IIIT® turns the air we breathe into a discovery we can see

The air around us contains many particles and processes that we do not ordinarily see. The IIIT® Project makes it possible to capture these invisible processes in a condensate that can be observed. This allows pupils and the public to work with a real sample of air and consider what is happening in the environment around us.

Bc. Adriána Voroničová

Author of the concept, technical solution and IIIT® Project

Foreword to the chapter ‘Black Rain’

We notice certain phenomena in the atmosphere only when they occur in an exceptionally intense or unusual form. At such moments, they suddenly appear to be something extraordinary or isolated.

In reality, however, many of these processes take place continuously in the atmosphere. The only difference is their intensity and whether or not we are able to notice them.

The atmosphere is a dynamic environment full of particles, aerosols, chemical substances and reactions. Wind carries dust from the landscape, industrial emissions mix with the air, water droplets capture microscopic particles, and processes of condensation and mixing take place in the atmosphere. Most of these phenomena occur on a scale that people do not ordinarily perceive.

When a specific situation arises in the atmosphere – for example, intense emissions, fires, military events or a high concentration of aerosols – these processes may become more pronounced. Precipitation may then carry a visible quantity of material, giving rise to phenomena described, for example, as ‘black rain’. Such situations remind us of an important fact: what we perceive as an exceptional phenomenon is often merely a particular version of processes that occur continuously in the atmosphere.

This is precisely why it is scientifically valuable to study such events on an ongoing basis. They enable a better understanding of particle transport, condensation and interactions between aerosols and water droplets. These mechanisms are addressed in the specialist literature as well as in atmospheric physics and environmental science.

The following chapter presents examples of documented situations in which these processes have manifested themselves in a more pronounced form – for example, as dark or polluted precipitation referred to as ‘black rain’.

Black Rain – Formation and Chemical Composition

Introduction

So-called ‘black rain’ is not a distinct meteorological type of precipitation. It is ordinary precipitation that captures a high concentration of aerosols, soot and other particles from the atmosphere as it forms or falls. In atmospheric chemistry, this phenomenon is known as wet deposition: the process by which precipitation removes gaseous and aerosol pollution from the atmosphere.

Mechanism of Formation

The formation of black rain is associated with a high concentration of particles in the atmosphere. Major fires, explosions or industrial emissions release large quantities of soot, dust and other chemical constituents into the air.

Water droplets in clouds form on small particles that act as condensation nuclei. If these particles consist of soot or combustion products, raindrops capture them as they grow or fall and carry them to the ground. This process is known as the scavenging of aerosols by precipitation.

Chemical Composition

According to the World Health Organization (WHO), fine particles in the air may contain, for example, sulphates, nitrates, ammonia, sodium chloride, black carbon (soot), minerals, metals and water.

The combustion of oil, coal, gas, wood or waste also produces polycyclic aromatic hydrocarbons (PAH). According to the Agency for Toxic Substances and Disease Registry (ATSDR), PAH are formed during the incomplete combustion of organic materials and are often found in soot and combustion products.

During major fires or industrial releases, smoke may also contain sulphur oxides, nitrogen oxides and various hydrocarbons. These substances may subsequently bind to aerosols and be removed from the atmosphere by precipitation.

Current Case – Iran

According to the Slovak portal iMeteo, reports of dark precipitation containing smoke and various constituents appeared after attacks on oil depots in Tehran. International media also reported extensive fires at oil depots that released large quantities of toxic smoke into the atmosphere.

It is important to emphasise, however, that without laboratory analysis of specific rainwater samples, it is not possible to determine the precise chemical composition of each instance of precipitation. Its mechanism of formation can nevertheless be explained scientifically on the basis of known atmospheric processes.

Conclusion

Black rain occurs in situations where precipitation captures large quantities of aerosols and combustion products present in the atmosphere. It is a natural wet-deposition process in which particles and chemical substances are removed from the atmosphere. The principal constituents of such precipitation may include soot (black carbon), mineral dust, sulphates, nitrates and organic residues produced by the combustion of oil or wood.

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IIIT® Emissions Collector – Scientific Explanation of Its Functional Mechanisms

Introduction

The IIIT® emissions collector is a device designed to capture constituents of the air and gaseous emissions in a liquid phase – a condensate. The condensate produced in this way enables further visual observation and subsequent analysis of the captured substances. This document explains its function on the basis of generally recognised processes in atmospheric chemistry and aerosol physics. The description draws on scientifically documented phenomena such as condensation, nucleation and aerosol deposition.

Basic Physical Processes Used to Capture Substances

Air contains a broad spectrum of gases, vapours and solid particles of various sizes. According to the World Health Organization, fine particulate matter (PM) may contain sulphates, nitrates, ammonia, mineral dust, organic carbon, black carbon and trace metallic elements.

When temperature or pressure changes, some substances may pass from the gaseous phase into a liquid or solid state. This process is known as condensation. Condensation is one of the fundamental physical mechanisms involved in the formation of clouds, dew and fog.

If particles or microscopic surface irregularities are present in a gas stream, they may act as condensation nuclei. Water vapour or other condensable substances may subsequently condense on these nuclei.

Aerosols as Condensation Nuclei

The atmosphere contains small particles known as aerosols. These particles may be solid or liquid, and their size may range from a few nanometres to several micrometres. Aerosols often serve as condensation nuclei for droplet formation.

According to NOAA, such particles are known as cloud condensation nuclei (CCN), on which water vapour can condense and form water droplets. The same mechanism may also operate during the condensation of various organic or inorganic substances from gases.

Capture of Substances by Condensation and on Surfaces

When gases come into contact with a cold surface, vapours may condense and certain volatile substances may be captured. This process is well known, for example, in the formation of dew and in industrial condensing heat exchangers.

According to the US EPA, various atmospheric compounds may be removed from the atmosphere by deposition or condensation on surfaces.

When gases are cooled, the following, for example, may condense:

- water
- organic hydrocarbons
- certain acids or oxides
- various polar organic compounds

On the basis of generally recognised processes in atmospheric chemistry, it may be expected that the condensational capture of a proportion of aerosols can also include the following types of substances:

- water vapour
- organic hydrocarbons and their oxidised forms
- polycyclic aromatic hydrocarbons (PAH)
- soot (black carbon)
- mineral dust particles
- nitrogen oxides and aerosols bound to them
- trace metallic elements bound to particles

Polycyclic aromatic hydrocarbons are formed mainly during the incomplete combustion of organic substances such as oil, coal or wood. These compounds are often found bound to soot or aerosols and may be transported through the air.

Formation of a Liquid Extract (Condensate)

If gases are cooled or transferred into an environment in which condensation occurs, certain constituents of the atmosphere or emissions may gradually become incorporated into the liquid phase being formed. The condensate produced in this way may contain dissolved gases, organic compounds and microscopic particles.

Such a condensate then represents a more concentrated extract of substances that were originally dispersed in the air.

Conclusion

The function of the IIIT® emissions collector can be explained using generally recognised processes in atmospheric physics and chemistry. The most important mechanisms include vapour condensation, the capture of aerosols on surfaces and the formation of condensation nuclei. These processes make it possible to transfer dispersed substances from the gaseous phase into a liquid condensate that can subsequently be analysed or observed.

References

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