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

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CONSTRUCTION AND ROAD DUST

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1 INTRODUCTION

The construction sector is one of the key economic industries in Slovakia and the European Union. It has a significant impact and influence on many sectors of the economy, local employment, and quality of life. The construction sector generates almost 10% of the European Union's GDP, and the 3 million companies operating in this sector provide approximately 20 million jobs (Adamkovičová et al., 2021). At the same time, the construction sector has a massive environmental impact, characterized by the generation of significant waste, the extensive consumption of natural resources and energy, considerable carbon dioxide emissions, and adverse impacts on biodiversity and soil integrity. Buildings contribute to over 30% of Europe's total carbon emissions and account for more than 40% of primary energy consumption across the continent. Additionally, construction and demolition activities produce the largest waste stream within the European Union (European circular economy stakeholder platform, 2021).

2 BACKGROUND

The construction industry is recognized as a major contributor to greenhouse gas emissions, playing a significant role in driving climate change. Globally, this sector accounts for approximately 19% of total greenhouse gas emissions (Labaran, Mathurb and Farouq, 2021). In Slovakia, the construction sector is responsible for nearly 7% of carbon dioxide (CO2) emissions into the atmosphere, making it the fourth-largest contributor to CO2 emissions among all economic sectors in the country (Rajničová, 2021). The construction industry encompasses various components with significant carbon footprints, including the production and transportation of materials like cement and aggregates. Cement production, in particular, is a major contributor, accounting for 7% of global carbon dioxide (CO2) emissions (Manzi and Bignozzi, 2020). Alongside cement production, the construction industry also impacts air quality through the production of steel and other building materials (Proreco, n.a.).

The impact of construction on the environment is largely determined by the building materials selected and the energy and resources used to operate the structures (Rajničová, 2022). Zeleňáková and Zvijáková (2012) summarized the emissions that significantly contribute to the negative impacts of construction, particularly on air quality, as follows: the production of construction materials and semi-finished products (dust, sulfur dioxide, nitrogen oxides, primary and secondary dust), construction activities (primary and secondary dust, exhaust gases, combustion engine emissions, organic solvents, spray emulsions), and transportation (exhaust fumes, secondary dust).

Assessing the environmental impacts of construction requires monitoring the entire life cycle of buildings, which lasts a very long time (Rajničová, 2022).

During the product phase, air pollution may arise from the delivery of raw materials, transportation, or the manufacturing process. Additionally, as previously noted, the

production of building materials significantly contributes to air pollution and the release of hazardous gases. Transportation involved in moving raw materials to manufacturing plants also plays a key role in this phase. In the construction phase, both construction sites and transportation associated with construction activities are major contributors to air pollution (Wieser et al., 2021). Exhalations from construction machinery and construction transport contribute 20-40% of the total pollutant emissions in urban areas, and there is often an exceedance of the maximum allowable emissions near construction sites (Moňoková and Vilčeková, 2020). Construction transport is estimated to account for 20 to 35% of total urban freight traffic within the EU. Despite its substantial contribution to pollution, the environmental impact of construction logistics during building activities has often been overlooked (Brusselaers, 2023). The construction industry depends on a large number of transport vehicles and diverse machinery, resulting in increased emissions of harmful substances into the atmosphere (Pakhomova, Moiseeva and Tereshina, 2018). Most vehicles used for transporting construction materials are driven by diesel engines, which are recognized as major contributors to road pollution, including nitrogen oxides and particulate matter (Han, Na and Lim, 2020). Projections indicate that by 2030, nitrogen oxide (NOx) emissions from non-road mobile sources will surpass those from on-road vehicles. By 2050, these sources are expected to account for more than 80% of total transportation emissions in regions such as East Asia, Europe, and North America (Li et al., 2023).

During the operational phase of a building, substantial energy is consumed, and pollutants are released. Heating, ventilation, and air conditioning (HVAC) systems are key contributors during this stage and can significantly influence indoor air quality. Additionally, the materials used in construction can also contribute to indoor air pollution. Depending on their characteristics and treatments, these materials may emit pollutants, playing a major role in the degradation of indoor air quality (Wieser et al., 2021). The design phase of a building is a critical stage where concepts are integrated, and the building's circularity is considered. By incorporating plans to use recycled materials or repurpose components from old structures, waste generation can be minimized. Furthermore, carefully strategizing the future reuse or recycling of materials at the building's end-of-life phase helps ensure that waste is avoided when the structure is decommissioned (Banihashemi et al., 2024).

During the end-of-life phase of buildings, significant air pollution occurs, particularly during demolition activities. The use of explosives in demolition releases harmful substances into the atmosphere, including aerosol mixtures similar to exhaust emissions, with high nitrogen content. Demolition also generates substantial dust emissions from the destruction of structures, sometimes amounting to several tons. Studies have shown that elevated dust concentrations can be detected over a kilometer downwind from demolition sites. The construction industry contributes up to 25% of dust-related air pollution (Moňoková and Vilčeková, 2020).

The construction industry contributes to the generation and release of solid particles into the air, referred to as PM (particulate matter), which negatively affect human health and air

quality (Rajničová, 2022). Construction activities generate significant quantities of particulate matter, posing risks to both construction workers and nearby residents. For workers, inhaling construction dust presents immediate and long-term health hazards, directly affecting the industry's workforce. For nearby residents, the effects are generally indirect, though health issues and related symptoms may not appear until several years later (Cheriyan and Choi, 2020). In construction, numerous activities can contribute to air emissions. Common construction tasks that generate fugitive particulate matter (PM) include land clearing and demolition, earthmoving, and cut-and-fill operations. Additional sources include equipment movement, mobile debris crushing machinery, vehicle transport (such as material loading, unloading, hauling, and dirt tracking onto paved roads followed by dust resuspension), and other site preparation tasks. Specific construction processes like concrete, mortar, plaster mixing, drilling, milling, cutting, grinding, sanding, welding, and sandblasting also release particulates. Finishing activities and wind-driven dust from temporary unpaved roads and exposed construction sites further contribute to emissions (European Environment Agency, 2023). High concentrations of particles of varying sizes and compositions can result in different levels of health damage. Smaller particle diameters pose greater health risks when inhaled, as they can carry toxic substances deeper into the respiratory system. PM10 particles can linger in the environment for extended periods, accumulate heavy metals and toxins, and present significant hazards to workers. PM2.5 particles and smaller can reach and settle in the lungs through the respiratory system. Prolonged exposure to elevated levels of dust particles increases the risk of illnesses and may lead to premature death from conditions such as silicosis, lung cancer, cardiovascular diseases, and chronic obstructive pulmonary disease (Yang et al., 2023).

3 CONCLUSION

The impact of air pollution from construction should not be overlooked. It is crucial to make sure that construction practices do not degrade the air quality. By utilizing eco-friendly materials, implementing rigorous regulations, and incorporating cutting-edge technologies, we can aim to strike a balance between growth and safeguarding the environment (Kunakair, 2023). Ecological solutions in construction require not only research, experimentation, new technologies, and the acquisition of experience but also the collaboration of all involved parties. The entire construction cycle—from cement production through logistical and transportation solutions to pouring concrete—must be coordinated to minimize emissions (Proreco, n.a.).

The current significance of the construction sector, with an emphasis on its sustainability highlighted by the European Green Deal and the European Union's New Circular Economy Action Plan, reflects the EU's determination to reduce the environmental impacts of construction (Adamkovičová et al., 2021). Slovakia, along with other EU member states, has committed to achieving carbon neutrality by 2050. Low-carbon technologies and materials, as

well as more responsible construction and operation practices, are therefore essential steps on the path to carbon neutrality (Moňoková and Vilčeková, 2020). As European buildings become increasingly energy-efficient and powered by renewable energy sources due to climate policies, so-called embodied emissions are gaining more attention. These emissions are generated during the production of building materials, the construction of the building, and its demolition and removal (Jenčová, 2023). Carbon dioxide emissions during the pre-operational phase are usually smaller compared to the emissions generated during the operation and maintenance phase. However, when looking at various time periods throughout a building's lifecycle, emissions from the pre-operational phase can become more substantial. As the lifespan of buildings shortens to less than 30 years, emissions from the pre-operational phase could make up as much as 50% of the total CO2 emissions (Paik and Na, 2019). To tackle these environmental issues, it's essential to embrace sustainable building methods that reduce the construction sector's environmental footprint. A vital approach to reaching this objective is the widespread use of environmentally friendly and sustainable building materials (Abera, 2024). When selecting building materials, it is advisable to choose those with the lowest possible CO2 emissions during their production and transportation. In this context, materials like wood and other naturally derived options with minimal processing, such as unfired clay, straw bales, and insulation made from plant fibers, offer significant benefits. A significant step toward a circular economy is the use of building materials made from recycled resources (e.g., foam glass, cellulose insulation) and designing building systems to facilitate the easy recycling of their components (Pifko, n.a.).

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