What is Particulate Matter (PM2.5) and the Environmental Significance

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KEY POINTS

- PM2.5 is the mass of particles 2.5 micrometres or smaller in a cubic metre of air, reported in µg/m³. The largest are about 30 times thinner than a human hair.
- A PM2.5 reading can come from a reference monitor, a low-cost optical sensor, a satellite estimate or a forecast model such as CAMS. Each has a different accuracy and averaging period.
- Some particles are emitted directly by burning, dust and sea spray. Others form in the air from gases such as sulphur dioxide, nitrogen oxides, ammonia and VOCs. In cooking areas of homes studied in Accra and The Gambia, biomass smoke was the largest source.
- The WHO's 2021 guideline levels are 15 µg/m³ for a 24-hour average and 5 µg/m³ for a yearly average. The WHO estimates outdoor air pollution caused 4.2 million premature deaths in 2019.

On 29 January 2026, a thick haze hid the hills around Kigali, and the CAMS forecast model put the city's PM2.5 at about 37 µg/m³ for the day (the haze and the data are in this post). That is about two and a half times the WHO's 24-hour guideline. PM2.5 is the fine smoke and dust in the air that you breathe without seeing. This post explains what a number like 37 means, how much to trust it and what to do about it.



What PM2.5 is

Particulate matter (PM) is a mix of solid and liquid particles floating in the air. The US Environmental Protection Agency (EPA) groups them by size. PM10 means particles 10 micrometres across or smaller. PM2.5 means particles 2.5 micrometres or smaller. A micrometre is a thousandth of a millimetre.

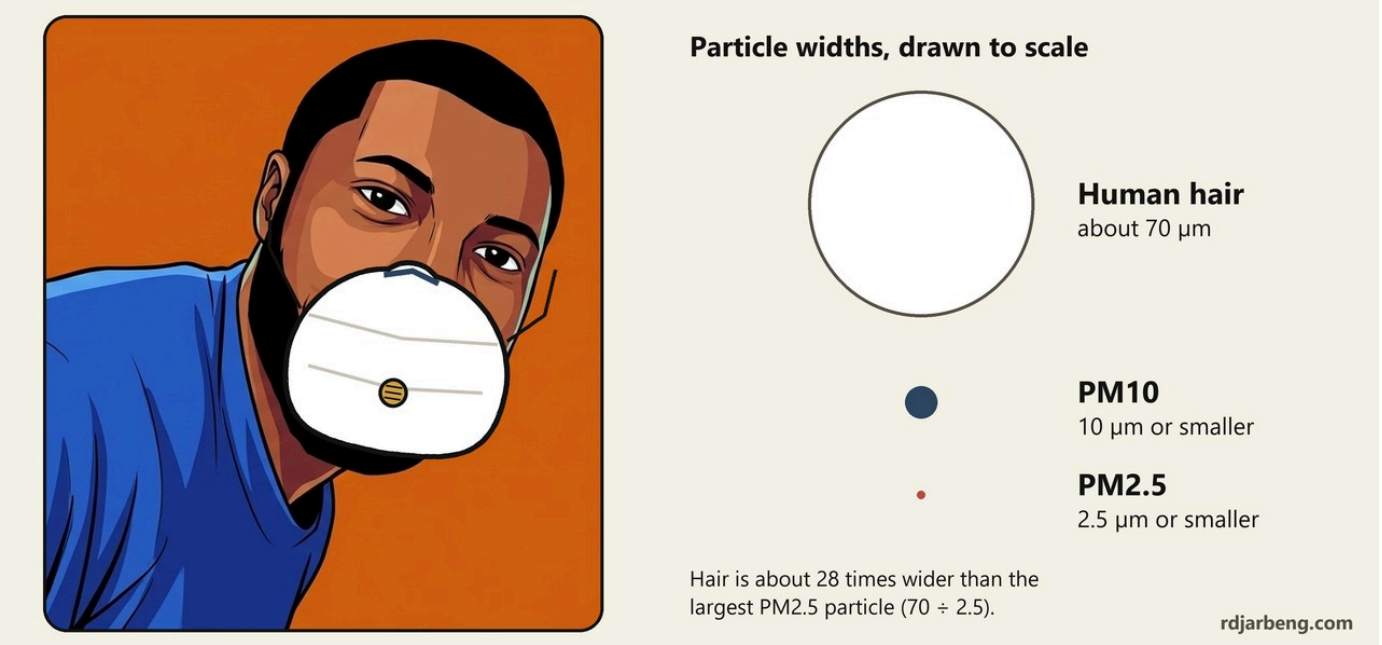
An average human hair is about 70 micrometres wide, according to the EPA. That is roughly 30 times the largest PM2.5 particle, since $70 \div 2.5 = 28$70 ÷ 2.5 = 28. The largest PM10 particles are about a seventh of a hair's width.

PM2.5 is reported as a mass concentration. It is the number of micrograms of particles in one cubic metre of air, written µg/m³. A microgram is a millionth of a gram. A reading of 15 µg/m³ means 15 micrograms of fine particles in every cubic metre.

Size matters because of how far particles travel inside the body. Both PM10 and PM2.5 can reach deep into the lungs, and PM2.5 can even enter the bloodstream, says the WHO.

How much PM2.5 is too much

The WHO's 2021 guidelines set guideline levels for PM2.5 of 15 µg/m³ averaged over 24 hours and 5 µg/m³ over a year. These are not safe limits. The evidence has found no level below which PM2.5 does no harm across a population (COMEAP).



Particle widths are drawn to scale: a hair is about 70 µm, PM10 up to 10 µm and PM2.5 up to 2.5 µm (EPA).

In 2019, 99% of the world's population lived where WHO guideline levels were not met (WHO). At an urban background site in Nairobi, PM2.5 averaged 21 µg/m³ in samples taken from 2008 to 2010 (Gaita et al., 2014). That 2008 to 2010 average was four times the WHO yearly level.

Both short-term and long-term exposure to particulate matter are linked to illness and death from heart and lung disease. Long-term exposure is also linked to lung cancer and to harm during pregnancy and birth. A US study of about 500,000 adults linked long-term exposure to deaths from lung cancer and from heart and lung disease (Pope et al., 2002). In 2013, the WHO's cancer agency classed particulate matter as a cause of lung cancer (WHO).

The WHO fact sheet estimates that outdoor air pollution caused 4.2 million premature deaths worldwide in 2019. About 89% were in low- and middle-income countries. Heart disease and stroke caused 68% of them, chronic lung disease 14%, lung infections 14% and lung cancer 4%. Outdoor and household air pollution together are linked to 6.7 million premature deaths a year.

In Africa, air pollution contributed to about 1.1 million deaths in 2019. About 63% of these were linked to household air pollution (State of Global Air, 2022).

Where PM2.5 comes from

Some particles are released straight into the air. These are primary particles. The EPA lists construction sites, unpaved roads, fields, smokestacks and fires. Burning fuel gives off black carbon, the soot from incomplete burning, along with organic particles (Bond et al., 2013). Wind lifts mineral dust, which can cross oceans (Prospero, 1999). Breaking waves throw sea salt into the air near coasts (Lewis & Schwartz, 2004).

Other particles form in the air from gases. These are secondary particles, and the EPA says most particles form this way. Sulphur dioxide (SO_2) from power plants and industry turns into sulphate. Nitrogen oxides (NO_x) from vehicles and industry turn into nitrate. Ammonia, mostly from fertiliser and livestock, combines with these to make ammonium salts (Behera et al., 2013). Volatile organic compounds (VOCs) from fuels, solvents and plants react to form organic particles (Hallquist et al., 2009).

In African homes, cooking smoke leads

About 2.1 billion people cook on open fires or inefficient stoves, says the WHO. The fuels include wood, crop waste, charcoal, coal, dung and kerosene. The same fact sheet says 923 million people in sub-Saharan Africa lacked clean cooking in 2022.

In the cooking areas of homes studied in Accra and The Gambia, biomass smoke was the largest source of PM2.5. It made up 39 to 62% of PM2.5 in Accra, depending on the neighbourhood, and 74 to 87% in Banjul and Basse (Zhou et al., 2014; abstract on PubMed). Road dust and vehicles added 12 to 33% in Accra.

Outdoors in cities, traffic and dust matter more. In Nairobi, they together made up about 74% of PM2.5 at the sites studied (Gaita et al., 2014). Fires add a seasonal layer. Fires in Africa account for 70% of the area burned worldwide, and most burn in the dry season (NASA).

Where a PM2.5 reading comes from

The number in an app can come from very different instruments, and they are not equally accurate.

Reference monitors are the most accurate. The standard method pulls air through a filter for 24 hours, and a lab weighs the filter (Barkjohn et al., 2021). Continuous monitors give hourly values. A common type, the beta attenuation monitor, collects particles on a tape and measures how much they block beta rays (HORIBA). These monitors are costly and need trained staff.

Low-cost sensors shine a laser through the air and measure the light that particles scatter. Damp air changes how particles scatter light. In US tests, raw readings from PurpleAir sensors overestimated PM2.5 by about 40%. Humidity adds error, so the EPA's correction includes a humidity term (Barkjohn et al., 2021). Placing a sensor next to a reference monitor lets you fit a correction. The EPA notes that sensor data quality varies widely.

Satellite estimates start from aerosol optical depth, a measure of how much particles in the whole column of air dim sunlight. A team at Washington University in St. Louis (USA) combines this with a chemistry model. They then calibrate it against ground monitors (ACAG). This gives PM2.5 estimates for places with no monitor.

Forecast models such as the Copernicus Atmosphere Monitoring Service (CAMS) make five-day global forecasts of aerosols. Its global grid cells are about 45 km across (Open-Meteo), so one value covers a whole city. The Kigali figure at the top of this post is a CAMS estimate, not a monitor reading.

Every value also covers a time window. Hourly values show changes through the day. A 24-hour average describes short-term exposure, and a yearly average long-term exposure (WHO).

Apps show either the concentration in µg/m³ or an Air Quality Index (AQI) number from 0 to 500 or more (AQI explainer). The US AQI for particles is based on a 24-hour average. For current conditions, the US AirNow site uses the NowCast, which works from recent hourly readings.

Haze and climate

Fine particles are the main cause of reduced visibility, or haze, in parts of the US, including many national parks (EPA). The same happened on a hazy day in Kigali in January 2026, when model estimates put PM2.5 at about 37 µg/m³. The airport, normally visible across the valley, all but disappeared.

Particles also affect climate. Black carbon absorbs sunlight and warms the air. Sulphate and nitrate particles scatter sunlight and have a cooling effect. Particles also change how clouds form (Bond et al., 2013; IPCC, 2021).

What to do with a PM2.5 reading

First, check the unit (µg/m³ or AQI) and the period it covers. Then check whether it came from a monitor, a sensor or a model. A 24-hour average above 15 µg/m³ is above the WHO guideline. The Kigali day from the top of this post is a worked example. It was a CAMS model value for a 45 km grid cell, not a monitor reading. At 37 µg/m³ it was about 2.5 times the WHO daily level. On the US scale it comes to an AQI of about 105, "Unhealthy for Sensitive Groups" (AQI explainer).

On bad days, the AirNow guide for particle pollution advises sensitive groups to make outdoor activities shorter and less intense. Sensitive groups include people with heart or lung disease, older adults, children and teenagers. Coughing or shortness of breath are signs to take it easier.

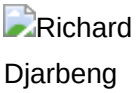
At home, the biggest change is the cooking fuel. The WHO counts solar, electricity, biogas, LPG, natural gas and alcohol fuels as clean at the point of use. The WHO adds that women and children carry the greatest health burden from cooking smoke.

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RECOMMENDED READING

Understanding the Air Quality Index (AQI)

Oct. 29, 2025

How Google forecasts Weather and Air Quality Data

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This Week in Air Quality Research: Novel Insights and Sensor Advances (23-June-2025)

Jun. 23, 2025

Guide to Accessing Air Quality Data from US Embassies Worldwide

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