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INCREASING THE VISIBILITY AND KNOWLEDGE BASE ON AIR QUALITY WITH BIG DATA AND ITS IMPACT ON THE POPULATION HEALTH

Erasmus+ KA220 Cooperation Partnerships

Industries/ Factories/ Biomass Burning

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1 INTRODUCTION

Industry is a key element of the European economy. At the same time, the industry contributes to more than half of the total emissions of some major air pollutants and greenhouse gases, as well as other significant environmental impacts, including the release of pollutants into water and soil, waste generation and energy consumption. Air pollution is often associated with the burning of fossil fuels. This undoubtedly applies to power plants, but also to many other industrial activities that may have their own electricity or heat production, such as iron and steel or cement production. During industrial production, pollutants are released into the air due to the handling of materials, their storage and transport, e.g. emissions of sulfur dioxide, non-methane volatile organic substances, solid particles, or nitrogen oxide and carbon monoxide[1]. Air pollution is one of the biggest threats for the environment and affects everyone: humans, animals, crops, cities, forests, aquatic ecosystems. The decrease in air pollution from industry was caused by a more significant slowdown in industrial production as a result of the covid-19 pandemic. And due to that the global biomass market is rapidly expanding, and many companies are leading the way in the growth of the biomass industry.

2 BACKGROUND

During industrial production, mainly solid pollutants are released into the air due to the handling of materials, their storage and transport. Other substances are emitted into the air mainly during the burning of fuels associated with the production itself. Metal production has long been among the biggest air polluters in Slovakia. The most important category is iron and steel production. The use of solvents is also a significant source of emissions. A wide range of substances containing non-methane volatile organic compounds are used in industry as well as in households: pure organic solvents or various mixtures used in industry, cleaning agents, paints, thinners, adhesives, cosmetics and toiletries, various household or care products about cars. This also includes emissions from asphalting roads.

2.1 Definition of industrial pollution

European Council (2024) defines that producing electricity, treating and managing waste, rearing livestock or making cement are examples of industrial activities which release polluting emissions into the environment. The discharge of pollutants into the environment can lead to health conditions such as asthma, bronchitis, cancer and heart failure. Emissions are considered to be responsible for thousands of premature deaths each year. IQAir (2024) presents that industrial pollution refers to the contamination of the environment air, water, and soil caused by industrial activities. These activities typically involve the manufacturing, processing, and extraction of raw materials, which produce waste products and emissions that

[1] sulfur dioxide (SOx)
non-methane volatile organic substances (NMVOC)
solid particles (PM_{10} and $PM_{2.5}$)
nitrogen oxide (NOx)
carbon monoxide (CO)
heavy metals (Cd, Hg and Pb)

are harmful to the natural environment and human health. Industrial pollution can result from a variety of sources, including factories, power plants, mining operations, chemical production facilities, and commercial transportation. Air pollution (Brofind, 2023; SolarImpulse Founation, 2024) is a form of environmental pollution that includes all physical, chemical, and biological phenomena that change the properties of the air with a consequent alteration of the geophysical balance. Two types of air pollution can be distinguished, depending on the source:

- *Anthropogenic:* is pollution that derives from activities related to the presence of human beings, such as combustion of fossil fuels, emissions from industries and factories, agricultural activities and waste production.
- *Natural:* is pollution that derives from natural phenomena

Industrial pollution is an additional term that means a huge amount of waste is discharged from various categories of industrial plants. Industrial waste or pollutants is generated from manufacturing or industrial processes (Salam and Sultana, 2022; Harrison, 2014). Air pollution can be defined as an alteration of air quality that can be characterized by measurements of chemical, biological or physical pollutants in the air. Therefore, industrial pollution means the undesirable presence of impurities or the abnormal rise in the proportion of some constituents of the atmosphere. It can be classified in 2 sections: visible and invisible air pollution. *Local:* this concerns the quality of ambient air within a radius of a few kilometers, than *Regional:* pollution like acid rain, photochemical reactions and degradation of water quality at distances of a few kilometers to a thousand kilometers and ***global:*** depletion of the ozone layer and global warming caused by the emission of greenhouse gases, mainly carbon dioxide (CO2) (SolarImpulse Foundation, 2024)

Biomass (NesFircroft, 2021), in ecological terms, refers to renewable organic matter that comes either from plants or animals. In the context of energy, it refers to any organic matter that can be used to produce energy. Because biomass can technically be used as a direct source of fuel, some people use the terms biomass and biofuel interchangeably. Biomass is one contender for replacing fossil fuels, but questions over its suitability, and the sustainability of its source, remain (Tunnicliffe, 2022). Biomass is a renewable energy resource that encompasses:

- Animal manure and human sewage
- Biogenic materials found in municipal solid waste such as cotton, paper, and wool products and yard, wool, and food wastes
- Waste materials and agricultural crops such as sugar cane, woody plants, switchgrass, soybeans, corn, algae, and crop and food processing residues
- Wood and wood processing wastes such as wood pellets, firewood, wood chips, sawdust, lumber, and black liquor from pulp and paper mills

European Environment Agency (2024) present the report which has shown the industrial releases of SOx and PM_{10} decreased about 70 % between 2010 and 2022 in the European Union. Other emissions decreased to a lesser extent: heavy metals (Cd, Hg and Pb) by 58 %, NOx by 48 %, NMVOC by 35 % and CO_2 by 25 %. During the same period, the value that industry generated for the economy as measured by gross added value (GVA) increased, indicating that European industry has become less emission intensive, as the ratio of air pollutant releases to

the production of industrial goods decreased. Emissions of pollutants associated primarily to activities that include combustion processes (e.g. electricity producers, iron and steel works, cement plants) are generally decreasing across the board and refers to emissions of CO_2, NO_x, SO_x and PM_{10}. Change of pollutant releases into air is shown on Fig. X This trend is consistent with the improvement of environmental performance of these industries and shifts of fuels (with a progressive abandonment of coal). Evidence points to EU policy as a key driver of these positive developments as significant emissions reductions (over 50 % since 2010) occurred in almost all countries that generally joined the EU. Heavy metals (Cd, Hg, Pb) are emitted in relatively lower amounts and have a naturally variable trend over time. There are several reasons for this, some related to the reporting mechanism (which includes estimations and operates with minimum thresholds) and others related to actual developments in each industry.

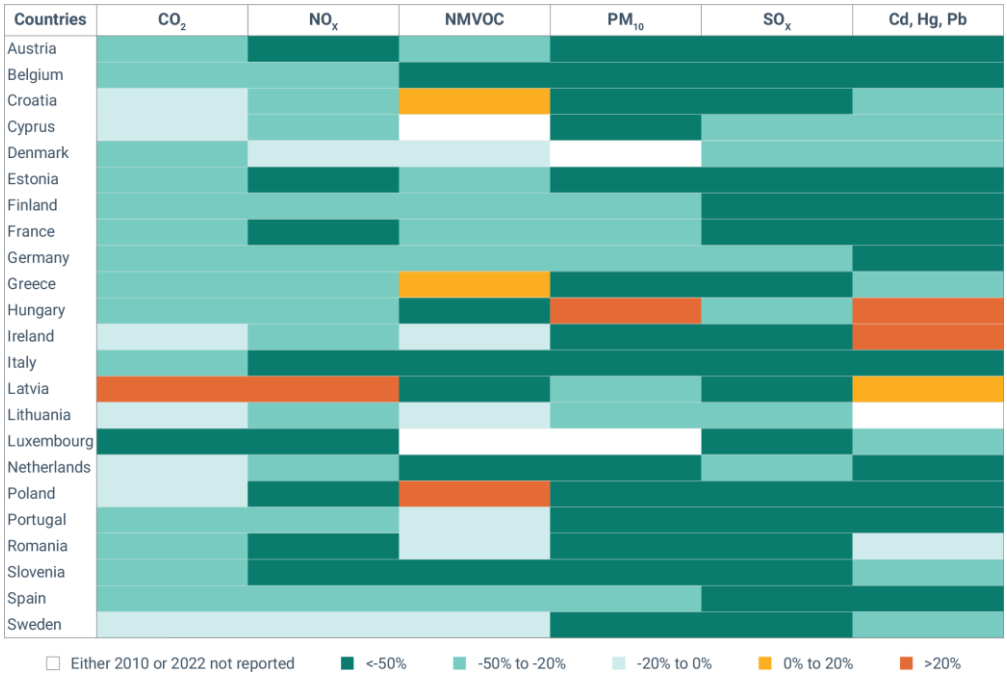

Figure 1 Change of pollutant releases into air in EU-27 countries in the period 2010-2022

Source: European Environment Agency (2024)

Types of industrial pollution

Several substances can have negative effects on air quality, but we generally consider the compounds with the highest emission volumes and, therefore, the predominant impact on air pollution. Types of air pollution include emission are following (IQAir, 2024; Brofind, 2023):

- greenhouse gases (e.g., carbon dioxide, carbon oxides CO and CO_2, methane),
- the release of particulates and aerosols,
- emission of sulfur dioxide (SO_x)
- nitrogen oxides (NOx), which contribute to acid rain
- the release of volatile organic compounds (VOCs)

- other hazardous air pollutants (HAPs)
- particulate dust (or particulate matter)

Sources of emissions in industries

Manufacturing encompasses diverse activities (Terrascope, 2024), and three prominent subsectors which produce the sources of emission in industries are 1) *Cement Production:* the high-temperature processes involved release significant CO_2 into the atmosphere, than 2) *Chemical Industry:* specific chemical reactions release greenhouse gases, emphasising the need for sustainable practices, research into alternative materials, and the adoption of cleaner production methods and the last one 3) *Metal Production:* particularly steel and aluminium manufacturing, involves energy-intensive processes that release substantial amounts of CO_2. Two categories of sources are defined as following (Singh, 2023):

- *Point-Source Emissions*: also known as stationary sources of emission, are released at height or ground level, from an identifiable source, and are dispersed in the atmosphere. Emissions from stationary sources. It is easy to trace the source of such emissions back to stacks, outlets, etc.
- *Non-Point Source:* A source of emission that is not easily identifiable. These are called mobile and fugitive emissions, they consist of leaks of particulate matter from transportation and loading, for example, are not identifiable and stationary sources. Also called diffuse or 'fugitive emissions' (non-point sources), are contrary to stack emissions and originate from an area, such as a stockpile or a road.

Impact of industrial pollution on the residents of an industrial township

From contaminating the environment to damaging human health, poor air quality is a major global challenge. No one is immune to the negative effects of air pollution, but many think this shared burden doesn't affect human lives. The solutions to this pressing issue are also key to tackling the climate crisis, fostering inclusive societies and improving childhood development. The amenities in an industrial township are used by people from age groups and Long-term exposure to these pollutants can lead to the following (Singh, 2023; Harrison, 2014):

- Respiratory and cardiovascular diseases
- Cancers
- Decreased lung function
- Increased frequency of asthma attacks
- Other respiratory illnesses
- Environmental degradation, such as acid rain
- Contribution to climate change
- Far-reaching impacts on human health and the environment.

Industrial air pollution also causes different impacts on people or environment such as (IQAir, 2024):

- Causes of industrial air pollution include:
- Inadequate laws and regulations to control emissions and waste.
- Poor enforcement of existing environmental standards.
- Reliance on older, less efficient technologies that produce more waste and emissions.
- Delayed adoption of cleaner, more sustainable practices.
- Increased production to meet global demand leading to higher emissions and waste generation.
- Intensive resource extraction and use.
- Cost-cutting measures leading to environmental negligence.
- Preference for cheaper, more polluting methods over sustainable options due to economic constraints.
- Shift of industrial activities to countries with looser environmental regulations.
- Increased transportation and logistics contributing to pollution.

Solutions towards industrial air pollution minimizing (Singh, 2023):

Industrial waste from factories is inevitable. And the ways factories manage that waste affect the surrounding environment, as well as human health. If not properly disposed of, industrial waste can contaminate soil, air, and water. But there are points throughout a factory's lifespan, and its entire production process, where changes can be made to reduce the pollution they produce and ensure proper precautions are in place to protect the environment around them. Here are a few ways to reduce industrial air pollution:

- Regular Environmental Impact Assessments
- Stricter Laws and Enforcement
- Rebuilding Habitats and Afforestation
- Proper Treatment of Industrial Waste
- Industry Site Selection
- Recycling

The general objective is to help protect ecosystems and human health (European Council, 2024; Harrison, 2014)**.**The rules aim to:

- prevent and control air, water and land emissions from Europe's largest industrial plants
- minimise the use of resources
- make processes more efficient

- encourage circular economy practices
- ensure waste prevention and control

Other industrial pollution steps for minimizing the air pollution are (Davis, 2022):

- *Building Factories in the Right Place:* the best way to reduce pollution in important ecosystems is to keep them from harm's way in the first place. When new industrial sites are being built, it is important to factor in location and the potential impact the site would have on the surrounding environment. Characteristics such as climate and topography significantly affect how pollutants spread, and these factors also need to be considered.
- *Powering Factories with Renewable Energy:* factories that require less energy to operate produce less air pollution. A large-scale shift to using renewable energy sources to power factories would result in less pollution over time and could also save factories money in the long run. But the initial investment in greener energy sources is often a hurdle that prevents many factories.
- *Analyzing Factory Waste:*by analyzing factorywaste output, factories can determine the amounts of different types of waste like food waste, chemical waste, glass, paper, and other elements. Once they have a clear picture of where they are making waste, it's much easier to make processes more efficient by upgrading equipment, reorganizing inventory, and establishing recycling systems for reusing materials at various stages of production.
- *Proper Treatment of Factory Waste[2]: p*hysical treatments are processes that may change the shape or size of the waste. In contrast, chemical treatments use chemicals to alter the composition of the waste, and biological treatments use organisms to break down waste components into simpler organic matter and biomass.
- *Factories Must Run Environmental Impact Assessments:* if harmful impacts are discovered in this assessment, it is the company's responsibility to take the necessary actions required to address the problem, and correct any negative consequences that have developed.
- *Laws and Enforcement Can Help Prevent Factory Waste:* **s**till, it often takes more stringent regulation to decrease factory pollution because many measures that reduce pollution cost money and take time to implement.

In addition to implementing these regulations, it is equally important for governmental agencies to take firm action against industries that do not follow pollution protocols and offer significant rewards for companies that operate within guidelines.

2.2 Industrial emmision and polluting segments

Industrial activities are a major source of pollution for Europe's soil and atmosphere**.** Releases of pollutants into the air and water by European industry have decreased over the past ten or

[2] Waste treatment is defined as the practice of changing the properties of industrial hazardous waste and making it less harmful.

so years. EU rules on industrial emissions have contributed to the reduction of pollutant releases. Thanks to current EU legislation, air pollution has decreased by 40-85% over the past 15 years, depending on the pollutant. The charts below show the trends in emissions reduction between 2010 and 2020 (European Council, 2024). Industrial emissions into the air in the EU is illustrated on Fig. X Chart showing a downward trend in industrial emissions into the air in the EU from 2010 to 2020 for several pollutants including carbon dioxide, nitrogen oxides, cadmium, lead, mercury.

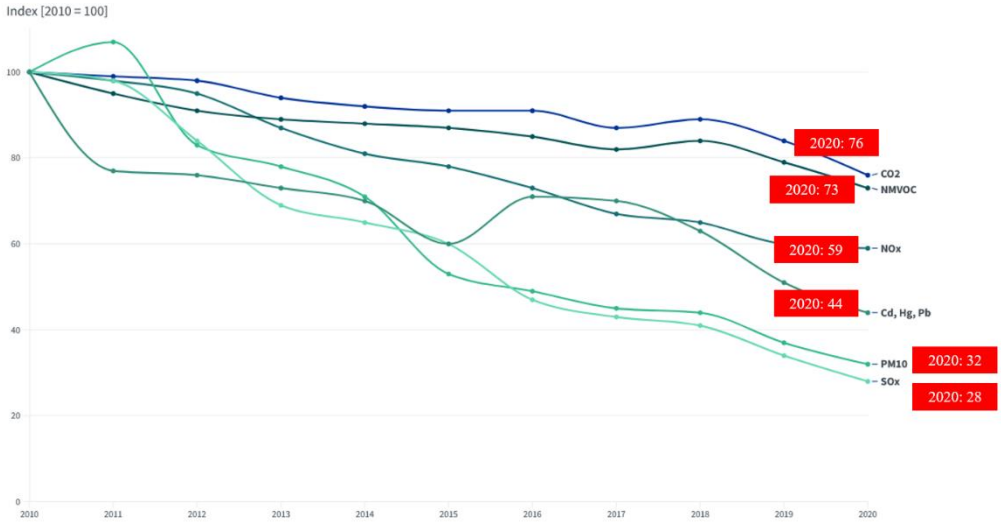

Figure 2 Industrial emissions into the air in the EU

Source: European Council (2024)

Therefore, the industrial pollution highlighted below focuses on this catastrophic type of pollution: air. This industry not only affected the nearby area but had a significant impact on the urban area as well. **Top polluting Industries are actually these (Climate Trade, 2023; Davda, 2024):**

- *Fossil fuels:* emissions from fossil fuels keep increasing, after a brief decline during the Covid 19 pandemic, they grew by 1 % in 2022, reaching 40.5 gigatons of CO_2. Shifting our energy sources from coal, oil and gas to renewable power such as solar and wind is necessary to stabilize our climate. A key initiative involves the use of carbon credits to achieve immediate impact essentially offsetting a portion of emissions by supporting projects such as reforestation and renewable energy plants.
- *Agriculture***:** accounts for about 11 % of greenhouse gas emissions. According to the Food and Agriculture Organization (FAO), global emissions due to agriculture were 9.3 billion tons of CO_2, led by methane and nitrous oxide emissions from crop and livestock activities.
- *Fashion:* and produces about 10 % of our annual carbon footprint more than all international flights and maritime shipping combined, it also consumes enough water to quench the thirst of five million people every year, and creates millions of tons of plastic and other waste that pollute our air and oceans.

- *Food retail*: includes the activities from markets, supermarkets and restaurants selling food to consumers and most of this sector's emissions come from food and plastic waste. It is estimated that food waste alone represents 8 to 10 % of global emissions. In the EU, 57 million tons of food is wasted every year: that's 127 kg per inhabitant.
- *Transport: a*bout 40 % of these come from the transportation of merchandise, while the rest (60 %) come from passenger travel, led by air travel. Electric vehicles, alternative fuels and initiatives.
- *Construction***: t**aking into account the extraction and transportation of building materials, construction processes and everyday operations buildings are estimated to emit about 40 % of global emissions.

The EEA[3] regularly assesses industrial pollution trends in Europe based on the E-PRTR[4] register and other data. These assessments show that industrial air and water pollution by emissions has decreased over the past decade. A strong and developing low-carbon industry based on circular material flows is part of the EU's industrial policy strategy. The goal is to create a developing industry that uses less and less natural resources, reduces polluting emissions in the air, water and soil and produces less waste. Other EU legislation so far sets more specific targets for reducing air emissions, such as the National Emission Ceilings Directive and the Industrial Emissions Directive, which aim at ambitious prevention and reduction of emissions, in particular through the continuous updating of the so-called Best Available Technologies (BAT)[5]. The use of the best available technologies and the implementation of the more ambitious targets of the Industrial Emissions Directive led to substantial reductions in emissions: 91% for sulfur dioxide, 82 % for particulate matter and 79 % for nitrogen oxides (European Environment Agency, 2021).

The manufacturing industry is a significant contributor to global air pollution, with industrial emissions releasing hazardous waste fumes that pose serious risks to both human health and the environment. As we can see on Tab. X industry prodcuces several emmisions which are damaged for air quality. Air pollution is the contamination of air by toxic or polluting particles and gases. The causes of climate change are often the same as the causes of air pollution: transport, the power sector, industrial emissions and crop burning. 85 % of all global air pollution comes from burning fossil fuels and biomass (Dnes dýcham, 2024).

Table 1 Sources of air pollution by industry and other sectors

[3] EEA European Environemntal Agency

[4] register E-PRTR: Európsky register uvoľňovania a prenosov znečisťujúcich látok

[5] BAT best available technology or best available techniques is the technology approved by legislators or regulators for meeting output standards for a particular process, such as pollution abatement.

Sector	PM_{10}	$PM_{2,5}$	SO_x	NO_x	NH_3	BaP	O_3	CO	NMVOC
Energy	8 %	6 %	42 %	28 %	0 %	16 %	0 %	11 %	28 %
Transportation	8 %	8 %	1 %	44 %	1 %	18 %	0 %	6 %	4 %
Agriculture	13 %	1 %	0 %	12 %	90 %	0 %	0 %	0 %	8 %
Industry	8 %	5 %	49 %	10 %	1 %	0 %	0 %	26 %	27 %
Waste manipulation	1 %	1 %	0 %	0 %	3 %	0 %	0 %	0 %	1 %
Household heating	62 %	79 %	8 %	6 %	5 %	66 %	0 %	57 %	32 %

Source: Dnes dýcham, 2024

The most important industrial polluters in Slovakia released thousands of tons of pollutant emissions into the air in 2021. Poor air quality causes an estimated 4.2 million deaths worldwide each year from stroke, heart disease, lung cancer, acute and chronic respiratory diseases. In the EU, the number of premature deaths as a result of poor air quality is estimated at 400,000. The largest industrial emitter has long been the ironworks in Košice, other important polluters produce aluminum, industrial fertilizers, cellulose, concrete or process oil. Producers of lime, cement, ferroalloys and metal products, glass, glass fibers, starch, electricity and heat from biomass were also placed in the top twenty. Data on the amount of emissions released from medium and large sources of air pollution are recorded in Slovakia by the National Emission Information System, which is managed by the Slovak Hydrometeorological Institute (SHMÚ). Data on the amount of emitted emissions are reported to the district authorities by the polluters themselves. The twenty most significant polluters in Slovakia emitted a total of 1544.70 tons of solid pollutant emissions, 11809.30 tons of sulfur oxide emissions, 17550.34 tons of nitrogen oxide emissions and 134738.19 tons of carbon monoxide emissions in 2021 (SHMÚ, 2024; Aktuality, 2023). Other companies are also Slovnaft, a.s., Považská cementáreň, a.s., Dolvap, s.r.o. or Bukocel, a.s.

Table 2 TOP 20: The biggest industrial polluters in Slovakia according to SHMÚ in the category: solid pollutants, i.e. mainly PM10 and PM2.5 particles

PM10 and PM2.5 particles	Emissions (in tons)	Share (in %)
U.S. Steel Košice, s.r.o.	439.11.	15.07
Duslo, a.s.	161.26	5.53
Slovalco, a.s.	148.74	5.1
Fortischem, a.s.	144.14	4.95
Mondi SCP, a.s.	117.89	4.05

Source: Aktuality, 2023

3 CONCLUSION

Industrial air pollution poses a serious threat to the health and well-being of residents in industrial townships. Industrial activities cause emissions of substances which harm human health and the environment. To reduce pollutant emissions, the use of natural resources and the generation of waste, EU industrial policy aims to drive a transition to a strong, climate neutral industry based on circular material flows. Additionally, it contributes to environmental degradation, including acid rain and climate change. By investing in technologies, industrial townships can protect the health of their residents, reduce environmental degradation, and help to ensure a sustainable future for all.To stop industrial pollution and prevent metal toxicity, there is a clear need for an overall waste treatment strategy with the goal of eliminating priority pollutants at their source.

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