039,000	6,484,000
Republic of Korea	1,427,000	4,777,000
Malaysia	1,390,000	5,124,000
The Netherlands	2,278,000	4,701,000
The Philippines	1,588,000	4,612,000
Switzerland	404,000	1,088,000

Thailand	1,178,000	4,008,000
United Kingdom	397,000	1,677,000
United States of America	4,106,000	13,119,000
Total:	**16,892,000**	**51,863,000**

The analysis found that:

1. The production of petrochemicals in the plastics value chain occurs within 10 km of areas with resident populations in all 11 countries studied in this research.
2. The Netherlands has the highest proportion of its population living near plastics-linked petrochemical production sites. Approximately 4.5 million people out of a total population of nearly 18 million (25.6%) are estimated to reside within 10 km of a petrochemical production facility.
3. Switzerland is the runner-up, with approximately 973,000 people out of a population of more than 8.8 million (10.9%) estimated to reside within 10 km facilities where petrochemical production takes place,
4. The United States has the largest number of people living near plastics-linked petrochemical production sites in absolute terms. Over 13 million Americans live within 10 km of a petrochemical production facility. The exposure risk is concentrated in Texas and Louisiana.
5. Airborne emissions from petrochemical production pose risks not only to local communities but also to populations across borders. Border zone areas in Canada, Germany, Malaysia, the Netherlands, Switzerland, and the United States contain petrochemical production facilities located within 10 kilometers of neighboring countries, placing communities on both sides at risk of exposure. These ‘transboundary exposure risk zones' highlight that pollution knows no borders.
6. The health risks associated with living near petrochemical production sites warrant further investigation in order to uncover the full extent of how upstream, midstream, and downstream plastics production processes affect people and communities. Cancer Alley in Louisiana, United States, is a well-documented example of how extreme pollution from the fossil fuel and petrochemical industries disproportionately devastates the health and lives of the African-American local population. Living alongside a dense concentration of petrochemical facilities, the communities in Cancer Alley face elevated rates of reproductive illnesses, respiratory ailments, and cancer (Human Rights Watch, 2024; Robinson et al., 2024).

This study estimates the risk of exposure to air pollution emissions from petrochemical production by place of residence alone, for resident populations living at a proximity tied to elevated health risks. Many other exposure pathways exist, and the real-life exposure scope may be larger than the estimates presented in this study. The results presented are not intended to assess the contribution of individual facilities to the level of risk to local resident populations from exposure to air pollution emissions, but rather to evaluate the potential proximity-based risk from exposure to air pollution emissions from the plastics-linked petrochemical production sector on a country-level. Therefore, any reference to “risk of exposure” in this report refers to the potential proximity-based risk from exposure to air pollution emissions, referred to above.

Contents

Introduction

The industrial production of plastics is a complex, energy-intensive process that transforms fossil fuels into synthetic polymers which are used extensively across sectors such as packaging, construction, healthcare, and electronics. This production system can be delineated into three principal stages:

Upstream: extraction and primary refining of fossil fuels (primarily crude oil and fossil gas) to yield hydrocarbon feedstocks;
Midstream: conversion of these feedstocks into base petrochemicals and their subsequent polymerisation into plastic resins;
Downstream: fabrication of end-use plastics products through moulding, extrusion, and other manufacturing techniques.

Both the upstream and midstream stages of the virgin plastics value chain, hereinafter referred to as ‘precursor production processes’, involve processes that transform and produce petrochemical feedstocks that supply the downstream stage, where end-use plastics products are manufactured.

This report focuses specifically on the midstream stage, which constitutes a central phase in the plastics lifecycle and will hereinafter be referred to as ‘petrochemical production’. It begins with the refinement of extracted fossil fuels into key feedstocks such as ethane, propane, or naphtha, which are then processed via high-temperature steam cracking and catalytic reforming. These reactions yield core monomers—including ethylene, propylene, butadiene, benzene, and other olefins and aromatics—that are subsequently polymerised into commercial resins such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS). These resins serve as the primary raw material for downstream plastic conversion.

The midstream phase is distinguished by its high operational intensity, both in terms of thermal energy demand and chemical throughput, as well as its significant environmental and public health externalities. Atmospheric emissions and waste streams associated with this stage include:

- Greenhouse gases (GHGs), including carbon dioxide and methane, which contribute directly to climate change;
- Volatile organic compounds (VOCs), such as benzene, toluene and 1,3-butadiene, many of which are hazardous air pollutants (HAPs) and ozone precursors;
- Other air pollutants, including particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides (NO_x), and sulfur oxides (SO_x).

Petrochemical production and health

Petrochemical production emits a range of harmful chemicals during the midstream phase of the plastics lifecycle. In this stage, feedstocks are primarily transformed through steam cracking and polymerisation into resins that form the basis of plastic products. During the process of steam cracking, an array of harmful pollutants can be released, including $PM_{2.5}$, PM_{10}, NO_x, SO_x, and VOCs. Among the more well-known VOCs emitted are benzene, ethylene, 1,3-butadiene, and toluene (Johnson et al., 2023). During polymerisation, additional VOCs—particularly benzene and 1,3-butadiene—may be released, depending on the specific type of polymer being produced (EIP, 2023). Among these pollutants, 1,3-butadiene and benzene are especially concerning due to their carcinogenic and neurotoxic properties. Chronic exposure to 1,3-butadiene increases the risk of leukaemia, benzene is linked to both leukaemia and reproductive harm in women, and long-term exposure to toluene can lead to adverse effects on the nervous and reproductive systems (IARC, 2012; CIEL, 2019). Despite regulatory controls and mitigation efforts, fugitive emissions from petrochemical facilities—often caused by equipment leaks or process upsets—can still occur and continue to pose significant health threats to surrounding residential populations.

A substantial body of literature from across Asia, Europe and North America establishes that geographic proximity plays a critical role in shaping health outcomes, including through pathways of air and water. Communities located nearer to petrochemical facilities face higher rates of illness, ranging from haematologic cancers (Jephcote et al., 2020), lung cancer (Lin et al., 2017, 2018), respiratory conditions (Domingo et al., 2020; Chang et al., 2020), kidney dysfunction (Yuan et al., 2021; Chin et al., 2022), and even adverse perinatal outcomes of low birth weight and preterm birth (Domingo et al., 2020; Huang et al., 2021; Oliveira et al., 2002; Yang et al., 2002), reflecting a clear spatial gradient of risk.

Therefore, public health agencies and researchers frequently adopt spatial buffers to assess and manage population vulnerability. For example, the United States (US) Environmental Protection Agency (EPA) commonly describes exposure zones within a 1 - 5 miles, approximately 1.6 to 8 km radius of facility operations (EPA, 2024)—a standard supported by numerous studies showing elevated concentrations of hazardous pollutants and elevated risks to health from cancer, respiratory illnesses, and reproductive harm within 2 to 10 kilometers of such facilities (Johnson et al., 2023; Domingo et al., 2020; Marquès et al., 2020). As petrochemical infrastructure continues to expand, understanding the spatial dynamics of exposure becomes increasingly critical for assessing cumulative health burdens, addressing environmental health disparities, and evaluating the human cost of continued petrochemical production.

Research objectives

The adverse health impacts of airborne pollutants emitted by petrochemical production facilities are well-documented. However, the number of people that live in the vicinity of a petrochemical production facility and are potentially at risk of exposure to air pollutants emitted from these production sites remains unclear in many parts of the world. In turn, this creates challenges in establishing an understanding of the health burden from petrochemical production on the resident population.

The aim of this study is to provide a quantitative estimate of the size of the populations at risk of being exposed to air pollutants emitted from petrochemical production, before the plastics fabrication stage, including emissions that are potentially harmful to human health and the environment. The goal is to expand our understanding of the potential impacts of the midstream stage of precursor production processes in the virgin plastics value chain. The production of plastic polymers and resins from recycled plastics materials, which involves crushing and melting the recycled materials to create nurdles used as feedstock for plastics products, is not considered in this study.

The spatial distribution of petrochemical production activities is first determined by leveraging a combination of open-access data, including governmental databases, publicly available corporate information, and self-published company data. Then it is compared against spatial population distribution data to estimate the sizes of the populations that live in risk-of-exposure zones.

In this study, the area within 5 km of a petrochemical production facility is defined as its **elevated risk-of-exposure** zone, comparable to zones used by the US EPA around petrochemical operations (EPA, 2024). The elevated risk-of-exposure zone is where people are considered to face a higher risk of exposure to air pollutants emitted by the facility compared to the general population. The area within 10 km is defined as the **extended risk-of-exposure** zone. The definition is based on evidence of increased concentrations of hazardous pollutants and elevated health risk recorded within 10 km of petrochemical operations, compared to background areas (Johnson et al., 2023; Domingo et al., 2020; Marquès et al., 2020). This study also defines and models **risk-of-exposure zones** as circles with radii of 5 km and 10 km, centred on the geographic coordinates of the either midpoint or the entrance of each petrochemical facility, depending on data availability.

The study area covers 11 countries across North America, East Asia, Southeast Asia, and Europe. Listed alphabetically, these countries are Canada, Germany, Indonesia, Republic of Korea, Malaysia, the Netherlands, the Philippines, Switzerland, Thailand, the United Kingdom (UK), and the United States (US).

Research scope and limitations

Definition of petrochemical production

The part of the plastics value chain that falls within the scope of this study is petrochemical production, which refers to the midstream stage of the plastics lifecycle, i.e., the manufacturing of **basic petrochemicals** such as ethylene, propylene, and benzene, and **petroleum-based polymers or resins** such as polyethylene (PE), polyethylene terephthalate (PET) polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC), although this list is not exhaustive. Basic petrochemicals are feedstocks in the production of petroleum-based polymers or resins. The petroleum-based polymers or resins mentioned above, which are known as nurdles when they are shaped as pellets, are common feedstocks in end-use plastics production. Petrochemical production facilities that produce and supply these feedstocks to the plastics value chain represent a subset of the overall petrochemical industry.

In addition to plastics, the broader petrochemical industry also produces feedstocks for the production of synthetic rubber, lubricants, dyes, paints, adhesives, and construction materials (Fractracker Alliance, 2025), which is not included in the scope of this study.

Production of plastics-linked petrochemicals

Petrochemical production is highly integrated, with major facilities typically supplying a wide array of end-use industries. This integration is especially pronounced in the production of basic petrochemicals, which serve as precursor chemical inputs for a wide host of industries that use fossil fuels in the manufacture of non-energy products, including plastics. The next stage along the value chain—converting basic petrochemicals into petroleum-based polymers and resins—is more specialised. Nonetheless, there are still broad crossovers and many facilities producing polymers and resins for the plastics industry also supply other industries.

The integrated infrastructures pose challenges when trying to identify which facilities belong to the plastics value chain. Many petrochemical production facilities support multiple industries, making it difficult or impossible to isolate those that supply plastics production specifically. To address this, the selection of facilities analysed in this study aims to be as comprehensive as possible, including all that are reasonably linked to the plastics industry.

For the purposes of this study, petrochemical production are defined at a facility level as follows:

- For basic petrochemicals, all identified facilities are included.
- For petrochemical polymers or resins, only facilities confirmed by government or industry sources to produce petroleum-based polymers or resins, also referred to as “plastics in primary forms” or “plastic raw materials”, are included.

While it is possible to identify the petrochemical production facilities that supply plastics production, in many cases these facilities do not only supply the plastics industry. As a result, not all air pollutant emissions from these facilities can be attributed solely to the plastics value chain. Accurately quantifying emissions tied to specific end-use product chains requires detailed facility-level analysis, which was not conducted in this study.

Consideration of exposure risk pathways

Exposure risk assessments are conducted based on an individual or household's place of residence, i.e., the resident population, which is defined as ‘all nationals present in, or temporarily absent from the country, and aliens permanently settled in the country (OECD, 2016)’. Consideration of other potential exposure pathways is not included in this study, such as occupation, access to childcare, healthcare, education, shopping or leisure activities.

Exposure risk assessment based on proximity of residence

The exposure risk to emissions from petrochemical production is assessed based on proximity to the production facilities alone, given evidence that these facilities emit a suite of pollutants, some of which can harm human health, and evidence that nearby communities face higher rates of health burdens. If a person resides within the elevated or extended risk-of-exposure zone, then they are considered to be at risk of proximity-based exposure in this study. However, within the parameters of this study, it is not possible to determine whether exposure risk translates to actual exposure. The actual emissions of a petrochemical production facility depend on a number of factors, including the products manufactured, operational protocols, pollution mitigation strategies, and technology. These factors are not considered in this study.

Research methodology

Summary
This study applied a GIS-based geospatial proximity analysis and followed three successive stages. First, the locations of all operational petrochemical production facilities in the study area were identified using secondary data, and plotted on a map. The range of secondary data sources used in this study, consisting of governmental databases, self-published company data, and corporate data sources, are described in the next section, under "Data category 1: Identifying the locations of petrochemical production facilities". Second, resident population distribution data, provided in gridded raster format, were overlaid onto the same map (Bondarenko et al., 2025). Finally, all raster data within the defined elevated or extended risk-of-exposure zones around each petrochemical production facility were totalled, to yield the total number of individuals in resident populations that live at a proximity to petrochemical production facilities linked to elevated risks of exposure to their emissions.

The analysis was performed in the open-source GIS software QGIS (QGIS.org, 2025) and used two categories of data, which are described in the following section.

Data category 1: Identifying the locations of petrochemical production facilities
The locations of operational petrochemical production facilities in the midstream stage of the plastics value chain are available via open-access data sourced from governmental databases, self-published company data, and secondary corporate information.

Cluster 1: Germany, the Netherlands, Switzerland, and the UK
Cluster 1 countries all maintain Pollutant Release and Transfer Register (PRTR) databases, from which the list of all petrochemical production sites and their locations were extracted. PRTRs are compilations of data on industrial activities within a country, including the locations of each facility, their ownership structure, and emissions. For this analysis, PRTR data was extracted for Germany, the Netherlands, Switzerland, and the UK (Thru.de, n.d.; Emissieregistratie, n.d.; FOEN, 2025; UK DEFRA, n.d.). The maintenance of PRTR databases is overseen by national authorities or affiliated governmental bodies. A list of the PRTR databases used in this study is provided in Table 1. All data was accessed between April 20 and May 11, 2025.

Cluster 2: Canada and the US
The Canadian and the US authorities maintain databases that are comparable in their tracking of industrial activity sites. The Canadian Greenhouse Gas Reporting Program lists all industrial facilities and their greenhouse gas emissions (Environment and Climate Change Canada, 2025). The US Facility Registry Service, managed by the US EPA, compiles information on the locations of industrial activity sites and their emissions in continental US and Puerto Rico (US EPA, 2025). The Canadian and US industrial activity databases used in this study are listed in Table 1. All data was accessed between May 7 and May 11, 2025.

Petrochemical production facilities in the databases of cluster 1 and 2 countries are identified and filtered using the industrial classification systems (ICS). Each facility in the PRTR databases or the Canadian and US equivalent is assigned an ICS code by the database, which indicates the product(s) that the facility manufactures. The ICS codes for the manufacturing of basic petrochemicals and petroleum-based polymers and resins are provided in Table 1.

Table 1. Databases of industrial activities and industrial classification system codes for the midstream stage of the plastics value chain (petrochemical production) for Canada, Germany, the Netherlands, Switzerland, the United Kingdom, and the United States of America.

Country	**Database name**	**Database source & year of data**	**Industrial classification system**	**ICS code for basic petrochemicals**	**ICS code(s) for petroleum-based polymers/resins**
Canada	Greenhouse Gas Reporting Program	Government (Current to 17/10/2024)	Canadian NAICS	325110	**325210*
Germany	German PRTR	Government (2023)	NACE	1920	2016
The Netherlands	Emissieregistratie ^ (Dutch PRTR)	Government (2023)	SBI	19201	20141 20160
Switzerland	SwissPRTR pollutant register	Government (2023)	NOGA	192000	201600
The United Kingdom	UK Pollutant Release and Transfer Register ^	Government (2023)	UK SIC	19200	20160
The United States of America	US EPA Facility Registry Service	Government (2025)	US NAICS	325110	***325211*

^One or more entries have been manually removed from the filtered output of the database following manual verification. These facilities were either decommissioned or confirmed not to be involved in petrochemical production and were likely misclassified.
**The Canadian NAICS code 325210 includes both petroleum-based polymers and resins production, as well as synthetic rubber manufacturing. Facilities identified as synthetic rubber producers were manually excluded, and the remaining entries were verified by the research team.*
***The US NAICS code 325211 is assigned to facilities producing petroleum-based polymers and resins. However, several facilities classified under this code were manually identified as biodiesel production sites. Due to the large volume of entries (over 2,000), it was not feasible to manually verify each facility. As a result, facilities under NAICS 325211 were excluded from the study. Consequently, the scope of petrochemical production analysis for the US is limited to the production of basic petrochemicals.*

Cluster 3: Republic of Korea, Indonesia, Malaysia, the Philippines, and Thailand

The countries in cluster 3 do not maintain a publicly available list of industrial production facilities that is classified by the manufactured product(s). Instead, petrochemical production facilities were identified by searching through open-access self-published company data and secondary corporate information. The initial data gathering was conducted by Greenpeace East Asia and the data underwent a source quality check. Only facilities that were confirmed to be in operation and producing petrochemical products that are within the scope of this study were included. These two criteria were checked by consulting the self-published information from the operating entities of the petrochemical production facilities and major media outlets. The compiled data then underwent an additional data verification process by a second Greenpeace East Asia team.

Self-published company data includes information on companies' own webpages, investor briefings, financial reports, press releases, and materials co-published with private or public entities. Information classified as secondary corporate data originates from sources other than the entities that operate or have ownership of the petrochemical facilities. They include publications by academia, the media, (inter)governmental agencies, financial data platforms, and industry/trade associations.

Self-published company data and secondary corporate data were cross-checked whenever possible. Sources were selected based on their credibility and established reputation. While every effort has been made to ensure quality, the comprehensiveness and accuracy of the list of petrochemical production facilities and their locations cannot be guaranteed. The data was collected in 2024 using the most recent sources.

All clusters: visual verification on Google Maps

The location data of petrochemical production facilities across the three country clusters was validated through visual verification on Google Maps. Petrochemical production facilities exhibit distinctive infrastructural features that differentiate them from the surrounding environment. These features enable identification through satellite imagery. The locations of all facilities except those in the US were confirmed using this method. Due to the high volume of facilities in the US, manual verification through satellite imagery was not feasible for each facility.

Data category 2: population count and distribution

Spatial population distribution datasets were extracted from WorldPop (Bondarenko et al., 2025) in May 2025 and used in this study. WorldPop is an open-access database of national and global geospatial raster data. WorldPop uses constrained top-down methods to estimate population count and distribution. The raster data gridded at a 100 x 100 metre resolution represents the number of people who are estimated to reside in each cell. Data for the year 2024 was used for all countries.

Petrochemical production facilities located near national borders may have risk-of-exposure zones that extend into neighbouring countries, which is defined as transboundary risk-of-exposure zones in this study. When this occurs, population count and distribution raster datasets for affected neighbouring countries were also included in the study. They are Austria, Belgium, France, Poland, and Singapore.

The WorldPop population count and distribution raster datasets were mapped to the global datum coordinate reference systems WGS84 (World Geodetic System 84). WGS84 models the Earth's surface, but it is unsuitable for more precise mapping in localised scales. The WGS84 coordinates from WorldPop were reprojected to local datum systems. The datum transformation process utilises the most commonly applied local datum systems for each of the 11 countries. These systems are typically based either on country-specific coordinate reference grids or on the Universal Transverse Mercator (UTM) zones corresponding to each country's geographic location.

The local datum systems applied in reprojection are listed in Table 2, below. Indonesia, Malaysia, the Philippines, Thailand, and the US span multiple local datum systems. For these countries, only the local datum systems corresponding to the geographic zones where petrochemical facilities are located are included in Table 2. The reprojections were executed on QGIS version 3.40.5-Bratislava.

Table 2. Local datum systems for geospatial applications

Country	National PCS	EPSG code
Canada	NAD83 / Statistics Canada Lambert	EPSG:3347
Germany	ETRS89 / UTM Zone 32N	EPSG:25832
Indonesia	DGN95 / Indonesia TM-3 zone 48.2 DGN95 / Indonesia TM-3 zone 49.2	EPSG:23834 EPSG:23836
Republic of Korea	Korea 2000 / Unified Coordinate System	EPSG:5179
Malaysia	Kertau (RSO) / RSO Malaya (m)	EPSG:3168
The Netherlands	Amersfoort / RD New	EPSG:28992
The Philippines	WGS 84 / UTM Zone 51N	EPSG:32651
Thailand	WGS 84 / UTM Zone 47N	EPSG:32647
Switzerland	CH1903+ / LV95	EPSG:2056
The United Kingdom	OSGB 1936 / British National Grid	EPSG:27700
The United States of America	NAD83 / Conus Albers	EPSG:5070

Geospatial analysis on QGIS

The geospatial analysis was executed in QGIS, version 3.40.5-Bratislava. The following steps were taken:

Step 1: The coordinates of petrochemical production facilities (data 1) and the reprojected population count and distribution raster datasets (data 2) were mapped, and overlaid.

Step 2: Buffer zones with radii of 5 and 10 km were generated around each petrochemical facility. The buffer zones are created by:

- First, individual buffer zones with radii of 5 and 10 km were generated around each petrochemical facility, resulting in individual zones for each facility. These are also the risk-of-exposure zones for each facility.
- Then, these individual buffers were combined to create buffer zones at the country level by merging overlapping areas into contiguous polygons. These polygons are the dissolved buffer zones. The purpose of merging overlapping areas is to ensure that they are not double-counted.

Step 3: Using zonal statistics, the raster data sums within the predefined dissolved buffer zones were calculated.

Step 4: The sum of raster population data within the dissolved buffer zones—where overlapping areas are merged into a single contiguous zone—represents the cumulative population estimated to live within 5 or 10 km of any petrochemical facility in the country. This approach eliminates double counting and provides a more accurate estimate of the total exposed population.

**The value of each 100 x 100 m grid cell in the population raster data layer was counted as long as more than 50% of the area of the cell falls within the buffer zone. All population figures were rounded to the nearest 1,000 to avoid implying false precision. Population estimates between 500 and 1,000 are represented as '< 1,000', while estimates below 500 are rounded down to 0."*

The next chapter presents the results of the geospatial analysis.

Results

The geospatial analysis produced estimates of resident population size in the elevated (5 km) and extended (10 km) risk-of-exposure zones surrounding petrochemical production facilities of the midstream stage of the plastics value chain in each of the 11 countries.

The country-level results are presented in the sections below, which summarise: (1) the number of operational petrochemical production facilities identified in each country as of the end of 2024, (2) the total estimated population at potential risk of proximity-based exposure, and (3) the breakdown of that population into national (residing in the same country as the facility) and transboundary (residing in a different country) segments. Country-level population figures were obtained from the World Bank (2025) and rounded to the nearest 1,000.

Canada

Petrochemical facilities upstream of plastics production in Canada are centralised in three regions: Central Alberta near Fort Saskatchewan, the Ontario Peninsula in southernmost Ontario, and along the St. Lawrence River (*Fleuve Saint-Laurent*) between Montréal and Trois-Rivières in Québec.

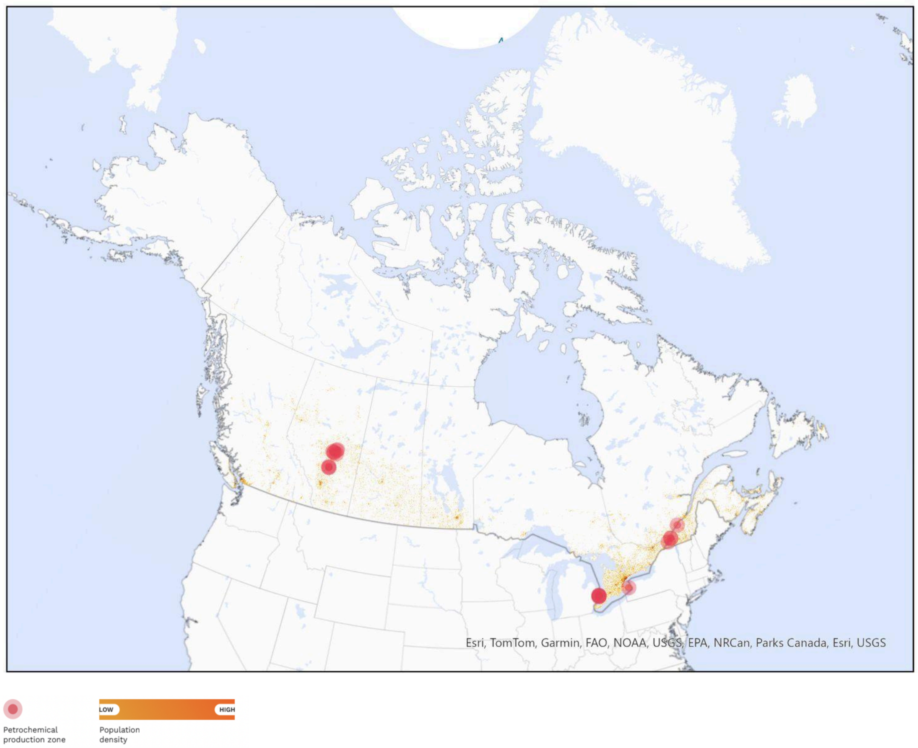


Figure 1. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Canada. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	40,098,000
Petrochemical facility count	20

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**765,000**
	Count of people at risk of exposure, national	731,000
	Count of people at risk of exposure, transboundary	US: 34,000
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**2,312,000**
	Count of people at risk of exposure, domestic	2,234,000
	Count of people at risk of exposure, transboundary	US: 78,000

Germany

Germany’s landscape is highly industrialised. The German chemical industry was the world’s fourth largest and the singlest largest in Europe in 2019 measured by revenue (GTAI, 2021). The manufacturing of basic petrochemicals and polymers constituted 36% of the chemical industry’s total production value in 2023 (VCI, 2024). The production of petrochemicals upstream of plastic fabrication is concentrated in North Rhine-Westphalia and Bavaria.

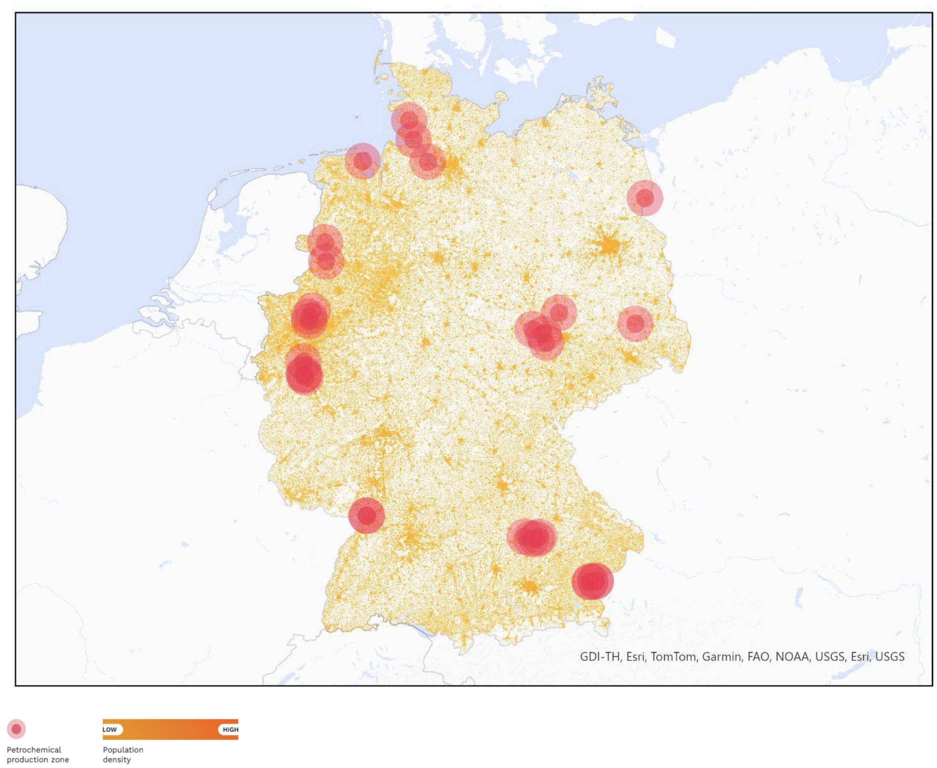


Figure 2. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Germany. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	82,280,000
Petrochemical facility count	29

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**1,320,000**
	Count of people at risk of exposure, national	1,317,000
	Count of people at risk of exposure, transboundary	Austria: 3,000
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**3,961,000**
	Count of people at risk of exposure, domestic	3,954,000
	Count of people at risk of exposure, transboundary	Poland: 1,000 Austria: 6,000

Indonesia

With the exception of one facility on Sumatra, Indonesia’s entire plastics-linked petrochemical production sector is situated on Java, the biggest cluster of which is found west of Jakarta in Banten province. Overcapacity of petrochemical production for all end uses is forecasted by 2030 in Indonesia, based on the current planned additions to capacity (Zero Carbon Analytics, 2024).

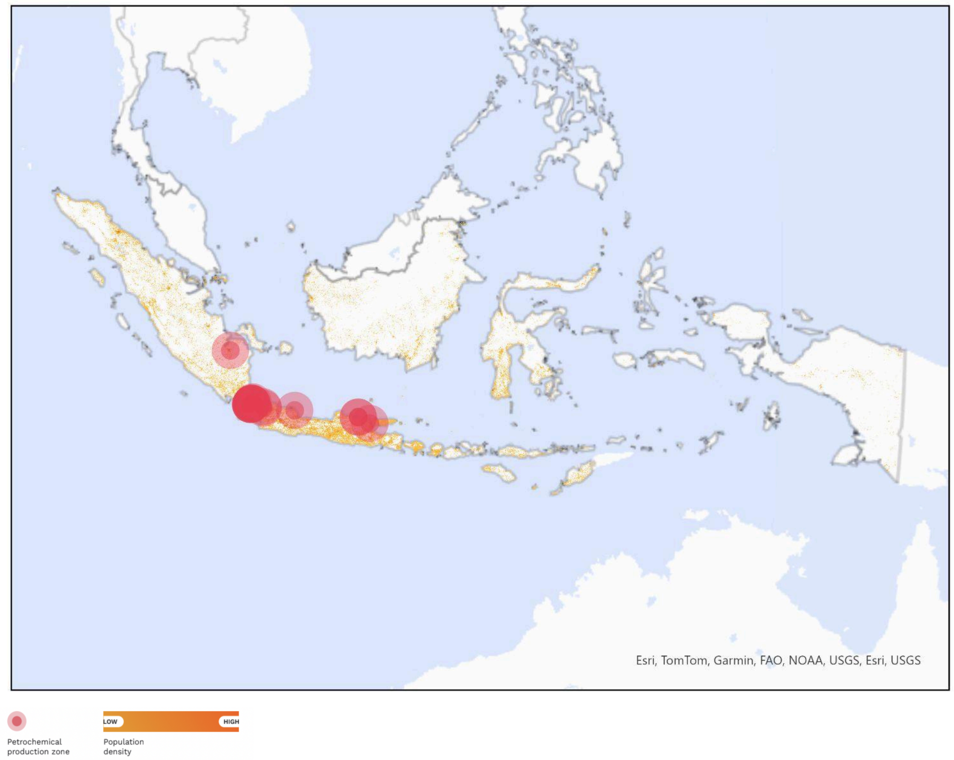


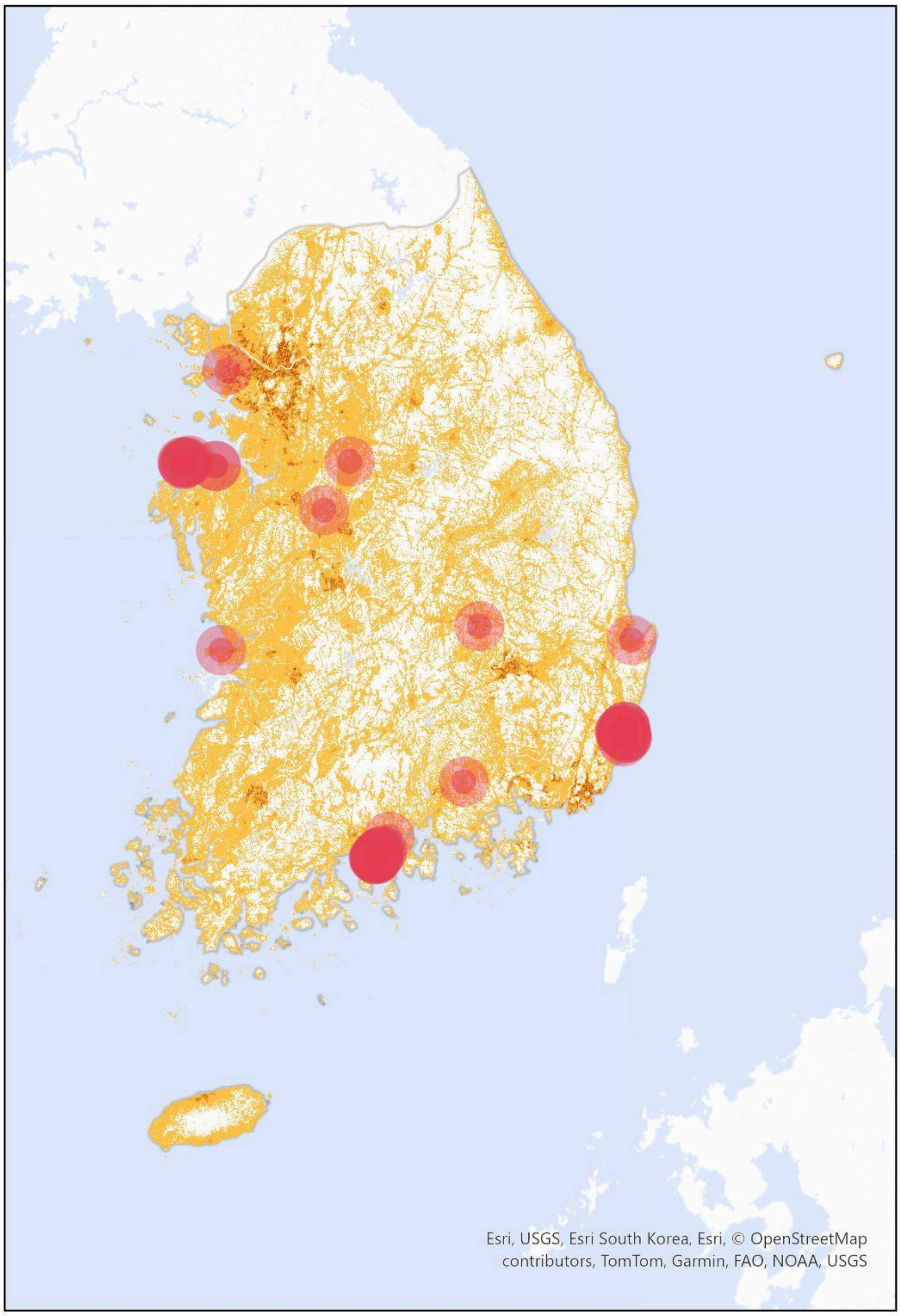
Figure 3. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Indonesia. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	281,190,000
Petrochemical facility count	18

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**2,039,000**
	Count of people at risk of exposure, national	2,039,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**6,484,000**
	Count of people at risk of exposure, domestic	6,484,000
	Count of people at risk of exposure, transboundary	0

Republic of Korea

The Republic of Korea's main petrochemical production areas are near the cities of Seosan, Ulsan, and Yeosu. According to the government of the Republic of Korea, Ulsan has the highest production capacity of petrochemicals as of 2022 (InvestKOERA, 2020). Overcapacity of petrochemical production for all end uses is forecasted by 2030 in the Republic of Korea, based on the current planned additions to capacity (Zero Carbon Analytics, 2024).



Population size (2023)	Petrochemical facility count
51,713,000	56

Figure 4. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in the Republic of Korea. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**1,427,000**
	Count of people at risk of exposure, national	1,427,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**4,777,000**
	Count of people at risk of exposure, domestic	4,777,000
	Count of people at risk of exposure, transboundary	0

Malaysia

Petrochemical production in Malaysia is generally centralised in designated industrial estates. The biggest of these estates by the number of petrochemical production facilities are Gebeng Industrial Estate, Pasir Gudang Industrial Estate, and Pengerang Integrated Petroleum Complex. Pasir Gudang Industrial Estate in southern Johor, Malaysia, is across the Johor Strait from Singapore. As a result, a large portion of the risk of exposure from Malaysia's petrochemical production falls on the population residing in Singapore.

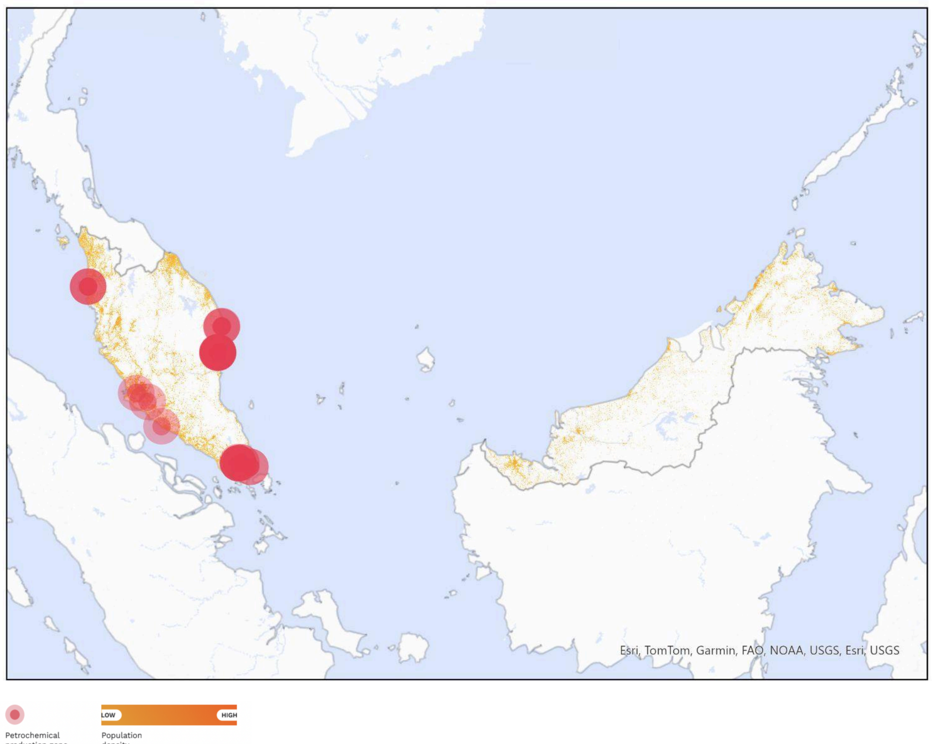


Figure 5. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Malaysia. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	35,126,000
Petrochemical facility count	27

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**1,390,000**
	Count of people at risk of exposure, national	1,101,000
	Count of people at risk of exposure, transboundary	Singapore: 289,000
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**5,124,000**
	Count of people at risk of exposure, domestic	2,996,000

	Count of people at risk of exposure, transboundary	Singapore: 2,128,000

The Netherlands

The Dutch chemical sector is Europe's third biggest by revenue (Cefic, 2024). The Netherlands is a major hub for petrochemical production, including those used in plastics manufacturing. There is a high concentration of petrochemical production facilities upstream of plastics production south of the Rotterdam–The Hague metropolitan area, along the distributary channels *Nieuwe Waterweg* and *Nieuwe Maas*. The large risk-of-exposure population size in the Netherlands can be attributed to the country's highly industrial nature and high population density, leading to residents living in relatively close proximity to sites of industrial activities.

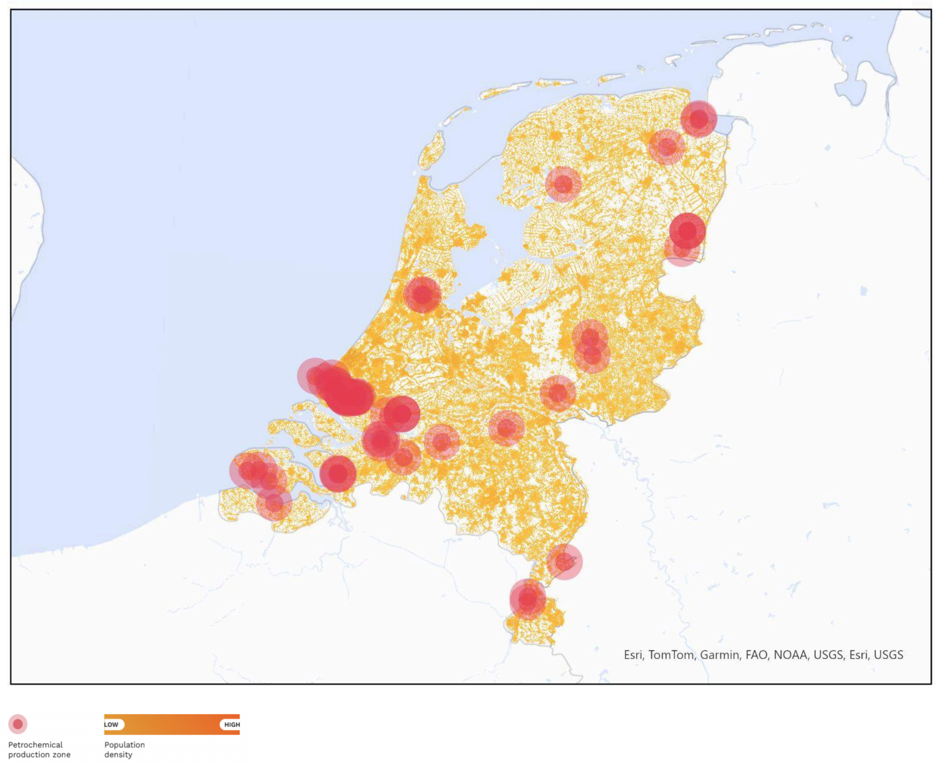


Figure 6. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in the Netherlands. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	17,877,000
Petrochemical facility count	52

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**2,278,000**
	Count of people at risk of exposure, national	2,272,000
	Count of people at risk of exposure, transboundary	Belgium: 4,000 Germany: 2,000
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**4,701,000**
	Count of people at risk of exposure, domestic	4,578,000

	Count of people at risk of exposure, transboundary	Belgium: 64,000 Germany: 59,000

The Philippines

The Philippines’ 6 petrochemical production facilities are located southwest of Manila in the densely populated island Luzon. A large petrochemical complex operated by JG Summit Olefins Corporation under JG Summit Holdings Inc. ceased operation in 2025 (Austria, 2025).

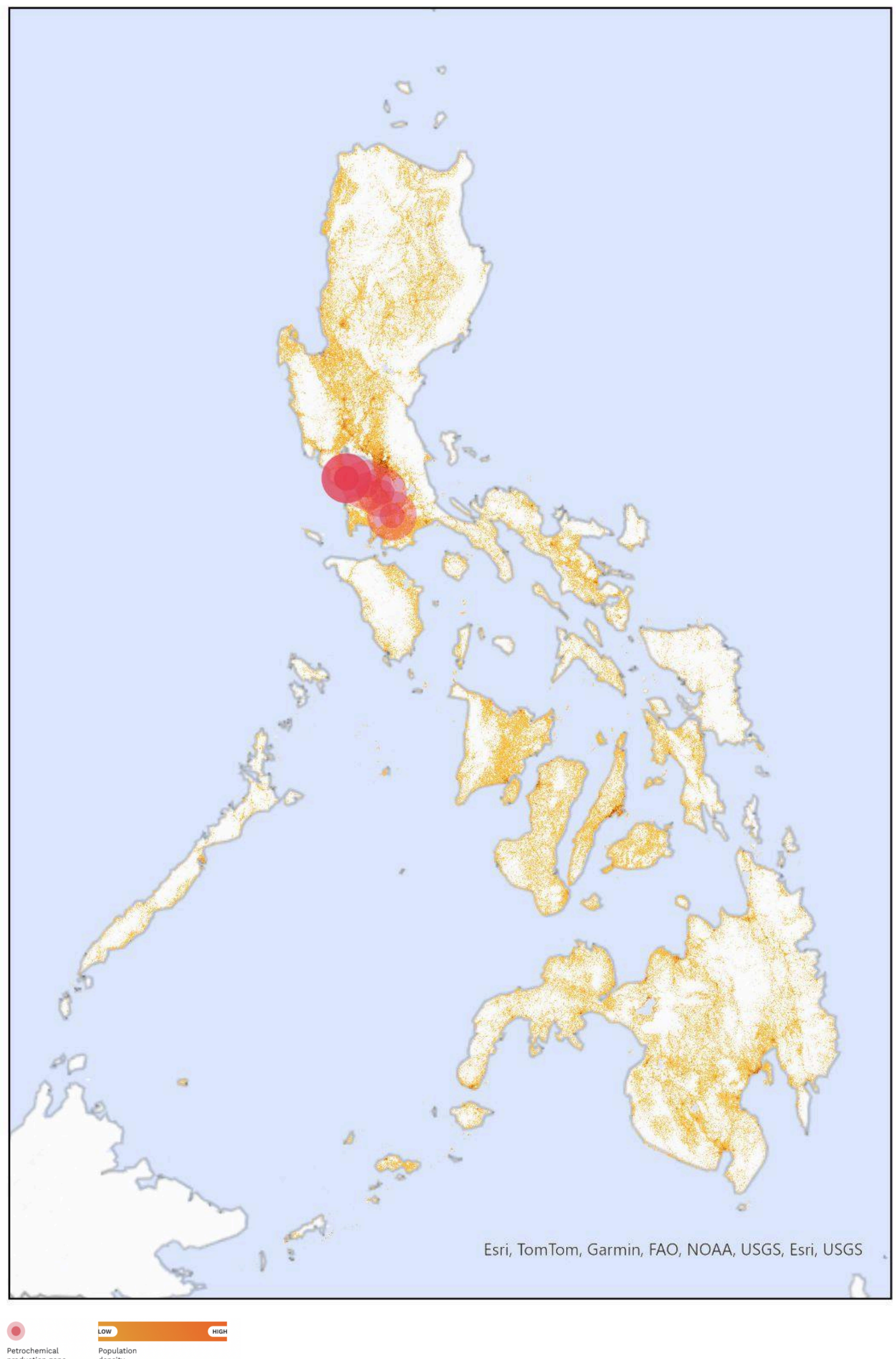


Figure 7. Population distribution (orange) and petrochemical production areas for the midstream stage of the

Population size (2023)
114,891,000
Petrochemical facility count
6

plastics value chain (red) in the Philippines. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.		
Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**1,588,000**
	Count of people at risk of exposure, national	1,588,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**4,612,000**
	Count of people at risk of exposure, domestic	4,612,000
	Count of people at risk of exposure, transboundary	0

Switzerland

The chemical industry in Switzerland is focused on the production of pharmaceutical and specialty chemicals (Swiss federal authorities, 2023). There is a small petrochemical production industry that supplies plastics producers. This study identified 8 petrochemical production facilities upstream of plastics production.

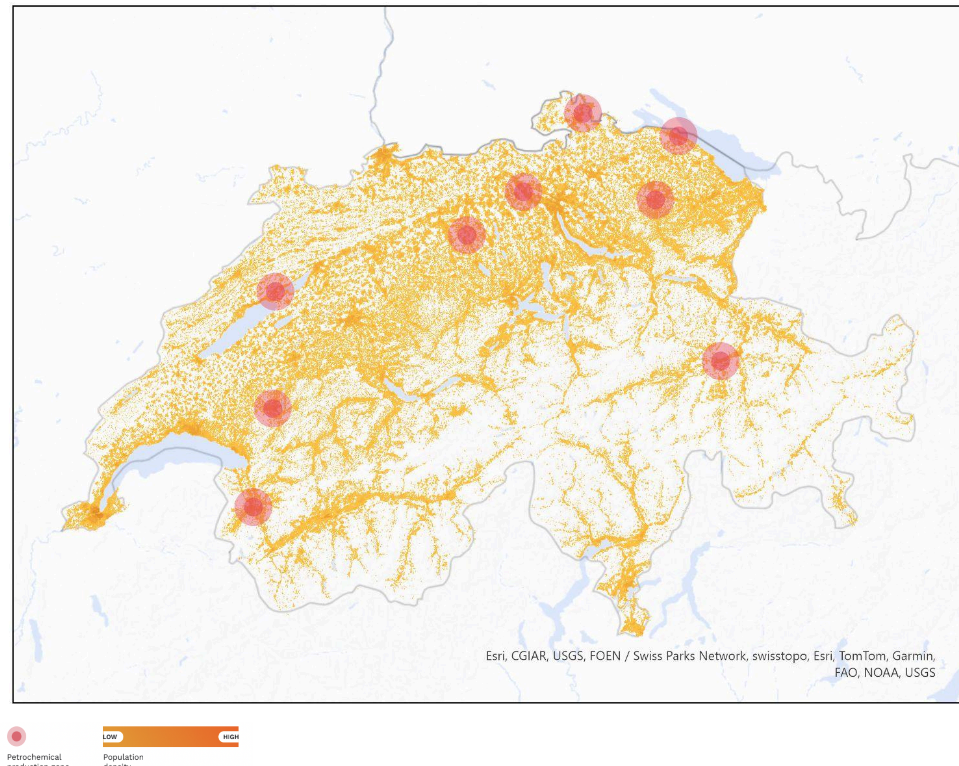


Figure 8. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Switzerland. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	8,888,000
Petrochemical facility count	9

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**404,000**
	Count of people at risk of exposure, national	355,000
	Count of people at risk of exposure, transboundary	Germany: 49,000
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**1,088,000**
	Count of people at risk of exposure, domestic	973,000
	Count of people at risk of exposure, transboundary	France: < 1000 Germany: 114,000

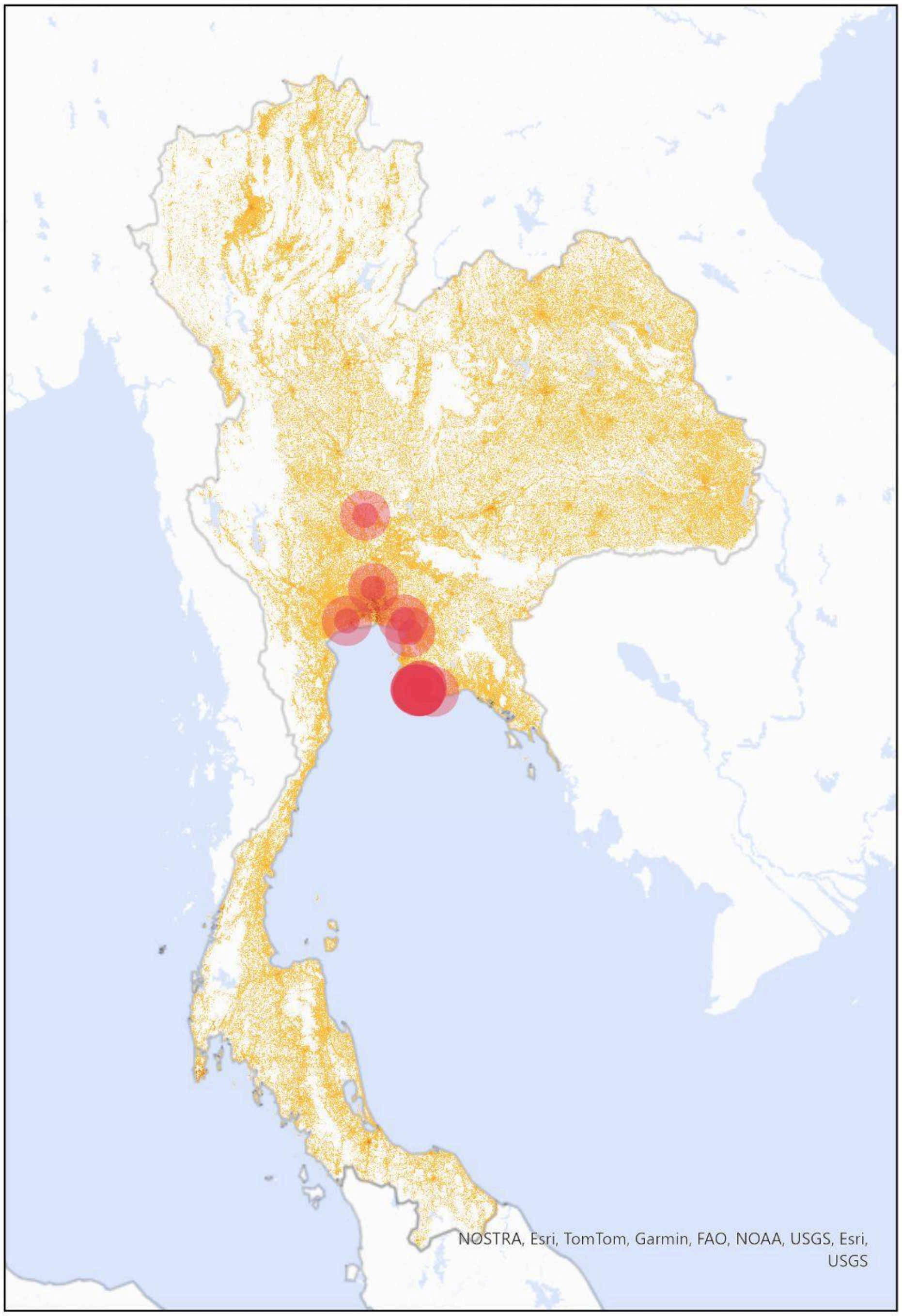
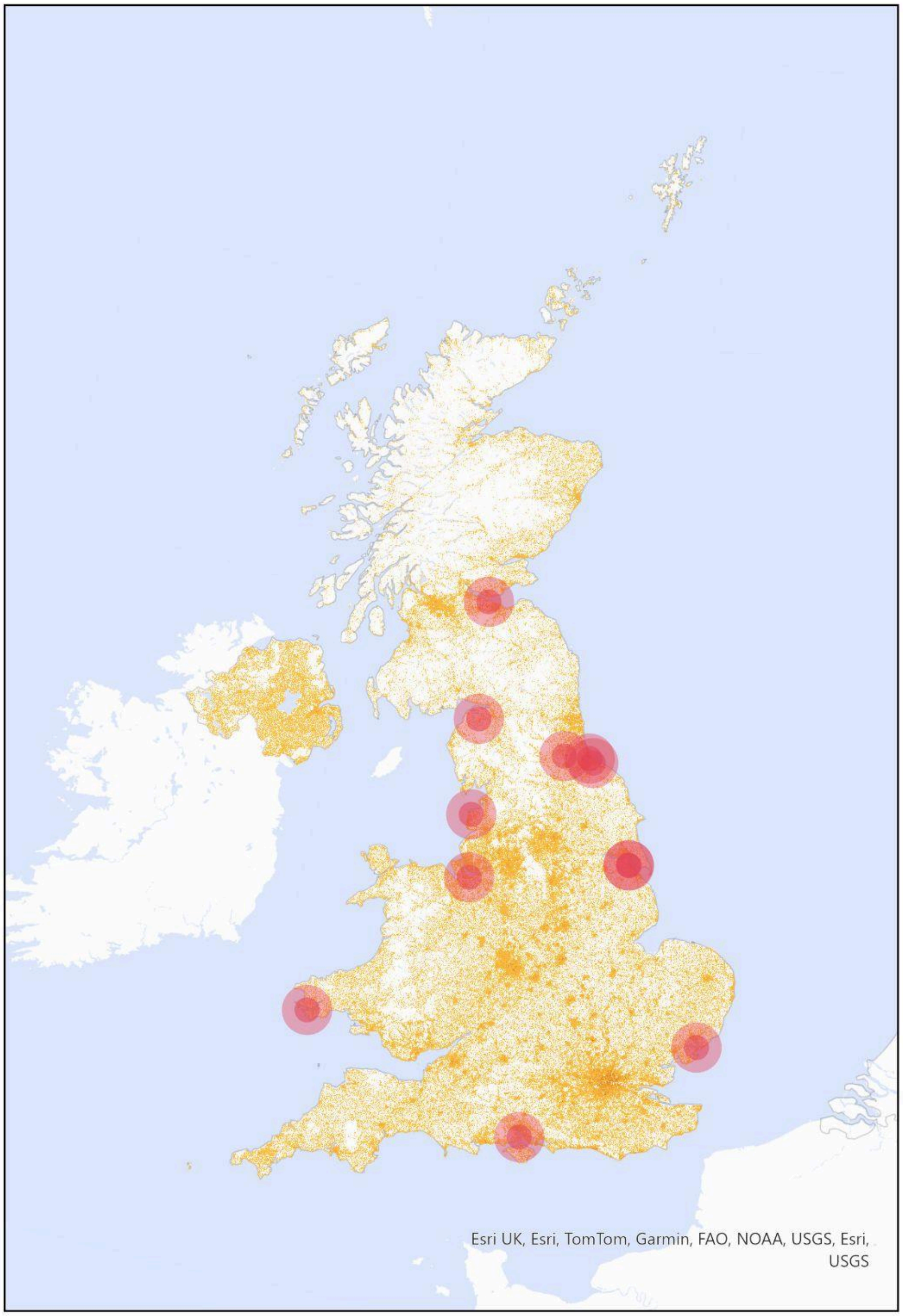
Thailand	
The primary hub of petrochemical production facilities in Thailand is found in Map Ta Phut Industrial Estate in the province of Rayong, southeast of Bangkok. This industrial estate is one of the biggest petrochemical industry complexes in Asia (Wiroon Tanthapanichakoon, 2019).	
	Population size (2023) 71,702,000 Petrochemical facility count 32

 **Figure 9**. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in Thailand. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.		
Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**1,178,000**
	Count of people at risk of exposure, national	1,178,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**4,008,000**
	Count of people at risk of exposure, domestic	4,008,000
	Count of people at risk of exposure, transboundary	0

The United Kingdom

The United Kingdom has an established petrochemical production sector. Among the biggest hubs of petrochemical production activity are Teesside and Humberside in North East England, Merseyside in North West England, and Grangemouth. In 2025, PetroINEOS announced a permanent halt of oil refining activities in Scotland's Grangemouth refinery (BBC News, 2025). The United Kingdom's chemical industry, including petrochemicals, is shrinking (Pfeifer, 2025).



Population size (2023)	68,350,000
Petrochemical facility count	12

 **Figure 10**. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in the United Kingdom. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.		
Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**397,000**
	Count of people at risk of exposure, national	397,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**1,677,000**
	Count of people at risk of exposure, domestic	1,677,000
	Count of people at risk of exposure, transboundary	0

The United States of America

The US analysis only included the production of basic petrochemicals. The production facilities of basic petrochemicals are found throughout the contiguous US. Southern Texas and Louisiana have a high concentration of petrochemical production facilities.

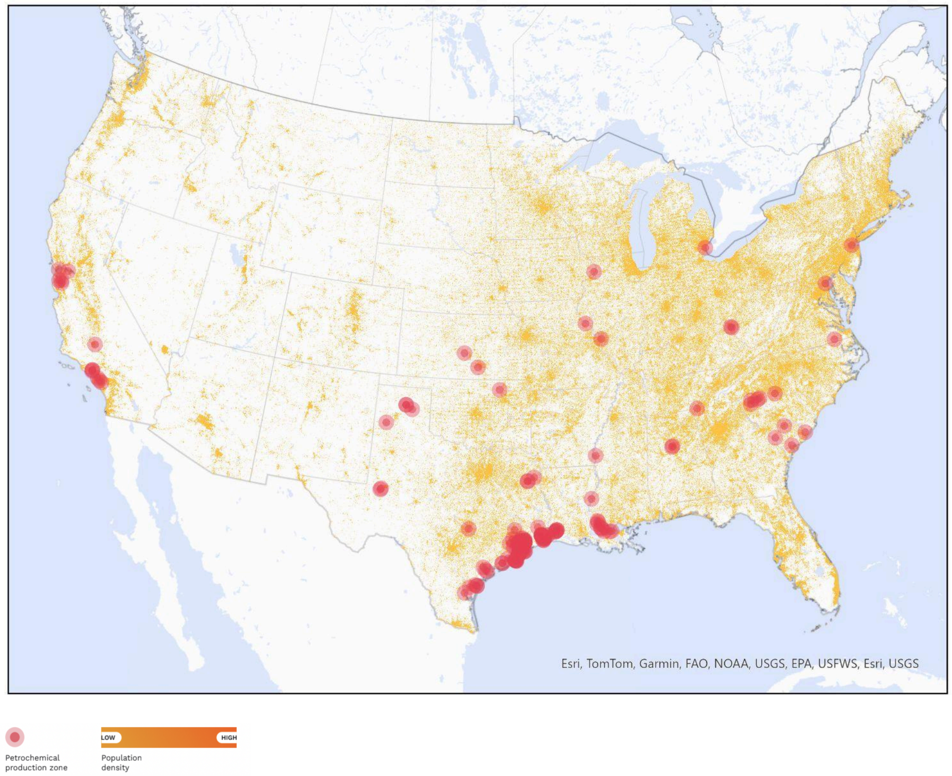


Figure 11. Population distribution (orange) and petrochemical production areas for the midstream stage of the plastics value chain (red) in the contiguous United States. Spatial population distribution data are from Bondarenko et al. (2025), and information about the distribution of petrochemical production was compiled by Greenpeace East Asia.

Population size (2023)	334,915,000
Petrochemical facility count	183

Within **5 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 5 km of a petrochemical production facility**	**4,106,000**
	Count of people at risk of exposure, national	4,106,000
	Count of people at risk of exposure, transboundary	0
Within **10 km** of petrochemical production facilities	**National and transboundary resident population count estimate living within 10 km of a petrochemical production facility**	**13,119,000**
	Count of people at risk of exposure, domestic	13,089,000
	Count of people at risk of exposure, transboundary	Canada: 30,000

Conclusions

The number of people residing within 5 km and 10 km of petrochemical production facilities was calculated using geospatial analysis in the 11 countries examined in this study. These populations constitute the risk-of-exposure groups that reside close enough to sites of petrochemical production to be at a higher proximity-based exposure risk to the air pollutants emitted.

Across the study area's 11 countries, the analysis found that over 16 million people reside within 5 km of a petrochemical production facility linked to the plastics value chain. This figure increases to over 51 million people when considering a distance of 10 km. These individuals live at a distance to petrochemical production facilities that has been associated with higher rates of negative health outcomes (Chang et al., 2020; Chin et al., 2022; Domingo et al., 2020; Huang et al., 2021; Jephcote et al., 2020; Lin et al., 2017; Lin et al., 2018; Oliveira et al., 2002; Yang et al., 2002; Yuan et al., 2021), possibly from the effects of being exposed to air pollutants emitted during petrochemical production processes.

Across different regions, the number of residents living within 5 km and 10 km of petrochemical production facilities is as follows:

- In Europe (Germany, the Netherlands, Switzerland, and the UK), 4,399,000 and 11,427,000;
- in North America (Canada and the US), 4,871,000 and 15,431,000;
- in the Republic of Korea, 1,427,000 and 4,777,000; and
- in Southeast Asia (Indonesia, Malaysia, the Philippines, and Thailand), 6,195,000 and 20,228,000.

Table 3: Regional population count residing at a distance to petrochemical facilities associated with exposure risk to emissions from petrochemical production

Region	**Locations of petrochemical production**	**Locations of populations at a distance tied to risk of exposure to emissions**	**Regional population count estimate within 5 km of a petrochemical facility**	**Regional population count estimate within 10 km of a petrochemical facility**
Europe	Germany Netherlands, Switzerland UK	Austria Belgium France Germany Netherlands Poland Switzerland UK	4,399,000	11,427,000
North America	Canada USA	Canada USA	4,871,000	15,431,000

Republic of Korea	Republic of Korea	Republic of Korea	1,427,000	4,777,000
Southeast Asia	Indonesia Malaysia Philippines Thailand	Indonesia Malaysia Philippines Thailand Singapore	6,195,000	20,228,000

In Canada, Germany, Malaysia, the Netherlands, Switzerland, and the US, the proximity-based risk-of-exposure zones around their petrochemical production areas are transboundary as they extend into neighbouring countries. This observation highlights the risk of border communities being exposed to air pollutants emitted from facilities located across national borders, and emphasises the importance of understanding air pollution emissions and their health impacts from a regional and global lens.

The exact composition and amount of air pollutants emitted vary by facility. The real-world individual- and population-level exposure is mediated by a range of complex interactions, including environmental factors, meteorological conditions, demographic traits, and facility-specific operational conditions, and the potential exposure to pollutants from the facility via other pathways such as liquid effluent disposed to waterways or solid waste in landfills. This study is designed to provide a country-level overview of exposure risk based solely on residential proximity to petrochemical facilities. The results are not intended to assess the contribution of individual facilities to exposure risk levels in local populations. Accurately assessing exposures on a facility-level requires site-specific research and epidemiological analysis.

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Glossary

Air pollutant	An unwanted substance found in the air in the form of a solid particle, a liquid droplet or a gas. The substance may be hazardous, harmful to human health if inhaled or damaging to the environment. Prominent examples are $PM_{2.5}$, the NO_x group and SO_2.
EPSG	European Petroleum Survey Group. A scientific organization that maintains a geodetic parameter database.
ICS	Industrial Classification System. A standardised categorisation system to classify industrial sites based on economic activity.
GIS	Geographic Information System. A framework for geographic data management, analysis, and visualization.
NACE	Nomenclature of Economic Activities in the European Community. A classification system to categorise industrial activities based on their main economic activities used in the European Union.
NAICS	North American Industry Classification System. A classification system to categorise industrial activities based on their main economic activities,
The Netherlands	The constituent country in the Kingdom of Netherlands located in continental Europe. The other three constituent countries, Aruba, Curaçao, and Sint Maarten, are in the Caribbean Netherlands.
NOGA	Nomenclature Générale des Activités économiques (English: General Classification of Economic Activities). A classification system to categorise industrial activities based on their main economic activities used in Switzerland.
NO_2	Nitrogen dioxide. A trace gas that is produced in all combustion processes. It converts from and to NO. The amount of NO_2 in the atmosphere is commonly used as a proxy to assess the health impact of the whole NO_x group.
NO_x	Nitrogen oxides. A generic term for NO and NO_2, a group of trace gases that are harmful to human health.
$PM_{2.5}$	Fine particulate matter / fine particles. Solid particles with an aerodynamic diameter of less than 2.5µm (i. e. small dust particles). They are so small that they can pass from the lungs into the bloodstream, affecting the entire cardiovascular system and causing a range of health impacts. Due to their small size, the particles stay airborne for a long time and can travel hundreds or thousands of kilometres. Fossil fuel combustion emits $PM_{2.5}$ directly, as fly ash and other unburned particles, and contributes to $PM_{2.5}$ indirectly through emissions of gaseous pollutants (particularly SO_2 and NO_x), which form $PM_{2.5}$ in the atmosphere. $PM_{2.5}$ is harmful to human health and thus an air pollutant.

PAC	Projection and Coordinate system. A spatial reference system used for mapping and surveying purposes.
PRTR	Pollutant Release and Transfer Register. A database that tracks the release and transfer of pollutants from industrial facilities to the environment.
Resident population	All nationals present in, or temporarily absent from the country, and aliens permanently settled in the country (OECD, 2016)
Risk-of-exposure	The risk that an individual or population will come into contact with a substance or an environmental condition.
Risk-of-exposure zone	The geographical area in which there is a risk that an individual or population will come into contact with a substance or an environmental condition.
SBI	Standaard Bedrijfsindeling. A classification system to categorise industrial activities based on their main economic activities used in the Netherlands.
SO_x	Sulfur oxides, a group of chemical compounds containing sulfur and oxygen, including Sulfur Dioxide (SO_2) and Sulfur Trioxide (SO_3). These compounds are trace gases produced naturally and by industrial processing of materials that contain sulfur, including burning coal in power stations and processing of some mineral ores. Human sources of SO_2 far exceed all natural sources even when accounting for volcanic activity. SO_x gases react with other substances to form harmful compounds, such as sulfuric acid (H_2SO_4), sulfurous acid (H_2SO_3) and sulfate particles and it is therefore a cause of acid rain and particulate matter pollution.
UK SIC	UK Standard Industrial Classification. A classification system to categorise industrial activities based on their main economic activities used in the United Kingdom.