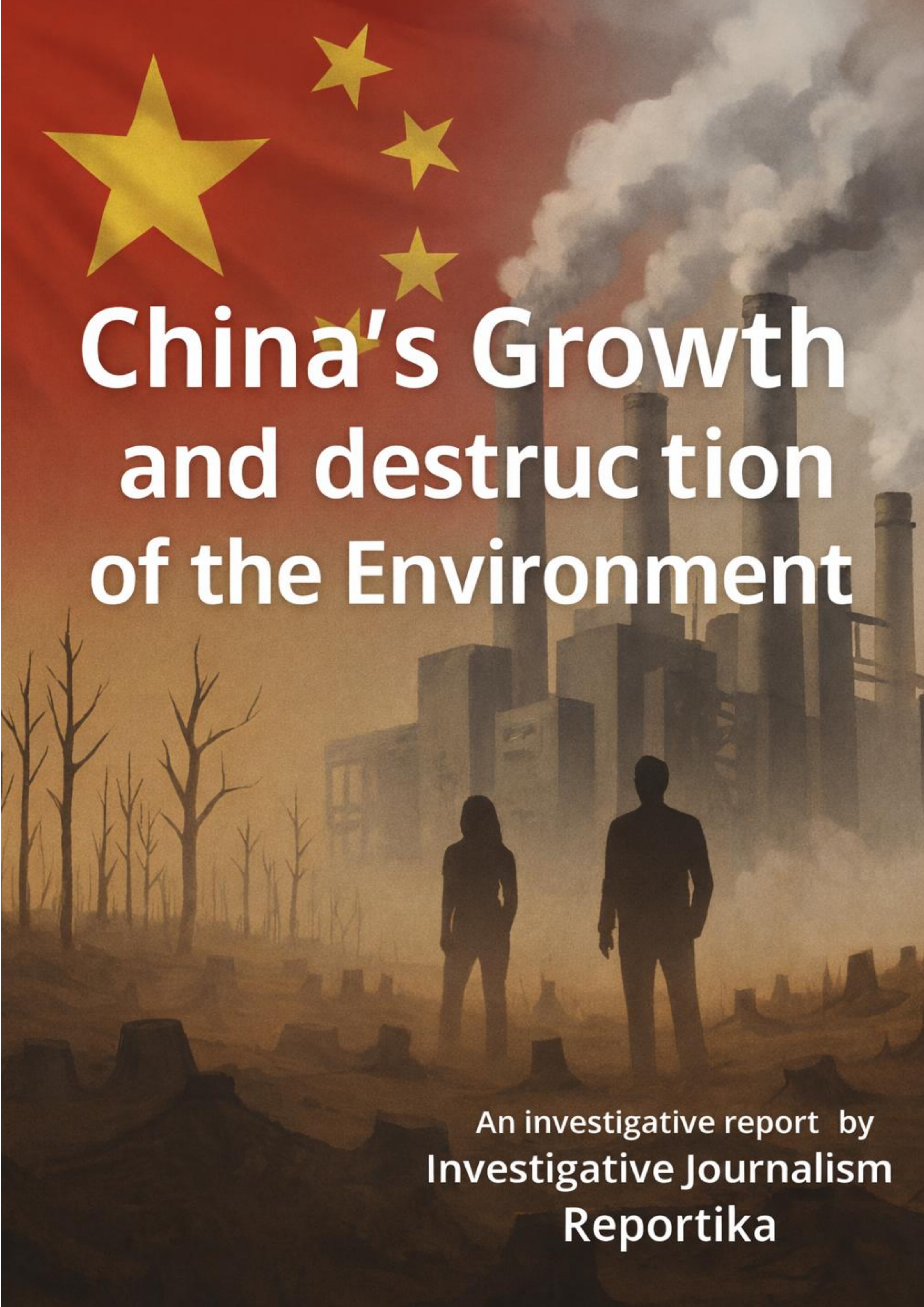
China’s Growth and destruction of the Environment



An investigative report by

Investigative Journalism

Reportika

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China's Growth and destruction of the Environment

Introduction

China's transformation into the world's second-largest economy over the past four decades is one of the most rapid industrialisations in history. It has also produced environmental damage of corresponding magnitude and duration. At its peak between 2005 and 2015, air pollution in northern China regularly exceeded levels considered immediately dangerous to human health; independent studies estimate it caused between 1.6 and 2.2 million premature deaths annually. More than 60 % of monitored groundwater and roughly one-fifth of the country's arable land have been classified as polluted, in many cases heavily, with cadmium, arsenic and other toxins entering the food chain.

For much of this period, official data were suppressed or manipulated, independent monitoring was obstructed, and environmental activists faced detention. Major policy shifts only arrived after sustained public anger in 2011–2013 forced the issue onto the political agenda. The 2013 Air Pollution Prevention and Control Action Plan and subsequent "war on pollution" produced undeniable results: nationwide PM2.5 concentrations fell approximately 57 % between 2013 and 2024, and hundreds of thousands of high-polluting factories and small coal boilers were closed or upgraded. Yet coal-fired power capacity continued to expand until 2023, total carbon emissions remain near all-time highs, and local governments have repeatedly been caught falsifying environmental data to meet central targets.

On the Tibetan Plateau and upper reaches of Asia's great rivers, an accelerated programme of dam construction, mining and infrastructure development has altered fragile high-altitude ecosystems at a pace and scale with few modern parallels. These projects have triggered serious land degradation, disrupted traditional herding communities, and raised transboundary water concerns for ten downstream countries.

This report examines the full arc of China's environmental crisis: the decades of unchecked pollution driven by growth-first policies, the coercive and often deceptive campaigns that eventually reduced some of the worst domestic impacts, and the continuing ecological costs now being externalised onto sensitive border regions and neighbouring states. It concludes that, despite genuine recent improvements in certain indicators, the fundamental governance model-centralised, opaque, and intolerant of independent oversight-continues to prioritise short-term economic and strategic objectives over long-term environmental security.

Industrialization, economic growth, and pollution in China

China's breakneck industrialization since the 1980s-often prioritized above all else under a growth-first policy framework-lifted hundreds of millions out of poverty but transformed the country into the world's largest polluter, with environmental degradation imposed on its citizens for decades with minimal accountability. Coal-fired power and heavy industry, long shielded by local governments and state-owned enterprises, drove explosive increases in air, water, and soil contamination until public health crises and social unrest finally forced a policy pivot in the mid-2010s. Even today, despite undeniable reductions in some pollutants, China remains the dominant source of global greenhouse gases, continues to expand coal capacity at a record pace, and grapples with entrenched water and soil pollution that threatens food security and public health.

Air Pollution

Figure 1 Air pollution metrics of China

- Between 2013 and 2020, harmful particulates (PM2.5) in China's air **fell by about 40%,** with the average **PM2.5 concentration dropping by 33% from 2013–2017 in 74 major cities.**
- Beijing exemplifies the shift: **PM2.5 dropped from 89.5 µg/m³ (2013) to ~33 µg/m³ (2024),** adding an estimated 3–4 years to average life expectancy (University of Chicago AQLI).
- Yet these "gains" started from levels no developed nation has ever tolerated for decades. In 2024, **China's national PM2.5 average remained nearly 6 times the WHO guideline of 5 µg/m³,** and a quarter of cities still fail domestic standards (In 2023, 13 of 31 provincial capitals failed to meet China's national standards for PM2.5, indicating persistent regional challenges).
- A troubling rebound occurred in 2023 (+3.4–3.6% year-on-year), the first increase since 2013, driven by industrial recovery and lax enforcement**. Improvements resumed in 2024, but progress has slowed dramatically (only -2.7% y-o-y) and remains vulnerable to data manipulation scandals and local protectionism.**

Greenhouse Gas Emissions

- **China's contribution to the world's greenhouse gas emissions** is staggeringly large, accounting for an enormous **25.29% of the global total.**
- **China is emitting more CO_2 annually than the US, EU, and India combined.**

GHG Emissions of G20 Countries (2022)

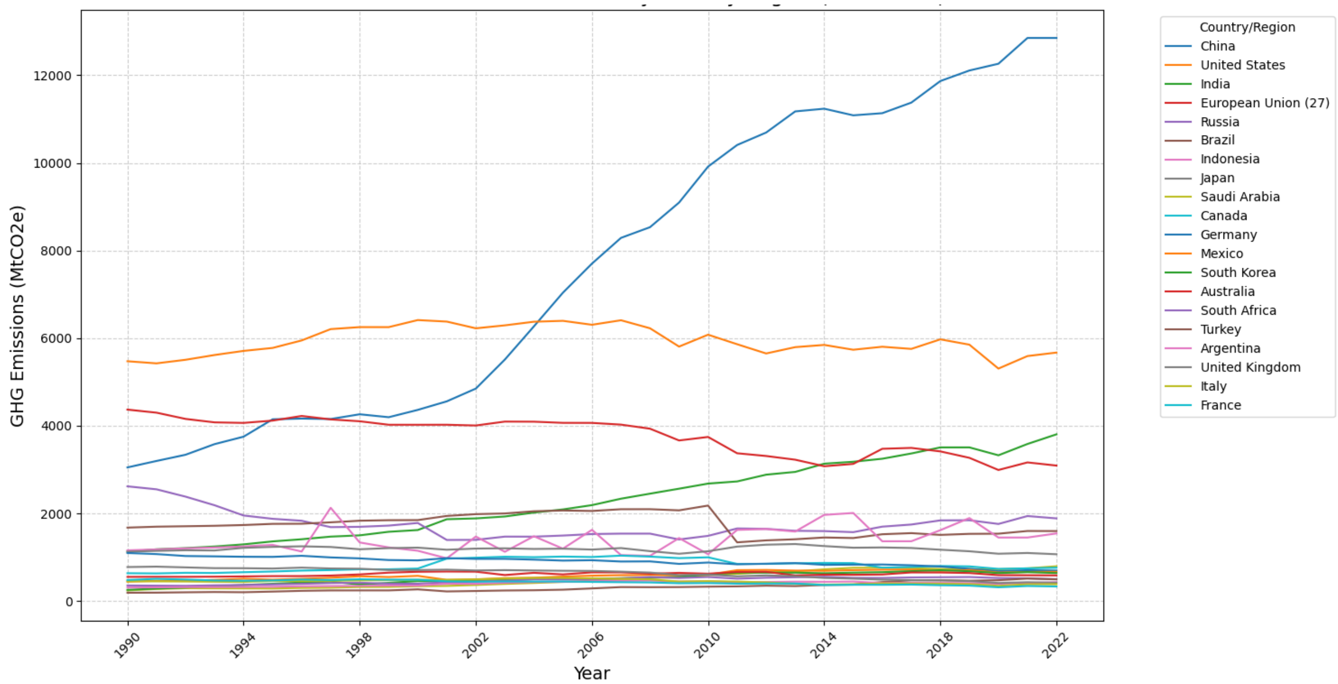

Figure 2 GHG emissions in G20 countries from 1990 to 2022 (Data Source : Climate Watch https://www.climatewatchdata.org/)

Unit: Gt = Gigatonnes, Mt = Megatonnes

Table 1 Highest GHG emitters in the world (2022)

Country/Group	GHG Emissions (2022)
China	**12.85 Gt**
United States	**5.67 Gt**
India	**3.81 Gt**
European Union (27)	**3.09 Gt**
Russia	**1.89 Gt**
Brazil	**1.60 Gt**
Indonesia	**1.54 Gt**
Japan	**1.07 Gt**
Saudi Arabia	**793.61 Mt (0.79 Gt)**
Canada	**760.62 Mt (0.76 Gt)**
Others	**5.14 Gt**

CO_2 Emissions

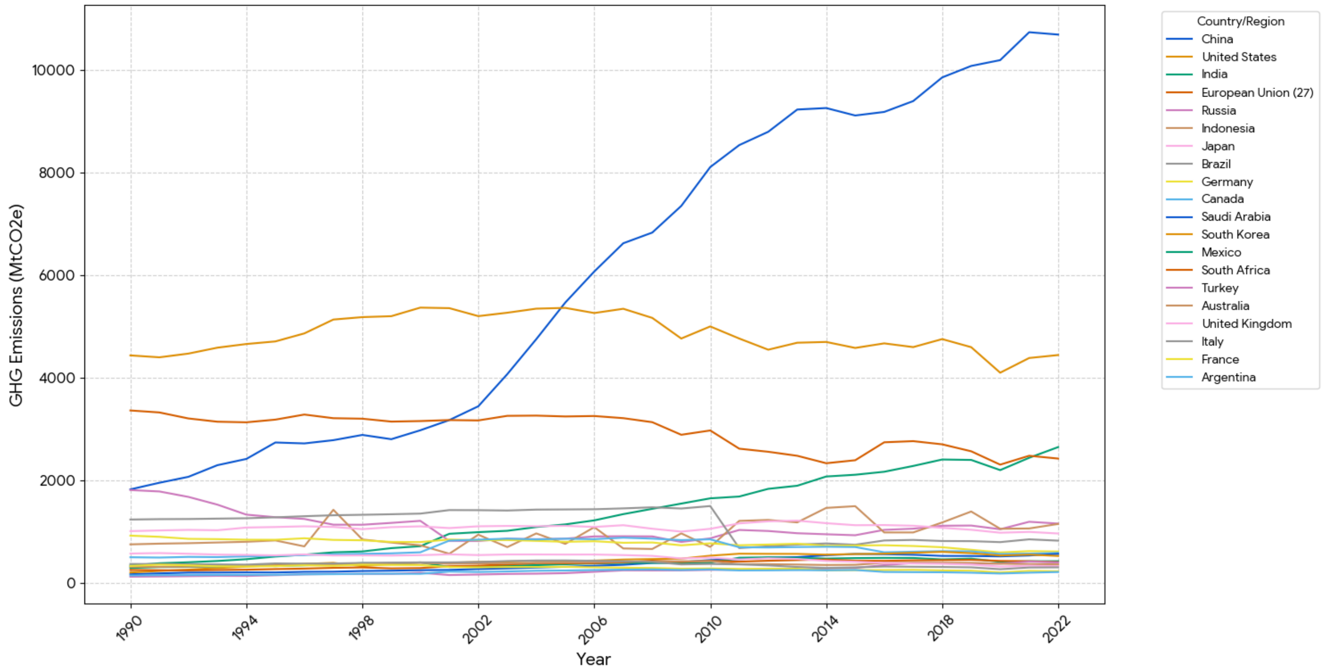

Figure 3 CO2 emissions in G20 countries from 1990 to 2022 (Data source : Climate Watch https://www.climatewatchdata.org/)

Table 2 Highest CO_2e emitters in the world (2022)

Country / Group	CO_2e Emissions
China	**10.69 Gt**
United States	**4.44 Gt**
India	**2.65 Gt**
European Union (27)	**2.42 Gt**
Russia	**1.16 Gt**
Indonesia	**1.15 Gt**
Japan	**0.964 Gt**
Brazil	**0.825 Gt**
Iran	**0.763 Gt**
South Korea	**0.527 Gt**

- China's annual CO_2 emissions rose rapidly during its manufacturing boom, **overtaking** the **US as the world's top emitter in 2006**.
- Year-on-year changes in emissions reflected economic cycles, **peaking with industrial expansion and levelling** off more recently due to clean energy policies.
- **From 2000 to 2020, total annual emissions nearly tripled, driven by coal combustion for energy and industry.**

Figure 4 CO2 emissions metrics of China

Coal Dependency: The Global Climate Roadblock

China remains the epicentre of global coal dependency, operating an unparalleled fleet that dwarfs the rest of the world combined and continues to expand despite record renewable deployment. As of mid-2025, mainland China hosts approximately **1,195 operational coal-fired power plants**-nearly half of the **global total of around 2,400–2,500 units** and more than **four times the number in India (second place with ~290).** This dominance appears starkly in global power-plant mapping, where dense clusters of black dots (representing coal) blanket eastern and northern China, while the United States, Europe, and most other regions show far sparser and declining coal infrastructure amid widespread retirements.

Although China has achieved explosive growth in wind and solar-**adding over 500 GW of clean capacity expected in 2025 alone**, pushing coal's share of electricity generation down to a **nine-year low of ~51% in mid-2025-the country commissioned ~21 GW** of new coal capacity in the **first half of 2025 alone.** Construction starts hit 46 GW in the same period, with projections of **80–100 GW** coming online for the full year, the highest pace since 2015–2016.

This ongoing coal binge, driven by provincial approvals and energy-security concerns rather than actual power shortages in many regions, offsets global phase-out efforts elsewhere and keeps China responsible for over half of worldwide coal-fired generation. The result is a deeply entrenched structural dependency that undermines Beijing's own pledges to "strictly control" coal growth through 2025 and begin phasing it down thereafter, locking in decades of excess capacity and emissions even as renewables increasingly marginalise coal's role in day-to-day power supply.

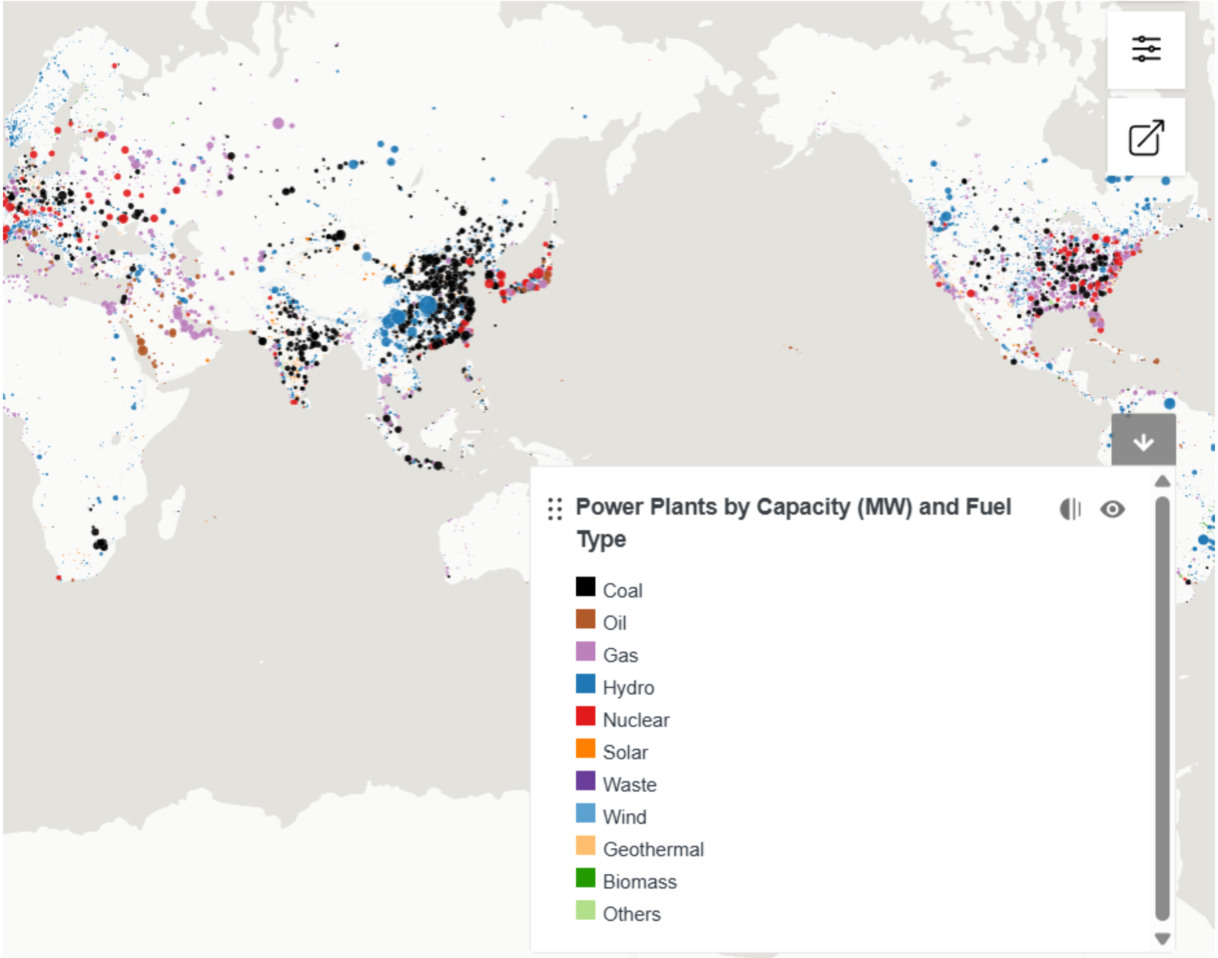

Figure 5 The dependence on Asia and North America

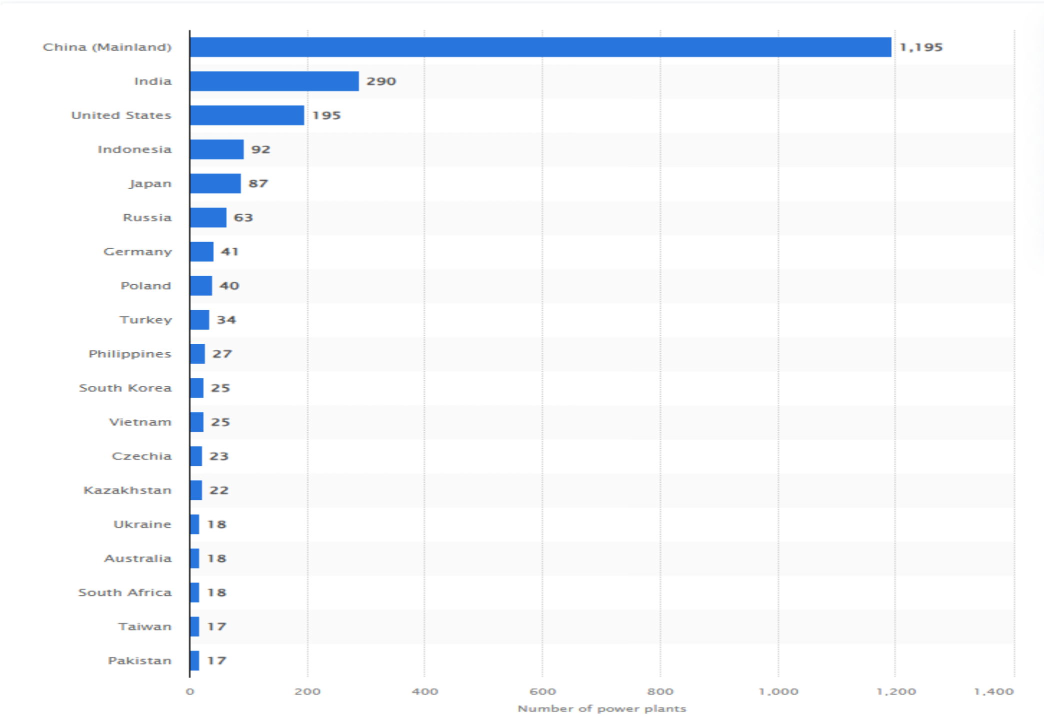

Figure 6 Countries and territories with the largest number of operational coal power plants worldwide as of July 2025 (Source : https://www.statista.com/)

Ozone (O_3) Pollution in China: A Growing Threat to Air Quality, Food Security, and Carbon Sinks

China's near-surface ozone pollution has emerged as one of the country's most serious and intractable environmental challenges. **Once overshadowed by PM2.5-dominated haze, O_3 is now the primary pollutant on more days than fine particles in many regions.** Between 2010 and 2021, ozone levels rose rapidly across the country, peaking around 2019–2020, and remain far above WHO guidelines despite recent slight declines. (Shi et al. (2025). Synergistic and Trade-Off Influences of Combined PM2.5-O_3 Pollution in the Shenyang Metropolitan Area, China: A Comparative Land Use Regression Analysis. Sustainability 17(17):8046. https://doi.org/10.3390/su17178046)

Current Status and Hotspots

- Nationally, the annual **90th-percentile maximum daily 8-h average (MDA8) O_3 concentration increased from ~130 µg/m³ in 2010 to a peak of ~170 µg/m³** around 2019–2020, then stabilised or slightly declined in some areas.
- The most severe and persistent O_3 pollution occurs in four major clusters:
    1. **North China Plain (Beijing–Tianjin–Hebei and southern Hebei, Shandong, Henan)**
    2. **Yangtze River Delta**
    3. **Pearl River Delta**
    4. **Sichuan Basin**
- Emerging high-O_3 zones now include the Fenwei Plain (Shanxi–Shaanxi) and parts of Northeast China (Shenyang Metropolitan Area).

Combined PM2.5–O_3 Pollution: Synergies and Trade-offs

Recent land-use regression (LUR) studies in the Shenyang Metropolitan Area (Shi et al., Sustainability 2025) reveal complex interactions between PM2.5 and O_3:

- **Synergistic factors (same directional effect on both pollutants)**
- **Tree cover and grassland reduce both PM2.5 and O_3**
- **Built-up area and permanent water bodies increase both**

Trade-off factors (opposite directional effect)

- **Longitude (eastward), elevation, population density, NO_2 column, and aerosol optical depth (AOD) higher PM2.5 but lower O_3**
- **Across the metropolitan area, PM2.5 dominates combined pollution in 47 % of the area, while O_3-dominant zones are rare (4 %) and localised.**

Spatially, PM2.5 still drives most "**compound pollution**" episodes in northern megacity clusters, whereas summer O_3 episodes increasingly dominate in southern and eastern coastal regions.

Impacts on Wheat Yield and Forest Productivity (2010–2021)

A comprehensive national assessment (Wang et al., Environmental Pollution 2023) using new meteorology-inclusive metrics (O_3MET for wheat, O_3RH for forests) quantified unprecedented ecological damage:

- **Wheat** (almost entirely winter wheat)
- **Average annual yield loss**: 26.5 million tonnes (17 % of potential yield without O_3 damage)
- **Annual economic loss**: ~US$ 11–15 billion
- **Loss increased at 1.8 Mt/yr over the 12-year period**
- **Heaviest relative losses (>25 %) in Henan, Shandong, Anhui, and Jiangsu -the core of China's "breadbasket"**

Forests (gross primary productivity, GPP)

- **Average annual GPP loss**: 552.6 TgC (equivalent to ~4 % of total forest carbon uptake)
- **Loss increased at** 13.9 TgC/yr
- **Highest absolute losses** in subtropical and temperate forests of East and South China

Dual high-impact zones where both wheat and forests suffer severe O_3 damage are concentrated in the **North China Plain and middle-lower Yangtze region**, exactly the areas with the highest population density, food production, and carbon-sequestration potential.

Drivers of Rising Damage

The study **attributes ~70–80 % of the increasing losses to rising ambient O_3 concentrations**, with the remainder due to unfavourable meteorological shifts (warmer, drier conditions that enhance stomatal uptake). This confirms that emission-driven O_3 increases, not just climate variability, are the primary culprit.

Policy Implications

1. Ozone is no longer just an urban air-quality issue; it is now a major threat to national food security and carbon-neutrality goals.
2. The eastern agricultural heartland faces a "triple burden": severe O_3 health effects, wheat yield losses, and forest carbon-sink weakening.
3. Current NOx- and VOC-control measures have slowed the rise but are insufficient to reverse damage; deeper cuts (especially in NOx from transport and industry) are urgently needed.
4. Vegetation-based mitigation (tree cover, grasslands) offers co-benefits for both $PM_{2.5}$ and O_3, but must be carefully designed to avoid excessive biogenic VOC emissions in warm, high-NOx environments.

In summary, ozone has replaced PM2.5 as **China's most costly air pollutant** when ecological and agricultural impacts are fully accounted for. Without accelerated precursor emission reductions, projected O_3 levels through 2030–2050 will continue eroding wheat yields and forest carbon uptake at rates that jeopardise both food-security and climate targets.

Water and Soil Pollution: A Persistent and Largely Unaddressed Legacy

China's decades of unchecked industrial expansion have left behind a toxic inheritance in its soil and water resources that remains one of the most severe on the planet. A 2014 national soil survey-whose full results were kept secret for years-revealed that **16.1 % of sampled sites (and 19.4 % of arable land) were contaminated**, primarily with **cadmium, mercury, arsenic, and lead.** Independent follow-up studies suggest the real figure **may exceed 20 %.** By 2020 the Ministry of Ecology and Environment acknowledged more than **200,000 contaminated brownfield sites**, concentrated in the eastern manufacturing heartland of the **Yangtze and Pearl River deltas**. Remediation has been slow, expensive, and largely limited to high-profile urban projects; vast areas of farmland continue to produce rice and vegetables with heavy-metal levels that exceed national food-safety limits.

Water pollution follows a similar pattern. Despite the 2015 **"Water Ten Plan"** and billions of yuan invested, as of 2024 roughly 15–20 % of monitored surface-water sections still fail to meet even the lowest grade for human contact (Grade V or worse). In the North China Plain, up to 80 % of shallow groundwater is unfit for drinking without treatment. Industrial clusters in Hebei, Shandong, and Henan continue to discharge untreated or inadequately treated wastewater, while lax enforcement and falsified monitoring data remain commonplace. The human and ecological cost is evident in the persistence of "cancer villages" along heavily polluted rivers and in the collapse of fisheries in lakes such as **Taihu and Chao.**

Microplastic Pollution in the Yellow River Basin: Focus on the Wuding River

A 2024 study (Wan S, Xu G, Xiong P, et al. Microplastic pollution characteristics and ecological risk assessment in the Wuding River Basin, China. Environmental Pollution. 2024;356:124228. https://doi.org/10.1016/j.envpol.2024.124228) in the **Wuding River (WDR)**, the largest sand-carrying tributary of **the middle Yellow River**, revealed widespread **microplastic (MP) contamination across its 491 km length** (Wan et al., 2024).

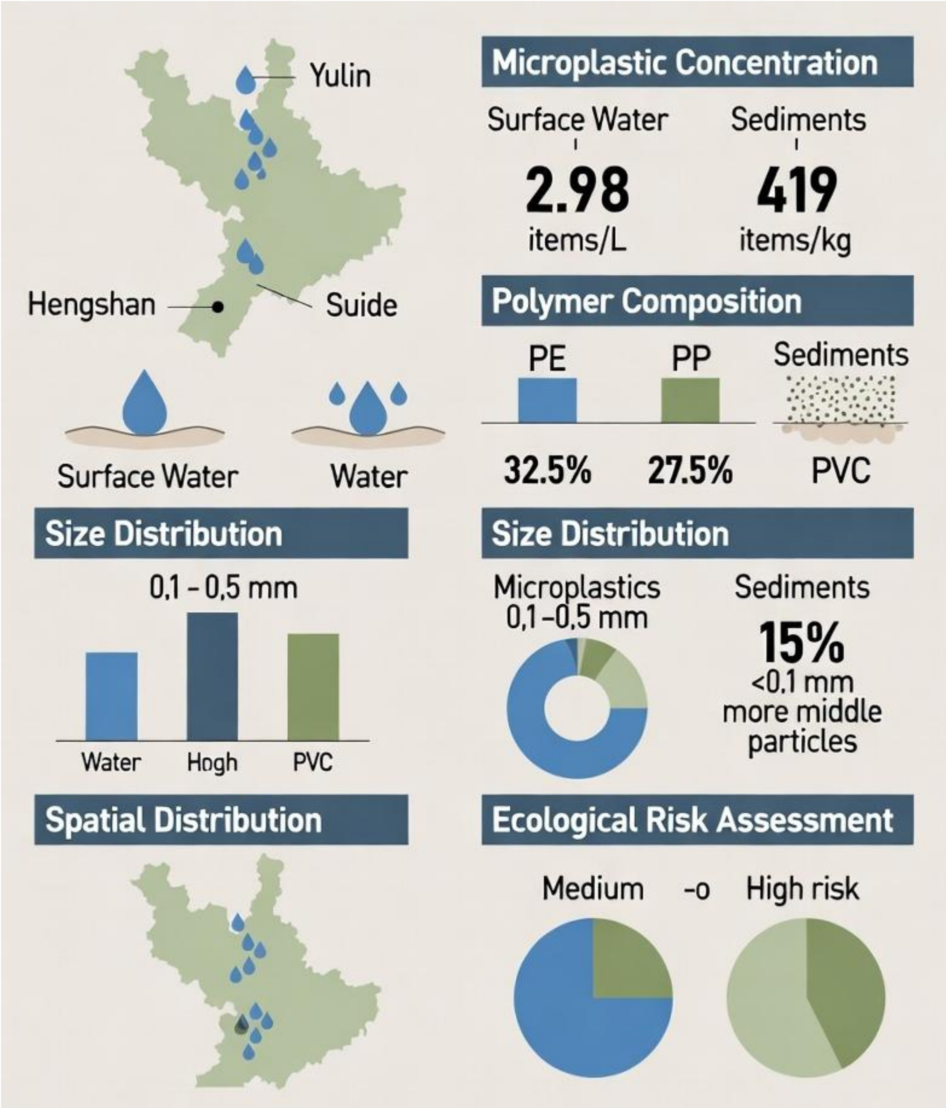

Figure 7 MIcroplastic pollution Wuding River

Key findings:

- **Surface water**: average 2.98 items/L (range 1.02–10.29 items/L)
- **Sediments:** average **419 items/kg** (range 120–1450 items/kg) -significantly higher than surface water
- **Dominant polymers:** PE (32.5%) and PP (27.5%) in water; more high-density fragments (e.g., PVC) trapped in sediments
- **Smallest MPs** (<0.1 mm) were 15% more abundant in sediments than water, due to settling of denser and finer particles
- **Urban areas (Hengshan, Yulin, Suide) showed peak concentrations** in surface water, linked to wastewater and land-use impacts
- **Sediments in middle and lower reaches posed medium to high ecological risk**, with PVC identified as the primary risk contributor

The study highlights that sandy, high-sediment rivers like the WDR act as major MP sinks, with fine sediments and low-flow zones enhancing retention and long-term accumulation - making the Yellow River Basin a previously under-recognized hotspot for microplastic pollution in inland China.

Manghe River Watershed (Jiyuan City) – Soil Heavy-Metal Catastrophe

A **October 2025 peer-reviewed study** published in PLOS ONE (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0335016#sec009) on the **Manghe River** watershed in **Jiyuan City -one of China's largest lead-zinc smelting and coal-intensive industrial hubs** -exposes alarming levels of **soil heavy-metal contamination that highlight systemic environmental governance failures across Chinese industrial zones**.

Key findings:

- **Cadmium** concentrations **averaged 46.4×** the Henan provincial background value
- **Lead 4.85× higher**
- **Mercury 3.52× higher**
- **Industrial** & **mining** storage lands recorded **severe pollution** (PLI = 6.6)

Elemental	Sample size	Minimum	Maximum	Mean	Standard deviation	Variance	Kurtosis	Skewness	CV	Soil background
Hg	121	0.00	2.54	0.12	0.29	0.08	42.0	5.69	2.35	0.03
As	121	0.30	98.2	19.2	12.9	166	14.6	3.34	0.67	11.4
Cr	121	21.2	87.0	55.4	9.18	84.3	1.89	−0.17	0.17	63.8
Cu	121	0.00	179	31.9	20.4	417	23.4	4.04	0.64	19.7
Ni	121	9.87	42.3	27.7	5.21	27.1	1.11	−0.38	0.19	26.7
Pb	121	0.00	924	95.3	142	20000	16.7	3.76	1.49	19.6
Zn	121	32.2	534	128	72.8	5290	10.1	2.83	0.57	60.1
Cd	121	0.55	115	3.43	10.5	109	110	10.3	3.05	0.07
pH	121	4.94	8.53	7.73	0.63	0.39	5.12	−2.11	0.08	8.03

https://doi.org/10.1371/journal.pone.0335016.t002

Using the PMF receptor model, researchers attributed:

- **35% of heavy-metal load** to direct industrial emissions (mainly zincing & cadmium from smelting)
- **27% to mixed transportation** + **agricultural sources**
- **11% to coal combustion**
- **27% to natural + agricultural inputs**

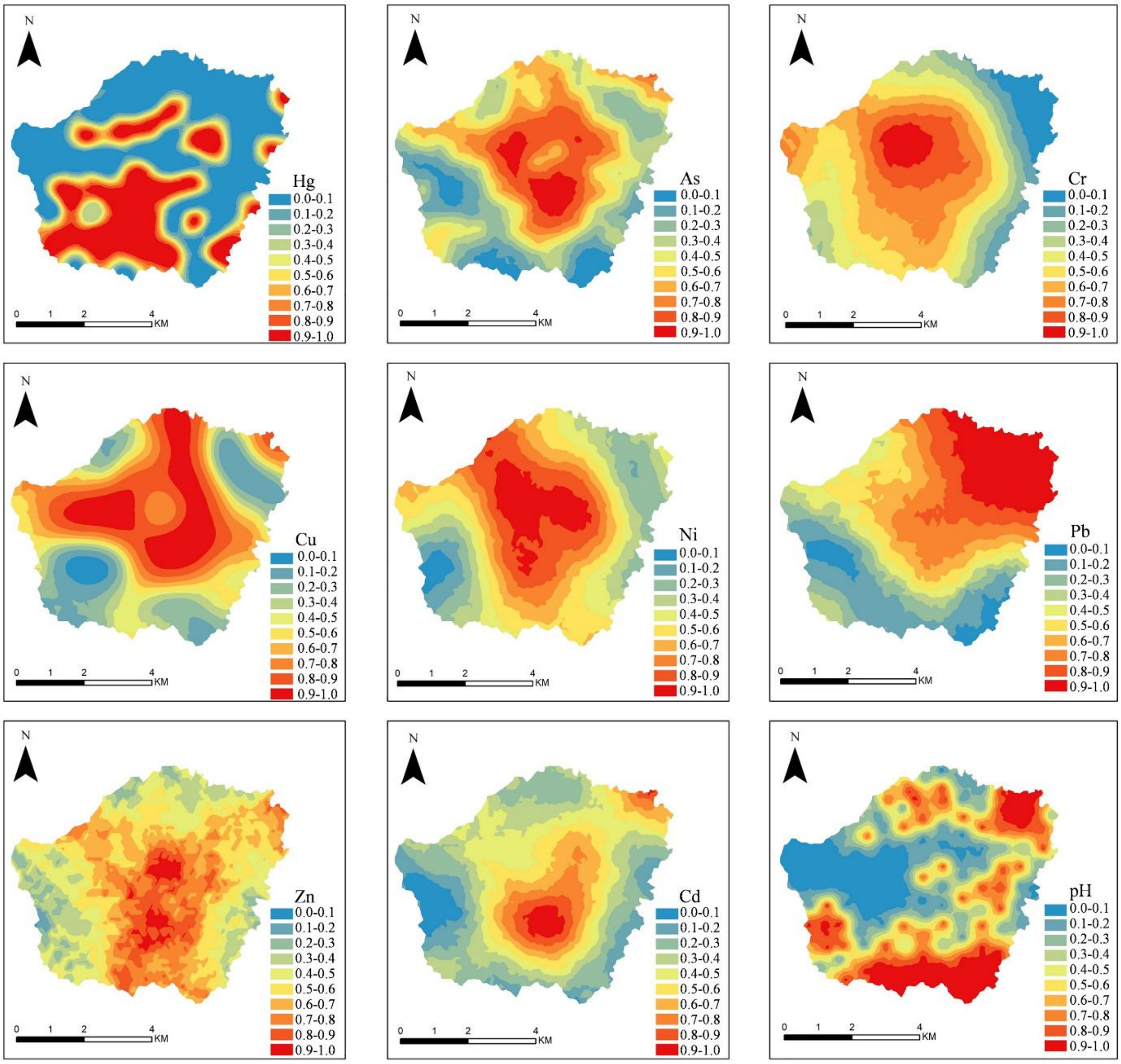

Figure 8 Distribution of soil heavy metal

Spatial mapping revealed clear toxic hotspots radiating from smelters and waste sites, confirming that decades of lax regulation, inadequate waste treatment, and continued coal reliance have transformed once-productive farmland into poisoned zones where cadmium-laced rice and mercury accumulation directly threaten food security and public health.

The **Manghe watershed is not an isolated case** -it is a textbook example of a pattern repeated across **hundreds of Chinese industrial clusters,** where GDP-first policies have consistently overridden enforceable environmental protection, leaving a multi-decade toxic legacy that will cost billions of yuan and generations to clean up.

Heavy Metal Contamination in the Dianchi Lake Basin: Lakes More Polluted than Rivers

A 2024 comprehensive study of the Dianchi Lake Basin (Yunnan Plateau, China) reveals stark differences in heavy-metal pollution between lake and river sediments, with lakes acting as the primary accumulation hotspot (Liang H-Y, Zhang Y-H, Du S-L, et al. Heavy metals in sediments of the river-lake system in the Dianchi basin, China: Their pollution, sources, and risks. Science of The Total Environment. 2024;957:177652. https://doi.org/10.1016/j.scitotenv.2024.177652).

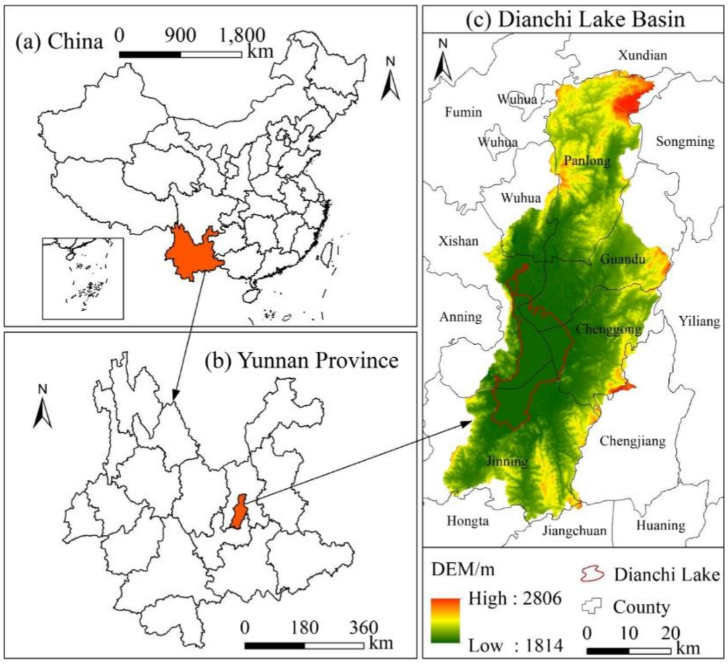

Figure 9 Location of Dianchi Lake Basin in China

Key findings

- At least 50 % of eight monitored heavy metals (Cd, Cr, As, Hg, Pb, Cu, Zn, Ni) exceeded local soil background values in both seasons.
- Lake sediments consistently showed higher concentrations than river sediments, especially for Cr, Ni, Cu, As, Cd, and Hg.
- Source apportionment (PMF + Geodetector):
    - River sediments: dominated by agricultural activities (fertilisers, livestock, aquaculture)
    - Lake sediments: dominated by urban sources (industrial discharges, traffic emissions, atmospheric deposition)

Risk assessment

- **Ecological risk:** primarily driven by Hg and Cd
    - **Lakes**: moderate–high risk (atmospheric deposition + traffic)
    - **Rivers:** moderate risk (agricultural inputs)

- **Human health risk:** As and Ni pose the greatest carcinogenic concern Children face significantly higher carcinogenic risk than adults
    - **Lakes**: risks tied to urban/industrial sources
    - **Rivers**: risks linked to agricultural and natural geogenic sources

The closed nature of the basin, limited water exchange, and intense surrounding urban–agricultural pressure make Dianchi Lake a long-term sink for heavy metals, underscoring the urgent need for differentiated, source-targeted remediation strategies.

Xianyang Groundwater (Shaanxi Province) – Hexavalent Chromium Crisis

A 2025 study (published August 2025 in Environmental Geochemistry and Health, Source: https://link.springer.com/article/10.1007/s10653-025-02731-2) on groundwater in the Xianyang region -a heavily industrialized part of Shaanxi Province on the Loess Plateau - documents widespread hexavalent chromium (Cr(VI)) contamination, with average concentrations reaching 48.7 µg/L in unconfined aquifers (nearly 10 times the WHO guideline of 5 µg/L) and 40.9 µg/L in confined aquifers.

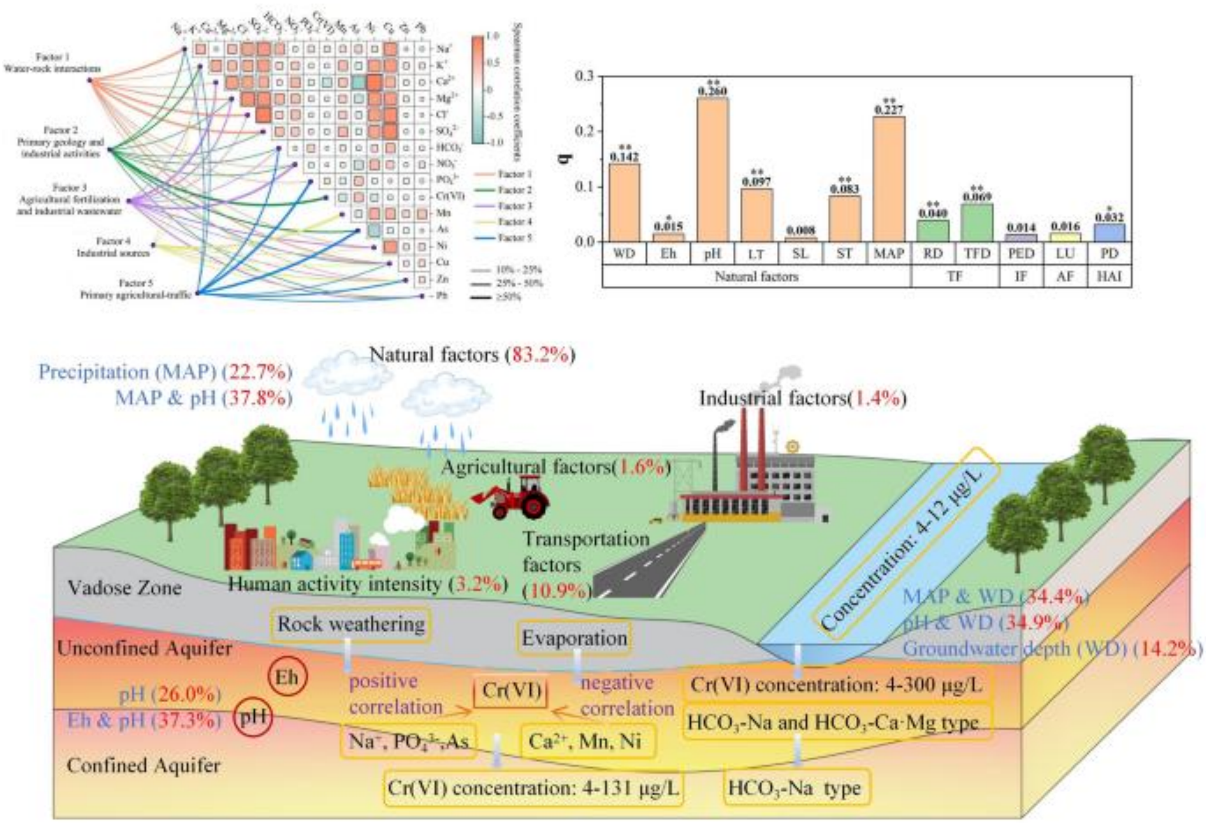

Figure 10 Ground water pollution in China

Researchers found that while natural factors (rock weathering, high pH, precipitation, and redox conditions) account **for 83.2 % of elevated Cr(VI)** in shallower unconfined groundwater -with pH (26 % explanatory power) and mean annual precipitation (22.7 %) as the dominant drivers -**anthropogenic inputs from industrial discharges, traffic emissions, and poor waste management** significantly exacerbate the problem, particularly where dual-factor interactions (e.g., precipitation + pH = 0.378 q-value) amplify mobility.

High-Cr(VI) samples were strongly associated with SO4·Cl-Na and HCO3-Na water types, typical of areas affected by leaching from chrome-related industries and untreated effluent. This case illustrates **how China's rapid industrialisation has overloaded even geogenically vulnerable aquifers**, turning naturally occurring chromium into a highly mobile, **carcinogenic threat** that now contaminates drinking-water sources for millions in the **Guanzhong Plain**, with remediation complicated by the interplay of natural hydrogeology and decades of unenforced pollution controls.

Imidacloprid (IMI) – China's Most Ubiquitous and Unregulated Neonicotinoid Poison

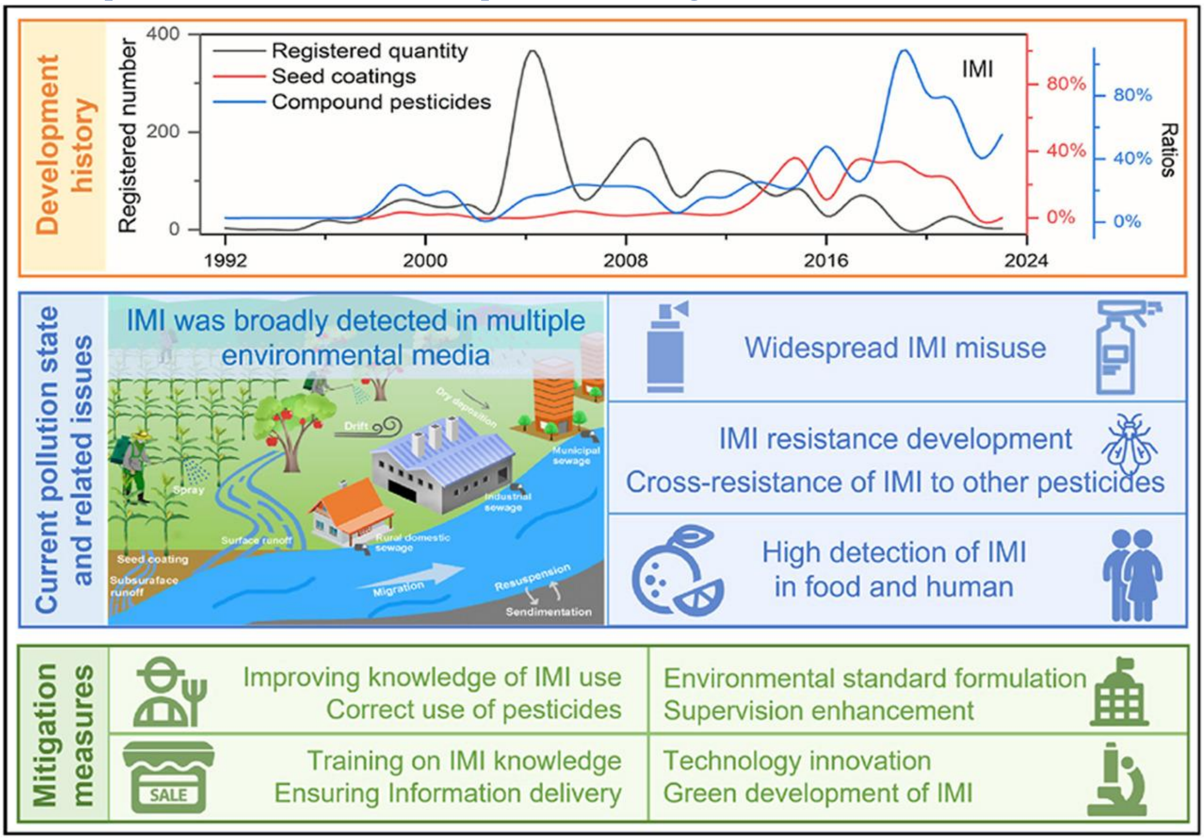

Figure 11 Detected in 90%+ of soils and waters, driving insect resistance and human exposure while regulation lags behind the EU by decades

A January 2025 review published in Environmental Pollution (Volume 365, 125394, Source: https://www.sciencedirect.com/science/article/abs/pii/S0269749124021110) delivers a **damning indictment of imidacloprid (IMI)** -the world's most-used **neonicotinoid insecticide** and the **flagship product of China's pesticide industry**. Despite being banned or severely restricted across the European Union since 2018–2019 for its devastating effects on pollinators, IMI remains essentially unregulated in China and continues to see rising use.

Key findings from the meta-analysis of hundreds of Chinese studies: **IMI is detected in over**

- **90 % of agricultural soils (average 54.6 ± 83.8 ng/g dw);**
- **81 % of surface waters (average 32.8 ± 103 ng/L) &;**
- **84 % of sediments (average 1.7 ± 2.9 ng/g dw) nationwide.**

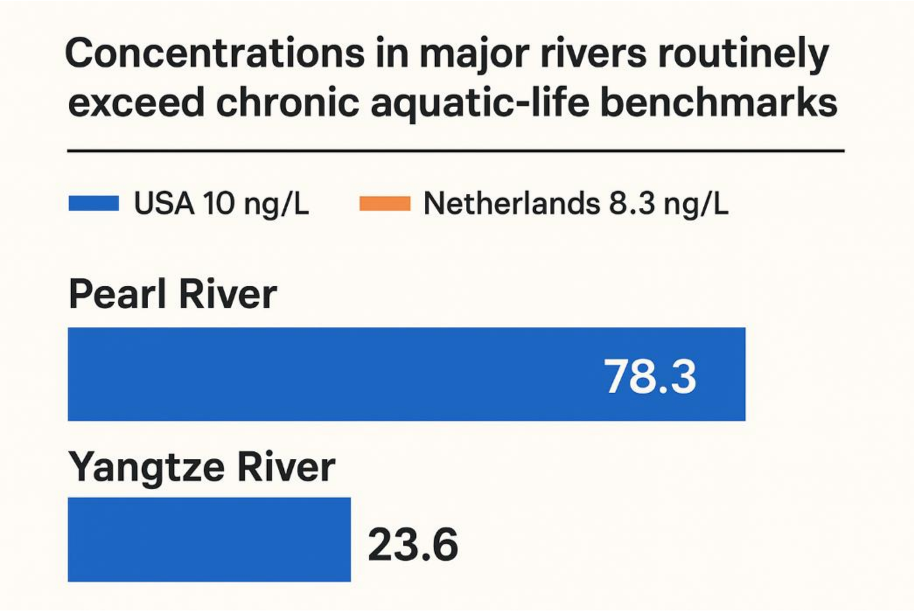

Figure 12 Concentrations in Pearl and Yangtze Rivers

Concentrations in major rivers routinely exceed **chronic aquatic-life benchmarks** set by the **USA (10 ng/L)** and the **Netherlands (8.3 ng/L)** -e.g., **78.3 ng/L in the Pearl River and 23.6 ng/L in the Yangtze.**

97 % of the 2,209 registered IMI products in China are formulated for **agricultural use**; many are still sold as seed coatings -the exact application method banned in Europe because it guarantees **near-100 % systemic release into the environment.**

Widespread overuse has triggered high-level resistance in **numerous pest species, forcing farmers into a toxic treadmill of higher doses** and compounded formulations.

IMI now shows near-ubiquitous human exposure: routinely detected in **Chinese food, drinking water, indoor dust, and human urine/blood/breast-milk samples**.

China remains the global manufacturing powerhouse for imidacloprid, producing 23,000 tonnes annually (2016 figures, likely higher today) -**more than the rest of the world combined** -while **domestic consumption sits at 3,000–4,000 tonnes per year**. The researchers conclude that, absent immediate joint action by government, farmers, and scientists (stricter registration rules, enforcement of integrated pest management, and phase-out of seed-coating formulations), imidacloprid will continue contaminating China's environment and food chain at levels that most developed nations have already deemed unacceptable.

The fact that the EU acted decisively more than six years ago while China still treats IMI as a routine agricultural input lays bare a persistent regulatory double standard that prioritises short-term yield protection over long-term ecological and public-health costs.

Per- and Polyfluoroalkyl Substances (PFAS) – China's "Forever Chemicals" Crisis

From **4,578 ng/L in the Daling River to 28,785 ng/L in the Xiaoqing River**: China Replaces Banned **PFOS/PFOA with Unregulated Short-Chain Substitutes** While Pollution Hotspots Explode"

A February 2025 review published in Toxics (Volume 13, Issue 2, source: https://www.mdpi.com/2305-6304/13/2/135#) delivers the most comprehensive snapshot yet of **PFAS contamination across China's major freshwater basins,** confirming that the country has **become the global epicentre of "forever chemical" pollution after production of legacy compounds shifted eastward following Western phase-outs**.

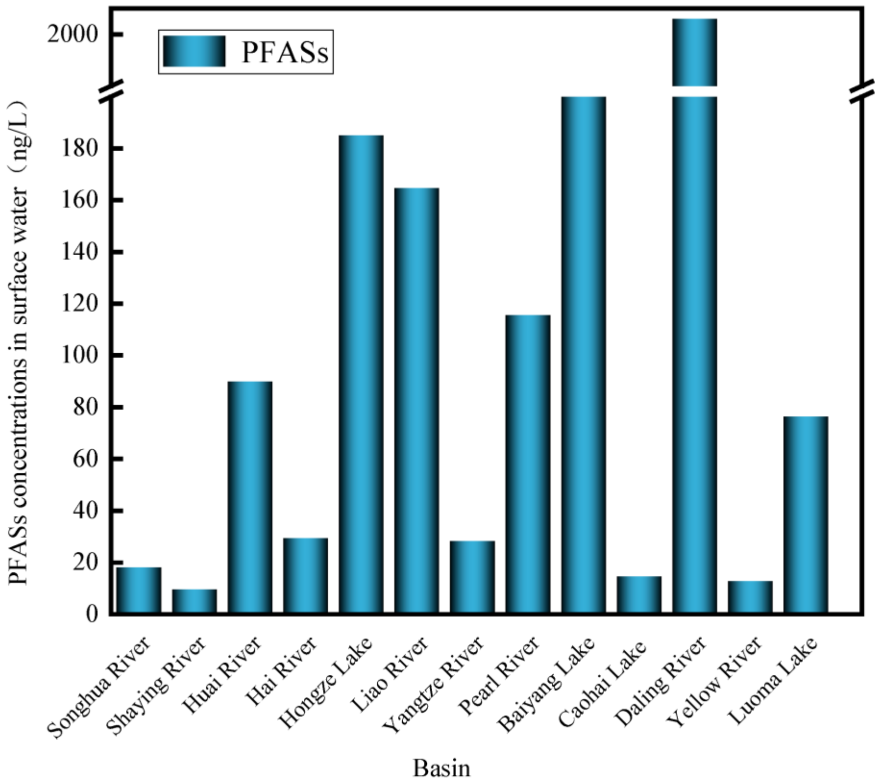

Figure 13 PFAS concentrations in surface water of typical basins in China (ng/L).

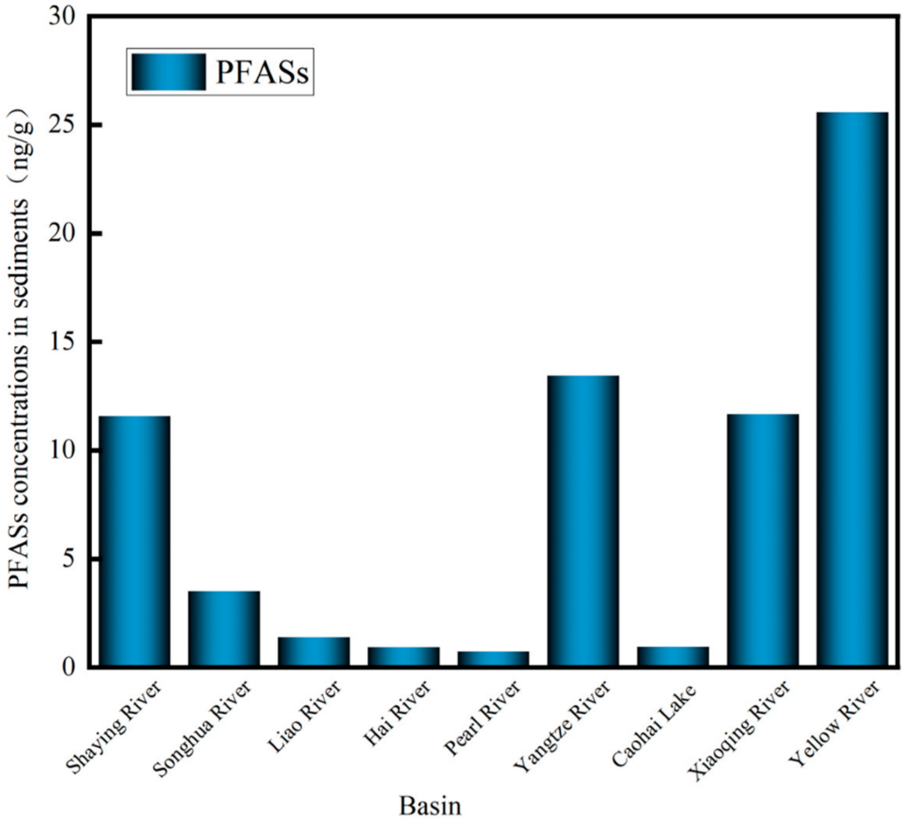

Figure 14 PFAS concentrations in the sediment of typical basins in China (ng/g).

Key findings from the meta-analysis of recent monitoring data:

- **Highest recorded surface-water concentrations worldwide:**
  – **Daling River** (fluorochemical park area): average 2,006 ng/L, peak 4,578 ng/L
  – **Baiyangdian** (North China Plain "Kidney of Beijing-Tianjin"): average 880 ng/L
  – **Xiaoqing River** (Shandong chemical hub): average 28,786 ng/L (2020–2024 data) – among the highest PFAS levels ever documented in any global river
- **Short-chain replacements now dominate:** PFBA, PFBS, PFPeA, and 6:2 FTS have largely supplanted banned PFOS and PFOA in surface water, driven by Chinese manufacturers switching to unregulated alternatives after the 2009/2019 Stockholm Convention listings.
- **Long-chain PFAS still rule sediments and biota:** Higher hydrophobicity causes PFOS, PFOA, and longer-chain compounds to partition into sediments (up to 36 ng/g in Yellow River) and bioaccumulate in fish liver, gills, and protein-rich tissues.
- **Aquatic organisms heavily contaminated:** ΣPFAS in Xiaoqing River gastropods and bivalves reach 17,100 ng/g ww – orders of magnitude above European or North American levels.

Despite the phase-out of legacy compounds, total PFAS loads remain stubbornly high or are rising in many basins because China continues mass-producing short-chain and novel substitutes **(e.g., GenX, ADONA, F-53B**) that are equally persistent and increasingly mobile in water. Eastern and northern industrial corridors (Daling, Liao, Hai, Huai, Yellow, and lower

Yangtze basins) show the worst contamination, directly correlating with fluoropolymer plants, textile finishing, metal plating, and firefighting-foam use.

Risk assessments in the paper conclude that while most basins remain at low to medium ecological risk under single-substance models, the researchers warn that **cocktail effects from dozens of PFAS simultaneously present are not captured** -a critical blind spot. **China's 2022 drinking-water standards (80 ng/L PFOA, 40 ng/L PFOS) offer virtually no protection against the short-chain flood now dominating surface waters.**

The review exposes a **regulatory whack-a-mole**: each time a legacy PFAS is restricted globally, **Chinese chemical giants simply roll out the next unregulated analogue,** perpetuating a **multi-decade contamination cycle** that has turned many of China's most important rivers and lakes into toxic sumps of indestructible fluorine chemistry.

Ocean Pollution

China plays a central, outsized role in **global ocean pollution**, particularly plastic debris entering the marine environment. Despite recent improvements in waste management, the country remains the top source of mismanaged plastic waste that ultimately reaches the oceans.

Key statistics and impacts (primarily 2020–2025 data)

- China ranks #1 globally for **mismanaged plastic waste** and **total plastic pollution entering the oceans** (Jambeck et al., Science 2015; updated estimates in Our World in Data 2024).

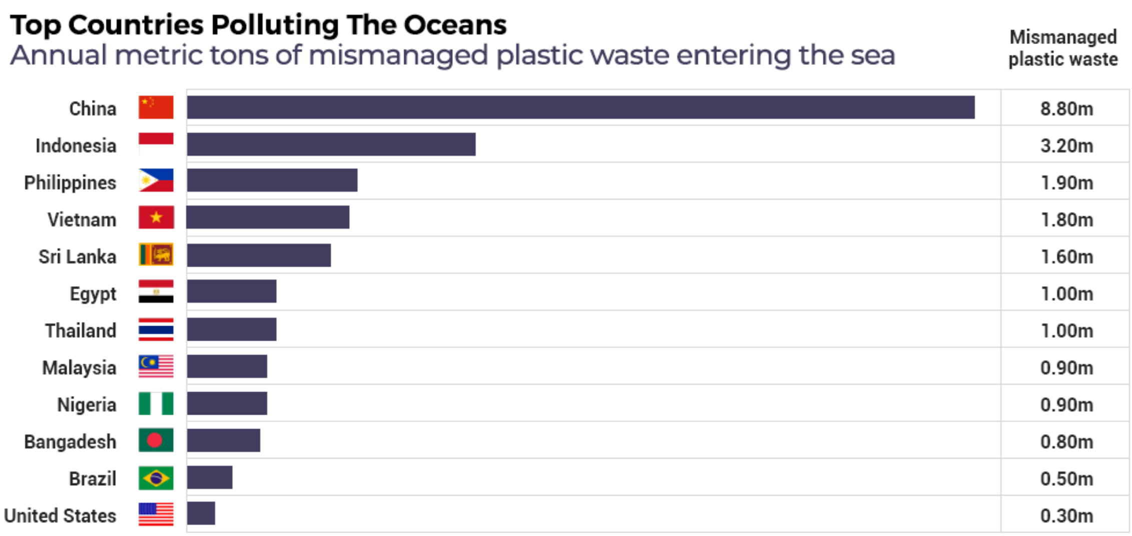

Figure 15 Top countries polluting oceans with mismanaged plastic wastes

- **Eight of the world's top 10 most polluting rivers are in Asia; five are Chinese**: **Yangtze** (Chang Jiang), **Yellow** (Huang He), **Hai He**, **Pearl** (Zhujiang), and **Mekong** (Lancang). Together with the **Indus**, **Ganges**, and others, these rivers account for **~90 % of all riverine plastic flowing into the oceans** (https://www.condorferries.co.uk/marine-ocean-pollution-statistics-facts).

- **The Yangtze River alone discharges an estimated ~1.5 million tonnes** of plastic into the **East China Sea annually** (historical peak; recent reductions due to waste bans, but still the largest single-river contributor).

- **China is the world's largest producer and consumer of plastics:** 29 % of global production, **with 1.5–2 million tonnes of plastic waste leaking into rivers and coastal waters** yearly (pre-2020 figures; post-2020 estimates ~0.8–1.2 Mt due to improved collection, yet still dominant).

- **Microplastics from synthetic textiles** (laundry wastewater) and tyre abrasion are major domestic sources; the **Pearl River Delta and Yangtze Delta** are hotspots for industrial and urban runoff.

- China's coastal "**dead zones**" and **eutrophication** (e.g., Bohai Sea, East China Sea) are exacerbated by nutrient runoff (nitrogen/phosphorus from agriculture) carried by these same rivers, creating hypoxic areas where marine life cannot survive.

Despite the 2018 import ban on foreign plastic waste and aggressive domestic recycling targets, rapid urbanisation, e-commerce packaging growth, and insufficient rural waste infrastructure continue to drive leakage. China's rivers act as the primary "highway" transporting land-based pollution to the Western Pacific and contributing significantly to the Great Pacific Garbage Patch.

Health Impacts: A Million-Plus Premature Deaths Every Year

China's industrial-focused growth-particularly between the early 2000s and early 2020s-created a massive, long-term public health burden driven by environmental pollution. Multiple global assessments, including those by the Global Burden of Disease (GBD) program and the World Health Organization (WHO), confirm that **more than 2 million preventable deaths occur annually in China due to pollution**. Outdoor air pollution alone has been responsible for **1.4–1.85 million deaths each year** until at least 2019, making it one of the country's most lethal risk factors.

Air Pollution (PM2.5, O_3, NO_2, SO_2)

- In 2019, **ambient PM2.5 was the third-leading risk factor for premature mortality**, contributing to **around 1.42 million deaths** and more than **33 million DALYs (disability-adjusted life years)** lost.
- **Total air pollution (indoor + outdoor) causes nearly 2 million deaths annually in China**, according to WHO estimates.
- **Ground-level ozone (O_3)** exposure now contributes to **hundreds of thousands of deaths yearly**, with severe impacts reported in agricultural regions and confirmed by recent cohort studies.
- After significant reductions in **PM2.5** since 2013, research shows **life expectancy in northern cities increased by 2–4 years**, though the **overall national death toll declined only modestly** due to ongoing exposure and population aging.

Water Pollution

- Contaminated drinking water and aquatic exposure are linked to **60,000–100,000 premature deaths each year** from heavy metals, nitrates, industrial pollutants, and waterborne pathogens.
- Rural communities and regions downstream of industrial zones experience **disproportionately high risks**, especially where water treatment is inadequate.

Soil Contamination & Food-Chain Transfer

- Government surveys reveal that **around 19% of China's arable land is contaminated** with heavy metals.
- Chronic dietary exposure to **cadmium, mercury, arsenic, and lead** increases risks of **kidney disease, developmental disorders, and cancer**, particularly in farming regions.
- Although major remediation campaigns began in 2014, **legacy contamination remains severe**, especially around mining areas and industrial clusters.

Emerging Contaminants

- **PFAS ("forever chemicals"), microplastics, and high-toxicity pesticides** are now widely detected in drinking water, crops, soils, and human tissues.
- Studies highlight **synergistic health impacts**, including **endocrine disruption, immune dysfunction, developmental toxicity**, and long-term metabolic risks.
- China's 2022 "Action Plan on Controlling New Pollutants" recognizes that **emerging contaminants represent the next major environmental health threat**.

Vulnerable Populations & Life Expectancy Impact

- **Children face the highest relative risks**, due to faster breathing rates, developing organs, and increased ingestion of soil and dust.
- During peak pollution years (pre-2013), residents of northern China lost **up to 5.5 years of life expectancy from $PM_{2.5}$ exposure alone**.
- Achieving WHO air-quality guidelines would yield **substantial nationwide gains in life expectancy**, though current improvements remain fragile amid industrial pressures, climate extremes, and rapid urbanization.

China's pollution crisis was **not inevitable**. Environmental protection was deprioritized in favor of GDP growth for more than a decade, allowing pollution levels to rise to catastrophic levels before emergency reforms were implemented. While air quality has improved in many major cities and life expectancy has recovered slightly, the **long-term health burden from contaminated soil, polluted rivers, and bioaccumulated toxins will persist for decades**. The human, economic, and ecological costs of these delayed interventions continue to shape China's public health landscape today.

Pollution Control Measures

Since 2015, China has implemented a sweeping overhaul of its environmental governance system—transforming pollution control from a loosely enforced framework into a highly centralized, target-driven regulatory regime. These reforms were designed to reverse the severe environmental degradation resulting from decades of rapid industrialization. While progress is evident in major cities, enforcement gaps continue to challenge the effectiveness of these policies, particularly in rural and interior provinces.

Air Pollution Control Measures

• **“Blue Sky Protection Campaign” (2018–2020):** China launched a nationwide campaign aimed at consolidating progress made under earlier clean-air efforts. Measures included stricter industrial emission caps, expanded real-time monitoring, and mandatory retrofitting of steel, cement, and power plants with advanced desulfurization and denitrification technologies.

• **Ultra-Low Emission (ULE) Standards for Coal Power Plants**: Beginning in 2015, China required all coal-fired power plants—new and existing—to achieve ultra-low emissions comparable to natural gas units. This included limits for SO_2, NO_x, and particulate matter using technologies such as flue-gas desulfurization, SCR systems, and high-efficiency electrostatic precipitators.

• **Mandatory coal-to-gas and coal-to-electricity switching**: Beijing-Tianjin-Hebei and northern provinces were required to replace small coal boilers with cleaner fuels, reducing winter smog episodes. Millions of households were transitioned to gas or electric heating systems.

• **Industrial restructuring & relocation policies**: Steel, cement, and chemical industries were consolidated across multiple provinces. Outdated facilities were shut down, and highly polluting factories were relocated away from heavy-population areas.

• **Vehicle emission and fuel-quality reforms**: China implemented **China V and China VI vehicle standards**, equivalent to Euro V/VI, and eliminated leaded fuel nationwide. Scrappage programs targeted high-emission “yellow label” vehicles and diesel trucks. Electric mobility policies accelerated the EV transition, supported by subsidies and an expanding charging network.

• **Nationwide PM2.5 monitoring network expansion**: From fewer than 200 stations in 2013, China expanded to thousands of $PM_{2.5}$, SO_2, NO_2, and O_3 monitoring sites by 2019, enabling data transparency and regional accountability.

Water Pollution Control Measures

• **“Water Ten Plan” (2015)**: A landmark policy aimed at improving water quality across major rivers, lakes, and groundwater bodies. Key measures included:
– Strict limits on industrial discharges into the Yangtze, Yellow River, and Pearl River systems.
– Closure or retrofitting of thousands of chemical plants located near waterways.
– Water quality redlines requiring provinces to meet minimum ecological thresholds.

• **Upgraded urban wastewater treatment standards**: Over 95% of Chinese cities expanded or upgraded wastewater plants. Advanced treatment (nitrogen, phosphorus removal) became mandatory in Tier-1 cities.

• **Crackdown on agricultural runoff**: Fertilizer and pesticide reduction targets, including mandatory organic substitution programs, integrated pest management, and livestock waste treatment systems.

• **River Chief System (2016–2018)**: A governance innovation that assigns local officials' personal responsibility for the condition of specific rivers and lakes. More than 300,000 river chiefs were appointed nationwide, creating direct administrative accountability.

• **Yangtze River Protection Law (2021)**: China's first basin-wide law restricting mining, chemical discharges, and waterway transport of toxic substances, alongside bans on new heavy-industrial projects near ecologically sensitive zones.

Soil Pollution Control & Food Safety Measures (2016–Present)

• **Soil Pollution Prevention and Control Action Plan ("Soil Ten Plan," 2016):** The plan addressed long-standing heavy metal contamination, with measures including:

- Identification of contaminated agricultural land and industrial sites.
- Mandatory soil testing and risk assessments for farmland.
- Crop substitution in contaminated zones (rice → corn, rapeseed, etc.).
- Rehabilitation targets for industrial brownfields and mining areas.

• **Soil Pollution Prevention and Control Law (2018):** China's first soil protection law, mandating liability for polluters, cleanup financing, and compulsory soil disclosure during land transfers.

• **National survey-based remediation programs**: After the 2014 soil survey revealed widespread contamination, China accelerated remediation of cadmium-, lead-, arsenic-, and mercury-affected zones, especially in Hunan, Guangxi, Guangdong, and Yunnan.

• **Strengthened agricultural product safety controls**: Residue limits were tightened for pesticides, heavy metals, and veterinary drugs, combined with farm-to-market traceability systems.

Emerging Pollutants Regulation (PFAS, microplastics, pharmaceuticals)

• **"New Pollutants Action Plan" (2022–2025)** : A major initiative to regulate PFAS, flame retardants, pharmaceuticals, microplastics, and endocrine disruptors. Measures include:

- Bans or phase-outs of long-chain PFAS compounds.
- Mandatory on-site treatment for industries producing fluorochemicals.
- Pilot programs for microplastic capture in wastewater plants.

• **Environmental risk assessments for priority chemicals**
China expanded its priority pollutant list to over 300 substances, requiring disclosure, emissions tracking, and ecological risk evaluations.

Climate Co-Benefit Measures linked to Pollution Reduction

• **National Carbon Trading System (ETS, launched 2021)**: Covers more than 2,000 power plants, encouraging cleaner production and penalizing high-emission facilities.

• **Renewable energy expansion**: China has rapidly scaled solar and wind energy capacity, reducing reliance on coal in key regions. Some provinces now mandate renewable power quotas for industries.

• **Green freight & logistics reforms**: Fuel-efficiency standards, electrification of buses and taxis, and low-emission zones in major cities contribute to reduce NO_2 and PM emissions.

Regulatory and Institutional Reforms

• **Ministry of Ecology and Environment (MEE) establishment (2018)**: Merged multiple environmental functions into one central ministry, increasing enforcement power.

• **Central Environmental Inspections ("Tigers and Flies" Approach)**: Rolling nationwide inspection teams audit provincial governments, industrial zones, SOEs, and local regulators. Penalties include fines, shutdowns, demotions, or criminal charges.

• **Public disclosure & data transparency tools**: Online pollutant discharge registries, real-time air quality dashboards, and mandatory corporate environmental reporting.

Ongoing Challenges

Despite China's ambitious pollution-control frameworks and high-level political commitment, several structural and systemic challenges continue to hinder meaningful progress:

1. Enforcement Gaps and Local Protectionism

While national regulations have strengthened since 2015, **implementation remains uneven**. Local governments—often dependent on revenue from polluting industries—frequently **delay enforcement, dilute penalties, or overlook violations** to protect economic interests. This has resulted in inconsistent pollution reduction outcomes across regions.

2. Industrial Overcapacity and Dependence on Coal

China's continued reliance on coal—especially in heavy industries like steel, cement, and chemicals—creates persistent air and carbon pollution. Despite the push for cleaner energy, **new coal-fired power plants and industrial expansions** continue to offset gains from renewable energy.

3. Agricultural Runoff and Rural Pollution

Rural areas remain a blind spot in China's environmental governance. Excessive use of fertilizers, pesticides, and livestock waste contributes to **severe non-point water pollution**, yet monitoring systems in rural regions remain underdeveloped.

4. Weak Transparency and Manipulation of Environmental Data

Multiple investigations and independent studies have highlighted **systemic opacity in China's environmental reporting**.

- Local authorities have been known to **withhold, alter, or selectively disclose** air and water quality data to meet political targets.
- The **CCP's tight control over environmental information**—including restrictions on research publications and suppression of independent monitoring—makes it difficult for citizens, researchers, and the global community to assess true pollution levels.
- High-profile cases of **air-quality data falsification**, removal of monitoring equipment, and politically influenced reporting undermine the credibility of China's environmental progress.

This lack of transparency not only hampers effective policymaking but also signals a deeper problem: **environmental governance remains subordinate to political image management**.

5. Urban–Rural Inequality in Environmental Protection

Major cities—Beijing, Shanghai, Shenzhen—benefit from advanced monitoring, stricter enforcement, and public pressure. In contrast, smaller towns and inland provinces face **weaker oversight, poorer infrastructure**, and greater pollution burdens.

6. Slow Progress on Hazardous Chemicals and Soil Pollution

Despite national action plans, contamination from **heavy metals, PFAS, and industrial solvents** remains widespread. Soil remediation projects are expensive and long-term, leaving millions of hectares of farmland and river basins still at risk.

7. Economic Priorities Often Override Environmental Goals

Periods of economic downturn prompt China to **relax pollution controls**, accelerate industrial output, or approve new coal projects. This cyclical pattern undermines sustained improvements and casts doubt on long-term commitments to ecological protection.

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