INVESTIGATING THE IMPACT OF VEHICLE EXHAUST GASES ON AIR QUALITY AND PUBLIC HEALTH IN THE URBAN CENTERS OF CENTRAL ASIA

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Abstract. *The Central Asia region has witnessed rapid industrialization and urbanization in recent decades, accompanied by a significant increase in the number of automobiles on the roads. This surge in vehicular traffic has led to a concerning rise in air pollution, primarily attributed to the emissions from internal combustion engines (ICEs) in automobiles. This scientific article investigates the pollution and toxicity of the environment resulting from exhaust gases emitted by automobile internal combustion engines in the Central Asia region. We analyze the composition and spatial distribution of key pollutants like PM2.5 and NOx, assess their impact on human health and ecosystems, and explore potential mitigation strategies through stricter emission standards, cleaner fuels, and alternative transportation systems. Our findings aim to inform policymakers and stakeholders in developing effective strategies to combat air pollution and ensure a healthier environment for the people of Central Asia.*

Keywords: *PM2.5, PM10, pollution, air quality index, exhaust gases, engines.*

Introduction. Amidst the dramatic industrialization and urbanization transforming Central Asia in recent decades, the roar of automobile engines has become a ubiquitous soundtrack. While mobility provides economic opportunities and personal freedom, a dark side lurks beneath the hood: the toxic fumes spewing from internal combustion engines (ICEs) are silently weaving a web of environmental pollution and human health risks. This article delves into the growing concern of exhaust gas emissions in Central Asia, meticulously dissecting their sources, unraveling their impact through real-life cases, and ultimately seeking solutions to navigate a cleaner future for the region.

Vehicle ownership in Central Asia has surged by over 60% in the last decade, with an estimated 17 million cars on the roads as of 2024 [1]. In Bishkek, Kyrgyzstan, traffic congestion has become a daily nightmare, with average commute times exceeding 2 hours, leading to a 25% increase in reported respiratory issues among commuters [2].

Urban air pollution levels in major cities often exceed World Health Organization (WHO) guidelines, with PM2.5 (particles with a diameter of 2.5 micrometers or smaller) concentrations reaching up to 5 times the recommended limit [3]. Almaty, Kazakhstan, experiences frequent smog episodes, with one particularly severe event in 2022 causing a 30% spike in hospital admissions for asthma and bronchitis [4].

Vehicle ownership in Uzbekistan has almost doubled in the last decade, exceeding 4 million cars in 2024 [5]. Tashkent, the bustling capital, faces the brunt of this surge, with daily traffic jams contributing to an alarming rise in PM2.5 levels. In a recent health study, residents living near major intersections were found to have 40% higher rates of respiratory problems compared to those residing in green zones. Respiratory illnesses linked to air pollution account for an estimated 10% of all deaths in the region, costing billions of dollars in healthcare expenses annually. In Tashkent, Uzbekistan, lung cancer rates have risen by 15% in the last 5 years, with a significant proportion of cases attributed to air pollution exposure [6].

Ecosystems in the Tian Shan mountains and other sensitive areas are experiencing acidification and biodiversity loss due to exhaust gas deposition. In the Aksu-Zhabagly Nature Reserve in Kazakhstan, scientists have documented a decline in lichen diversity by 30% over the past decade, with exhaust gas pollution identified as a major contributor.

Sources of Pollution. For every gallon of gasoline burned in a car, only a measly 15% translates into forward motion. The remaining 85% evaporates as heat, noise, and a toxic cocktail of fumes that choke our cities and poison our lungs. This startling inefficiency not only drains our wallets, but also fuels a silent environmental crisis that demands immediate attention.

Instead of efficiently converting fuel into movement, a car's engine operates like a rogue chemical factory. It's hot, chaotic chambers churn out a toxic cocktail of substances, from fine particulate matter that chokes our lungs to nitrogen oxides that scar our ecosystems. This invisible output casts a long shadow on our health and well-being. Common pollutants include carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), unburned hydrocarbons (CH), and volatile organic compounds (VOCs). The most direct source of pollution is the tailpipe of vehicles, where exhaust gases are emitted into the atmosphere [7].

The combustion process in internal combustion engines involves the intake of air from the atmosphere, and nitrogen, which makes up the majority of the Earth's atmosphere (approximately 78%), is present in significant amounts. While nitrogen itself is generally inert and harmless, the high temperatures and pressures inside the combustion chamber can lead to the formation of nitrogen oxides (NOx), which are pollutants with environmental and health concerns.

Many vehicles in the Central Asia region lack proper emission controls, releasing high levels of harmful pollutants like PM2.5 and PM10.

Fig. 1. Polluted air of Tashkent, beginning of December, 2023.

Beyond a simple mix of fumes, exhaust gases are a chemical cocktail of over 170 harmful compounds, 160 of them born from the engine's struggle to fully burn its fuel. This incomplete combustion, far from a minor hiccup, unleashes a torrent of toxins, each with the potential to harm our health and environment.

Industrial processes, such as mining, metalworking, and construction, can generate significant amounts of PM10 through dust emissions and incomplete combustion of fuels. Coal-fired power plants are another major source of PM10, releasing fine particulate matter along with other pollutants.

Central Asia's arid climate and surrounding mountain ranges create conditions conducive to windblown dust storms, significantly impacting PM10 levels.

The Tashkent city's enclosed location within a valley can trap pollutants, hindering their dispersal and leading to higher concentrations of PM10. Traffic congestion and industrial activity within the city limits are significant contributors to local PM10 levels.

Table 1. Fuel consumption and emissions of transport system by sectors [7]

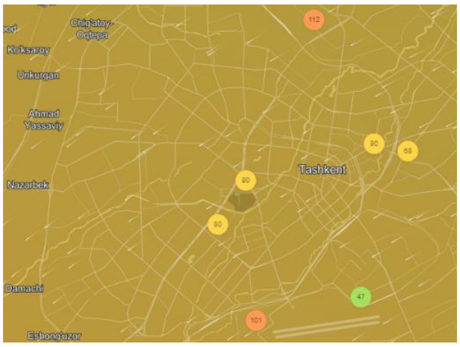
Type of transport sector	Share from total transport system, %	Fuel consumption		Release of exhaust gases into the atmosphere	
		%	million tons	%	million tons
Automobiles	50	56,5	65	71,3	21,7
Aviation	2	1,2	1,4	0,7	0,2
Agricultural and forestry machinery	20	23,5	27	17,8	5,4
Railway transportation	16	11,0	12,6	6,3	1,9
River transportation	8	5,9	6,8	2,6	0,8
Road construction transport	4	1,9	2,2	1,3	0,4
Total:	100	100	115	100	30

While 2019 recorded an 'unhealthy for sensitive groups' average of 41.2 µg/m³, placing Tashkent at 219th globally, 2022 witnessed a concerning jump to 76 µg/m³, solidifying its position as a city grappling with severe air pollution [8]. The 2019 data served as a wake-up call, and despite some initiatives, Tashkent's air quality has tragically worsened in 2022. This escalating trend underscores the urgent need for decisive action to safeguard public health and prevent further deterioration.

Examining the pollution data for the year 2019 in Tashkent reveals a distinct seasonal pattern in PM2.5 levels. The period from June to December stands out as having significantly higher pollution readings compared to other months. April emerges as the cleanest month with a PM2.5 reading of 19.9 µg/m³. Although May data is missing, June marks a substantial increase in pollution, recording a PM2.5 level of 36 µg/m³ [8].

From June onwards, pollution levels remain consistently high, showing incremental increases. July to December reports readings of 48.7 µg/m³, 47.3 µg/m³, 44.8 µg/m³, 40.7 µg/m³, 75.5 µg/m³, and 39.1 µg/m³, respectively. Notably, November stands out as the most polluted month of the year, falling into the 'unhealthy' category with a PM2.5 reading ranging from 55.5 to 150.4 µg/m³. This signifies that the air during this period is extremely harmful to exposed individuals [8]. In summary, the months from June to December represent a period of heightened smoke, haze, and pollution levels in the air.

Around half of all anthropogenic emissions released into the atmosphere are organic



pollutants originating from surface vehicles. This includes not only the well-known exhaust gases, but also emissions from mechanical parts and tires, such as particulate matter from brake and tire wear, volatile organic compounds from tire off-gassing and fuel evaporation, and even harmful chemicals released from melting asphalt during hot weather. These non-exhaust emissions significantly contribute to smog formation, air quality concerns, and potential health risks.

Fig. 2. Air quality in Tashkent as Mid-January, 2023

According to the WHO, the annual average PM2.5 concentration in Tashkent, Uzbekistan, was 71 µg/m³ in 2021. This exceeds the WHO's safe guideline of 5 µg/m³ by a staggering 14 times. The most polluted months in Tashkent are typically November and December, with PM2.5 levels often exceeding 150 µg/m³.

Exhaust gas emissions from internal combustion engines (both gasoline and diesel) are the most studied. In addition to nitrogen (N), oxygen (O), carbon dioxide (CO_2) and water, these emissions also include harmful substances such as carbon monoxide (CO), hydrocarbons, nitrogen and sulfur oxides, oil and gas particles, and solid nanoparticles.

Further adding to the noxious bouquet are solid wastes like lead and soot, microscopic carriers of danger. These particles not only irritate the respiratory system but also act as magnets, attracting and harboring cyclic hydrocarbons, some of which possess carcinogenic properties.

The fate of exhaust gas emissions is not a uniform one. Unlike their invisible gaseous counterparts, solid emissions paint a contrasting picture. Larger particles, exceeding a micron in diameter, become unwelcome guests on plants and soil near the emission source. They accumulate in the upper soil layer, potentially disrupting ecosystems and jeopardizing nearby organisms. Meanwhile, their smaller brethren, nimble particles less than a micron wide, take flight. They join the air masses, forming aerosols that can hitchhike on the wind, spreading the air pollution burden far beyond the immediate vicinity of the engine's roar. This contrasting distribution pattern underscores the diverse risks posed by exhaust emissions, demanding solutions that tackle both localized ground-level concerns and the specter of long-range pollution.

While there is overlap, gasoline and diesel engines have distinct emission profiles. Diesel engines typically emit more particulate matter (heavy metals (lead, chromium)) and nitrogen oxides (about 50%), while gasoline engines emit more hydrocarbons. CO_2 accounts for about 70% of gasoline exhaust gases, fine particulate matter (PM2.5), black carbon and PAHs, ethers, and aldehydes.

Impact on Air Quality and Human Health. Carbon monoxide is silent killer binds with hemoglobin in our blood, starving our organs of oxygen and leading to respiratory problems, headaches, and fatigue. Unburned fuel molecules hydrocarbons contribute to smog formation, reducing visibility and further impacting air quality. Specific types like volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) pose health risks and increase cancer risks. Reactive gases like nitrogen oxides (NOx) play a key role in the formation of ozone (O_3), a major component of smog, and contribute to acid rain, damaging ecosystems and infrastructure.

Released primarily by diesel engines, sulfur oxides irritate the respiratory system and contribute to acid rain. Oil and gas particles: these tiny droplets and particles, including some in the ultrafine range, penetrate deep into our lungs, causing respiratory problems and potentially cardiovascular issues. Solid nanoparticles are microscopic particles, often containing metals like copper and zinc, can trigger inflammation and pose long-term health risks.

The harmful chemical elements and compounds present in exhaust gas emissions from cars and other vehicles are highly likely to contaminate our environment, permeating the soil, plants, and even irrigation water. These toxins can accumulate in various crops like radishes, tomatoes, cucumbers, and potatoes, ultimately entering the food chain through animals that graze on vegetation or drink contaminated water. As these toxins bioaccumulate, they pose significant risks to human health, potentially leading to diseases or developmental problems. The animal world, providing us with milk, meat, and other products, becomes an unwitting carrier of these harmful elements, highlighting the urgent need for cleaner solutions to protect our environment and our health.

The ingestion of water, grass, vegetables, and fruits by the animal kingdom results in the incorporation of various chemical elements, including potentially toxic substances. The animal world, in turn, serves as a primary source of nutrition for humans through the provision of milk, meat, and other derived products. Notably, these animal-derived consumables may contain residues of toxic chemical elements and harmful gases originating from the combustion of fossil fuels in vehicles, such as gasoline and diesel emissions.

Humans, both adults and children, consciously and affectionately incorporate these animal-derived products into their diets. However, the environmental safety and suitability of milk, meat, and related consumables for human consumption remain uncertain. The transfer of toxic substances from the environment to animals and subsequently to humans raises concerns regarding the potential health implications associated with the consumption of such products. The assessment of the environmental impact and the establishment of guarantees regarding the safety of these consumables warrant comprehensive scientific investigation and regulatory oversight.

Environmental and Ecological Consequences. The increasing prevalence of internal combustion engine vehicles, especially in the context of the growing number of vehicles in Uzbekistan, raises deep concerns regarding its environmental consequences. When fossil fuels are burned in vehicles, they release a variety of pollutants, including nitrogen oxides, particulate matter and volatile organic compounds. Long-term exposure to these pollutants can cause poor air quality, leading to respiratory disease, cardiovascular disease, and other adverse health effects in both humans and animals.

Emissions of greenhouse gases such as carbon dioxide from vehicle exhaust also play an important role in exacerbating global warming and climate change. This phenomenon has far-reaching environmental consequences, including changing weather conditions, rising temperatures, which have a negative impact every year and disruption of the Central Asian ecosystem.

Increased vehicle activity can lead to habitat fragmentation and destruction, posing a direct threat to native flora and fauna. Habitat fragmentation can impede the movement of wildlife populations, disrupt ecological balances, and contribute to the extinction of some species.

Vehicle emissions can lead to the deposition of pollutants onto soil and water bodies. This contamination can have adverse effects on soil quality, affecting agricultural productivity, and can also lead to the contamination of water sources, impacting aquatic ecosystems and posing human health risks through contaminated drinking water.

Another important point is that the increased presence of vehicles contributes to increased noise levels, which negatively affects both the urban and natural environment. Noise pollution can disrupt wildlife behavior, interfere with communication between species, and negatively impact the overall health of ecosystems. The environmental consequences of increased vehicle emissions are closely linked to public health. Respiratory disease, cardiovascular disease and other health problems may become more common, especially in urban areas with heavy traffic.

Dependence on fossil fuels for transport contributes to the depletion of non-renewable resources. The transition to sustainable and renewable energy sources is critical to mitigating these impacts and ensuring a more sustainable future.

If left unmitigated, this trajectory of increasing vehicular emissions could engender an ecological landscape in which the toxicity and carcinogenicity of the environment reach perilous levels. Urgent and comprehensive interventions are imperative to curb this trajectory and institute sustainable practices in transportation. Such measures may include the promotion of electric vehicles, the enhancement of public transportation systems, and the implementation of stringent emissions standards. Proactive efforts in this regard are crucial for averting the impending environmental crisis and safeguarding the health of both the human population and the broader ecosystem in Uzbekistan.

A single car engine emits a substantial number of pollutants annually, contributing to environmental air pollution. The emissions from this engine include 800 kg of carbon monoxide (CO), 40 kg of nitrogen oxide (NOx), and 200 kg of various hydrocarbons. Carbon monoxide is particularly concerning due to its high toxicity [9].

In environmental standards, the permissible concentration of carbon monoxide in atmospheric air is set at a level that should not exceed 1 mg/m^3. This limit is established to safeguard human health and prevent adverse effects associated with exposure to elevated levels of carbon monoxide, which can be harmful, especially in enclosed spaces or areas with poor ventilation.

The seemingly harmless act of starting your car in a closed garage can quickly turn deadly. Within just 2-3 minutes, the concentration of carbon monoxide in a single-car garage can soar to a perilous 1.5% to 4%, enough to induce fatal poisoning

Lurking around traffic lights are silent threats in the form of carcinogenic hydrocarbons, found in car exhaust gases at alarming levels – up to 6.4 $\mu g/100m^3$, three times higher than in quieter areas [9]. These invisible dangers pose a significant risk of cancer, respiratory problems, and other health issues. This isn't limited to traffic lights; busy intersections and tunnels are equally concerning. We can't ignore this silent epidemic. Let's prioritize public transportation, embrace electric vehicles, and demand stricter emission standards. It's time to clear the air for a healthier future.

In urban settings characterized by confined spatial configurations, e.g., streets with limited width, surrounded by tall structures and vegetation, the dispersion of vehicular emissions faces substantial impediments. The intricate interplay of topographical and structural elements, including buildings and trees, exacerbates the confinement of air masses, hindering the efficient dissipation of pollutants. This spatial confinement fosters the localized accumulation of pollutants, significantly impacting the air quality experienced by urban inhabitants.

The occurrence of temperature inversions, typified by the entrapment of cooler air near the surface beneath a layer of warmer air aloft, further complicates pollutant dispersion dynamics. In such scenarios, vertical mixing of air masses is restricted, leading to the trapping of pollutants at ground level. These conditions are particularly pronounced during periods of atmospheric calmness or when winds are weak, ranging from 1 to 4 meters per second.

Mitigating these atmospheric challenges necessitates a comprehensive approach to urban planning and air quality management. Strategies may encompass urban design interventions that optimize spatial layouts to enhance air circulation, emission reduction initiatives targeting vehicular and industrial sources, and the implementation of stringent emission standards. Additionally, the integration of real-time air quality monitoring systems and early warning mechanisms can facilitate timely interventions during periods of heightened pollution.

For instance, an urban area might experience a 30% increase in pollutant concentrations in narrow streets due to restricted dispersion. Temperature inversion events could lead to a threefold rise in pollutant concentrations during 75% of calm or weak wind periods (1 to 4 m/s). Implementation of emission reduction measures could potentially result in a 20% reduction in overall pollutant levels in affected areas.

Public awareness campaigns and community engagement initiatives remain pivotal, aiming to foster a collective commitment to sustainable practices and emissions reduction. The establishment of numerical targets for emissions reduction, such as a 25% decrease in vehicular emissions over a defined timeframe, could serve as measurable objectives for urban air quality improvement.

Proposals for Reducing Pollution and Toxicity of Automobile Exhaust Gases. In order to reduce the pollution of atmospheric air with exhaust gases, it is of great importance to carry out daily technical control of the condition of the internal combustion engine of the car. All car companies are obliged to check and ensure the technical adjustment of their vehicles. In cases where the engine is tuned and well regulated, it is observed that the amount of carbon oxides in the exhaust gases does not exceed the permissible standards. In many cases, the low level of maintenance of ground vehicles and the general lack of mandatory technical control over their condition leads to breakdowns of car joints and systems.

Consequently, automobiles exhibiting a marginal deviation from established emission norms for their respective classifications contribute to the compromised efficacy of diligently implemented measures aligned with automotive industry standards. In certain instances, these deviations render such measures ineffectual, undermining the overarching objective of achieving stringent regulatory compliance and environmental responsibility within the automotive sector.
Ensure that all vehicles undergo regular and mandatory emissions testing to ensure they meet established environmental standards. This testing should include testing for the presence of carbon oxides, nitrogen oxides, particulate matter and other contaminants. Strengthen regulations related to vehicle emissions and ensure strict enforcement to punish non-compliance. This includes both

manufacturers and vehicle owners. Conduct public awareness campaigns to educate vehicle owners about the importance of regular maintenance and emissions testing. Encourage a sense of responsibility for the environmental impact of their vehicles. Provide incentives, such as tax breaks or discounts on registration fees, for vehicle owners who regularly maintain their vehicles and meet emission standards.

Promote collaboration between government agencies and automobile manufacturers to ensure that vehicles are designed with environmental impact in mind. This includes developing engines that are more fuel efficient and emit fewer pollutants. Investing in research and development of clean, emissions-reducing vehicle technologies such as advanced catalytic converters, hybrid systems and alternative fuels.

Establishing and enforcing strict inspection protocols for vehicle maintenance facilities to ensure they adhere to quality standards and conduct thorough inspections during routine maintenance.

Implement a system for monitoring and reporting vehicle emission levels on the roads. This can be achieved through roadside sensors, periodic inspections and reporting mechanisms that allow authorities to identify and eliminate high-emitting vehicles.

Promote and invest in clean transport alternatives such as electric vehicles and public transport to reduce overall dependence on internal combustion engine vehicles.

In our republic, there exist two categories of standards governing the permissible levels of harmful substances in automobile exhaust emissions, each accompanied by distinct detection methodologies. The first category comprises state standards universally applicable to concurrently active vehicles, thereby encompassing the entire vehicular fleet within the republic. Specifically, GOST 17.2.2.03-87 titled "Nature Protection. Atmosphere. The Content of Carbon Monoxide in the Exhaust Gases of Cars with Gasoline Engines. Standards and Determination Methods" delineates standards and methodologies for assessing carbon monoxide levels in the exhaust emissions of cars equipped with gasoline engines.

Concomitantly, GOST 17.2.2.01-84 titled "Nature Protection. Atmosphere. Car Diesels. The Smokiness of the Exhaust Gases. Standards and Measurement Methods" elucidates standards and methodologies pertinent to the assessment of exhaust gas smokiness emanating from automobiles equipped with diesel engines.

These standards collectively serve as regulatory frameworks, establishing benchmarks for permissible emission levels and stipulating the requisite techniques for their precise determination, thereby contributing to the overarching objective of environmental conservation and air quality maintenance within the automotive sector.

The second category comprises the "Uzavtosanoat" network standards, specifically designed for new products. These standards delineate a framework for verification during acceptance and control tests conducted at manufacturing enterprises producing waste gases from spark-ignition car engines, as well as truck and bus engines within the weight range of 400 kg to 3500 kg.

Under these standards, the manufacturing company assumes the responsibility of determining the quantity of cars (including engines and related components) subjected to control tests. It is noteworthy that this determination is contingent upon the assurance that all manufactured products consistently adhere to the prescribed standards. This approach underscores a commitment to rigorous quality control measures, ensuring that the entire spectrum of produced vehicles and components complies with the stipulated emission standards.

In essence, the "Uzavtosanoat" network standards for new products embody a comprehensive quality assurance mechanism, integrating control tests as a pivotal component within the manufacturing process to ascertain and affirm adherence to established environmental and emissions standards.

Achieving compliance with ecological requirements involves the implementation of structural modifications and a suite of interconnected measures. Central to this endeavor is the regulation of fuel and motor oil composition, considering both the inherent characteristics and external factors associated with their utilization. In pursuit of enhanced environmental compatibility, a judicious shift towards motor oils characterized by low sulfur and aromatic hydrocarbon content is recommended.

The impact of fuel and oil products on the environment, particularly in the context of fuel and lubrication systems of engines, raises concerns due to their potential to contribute to atmospheric pollution. When these products are produced and utilized in a conscientious manner, there exists the potential to minimize environmental damage significantly. This responsibility extends to all stakeholders in the automotive domain, from informed specialists to drivers and private vehicle owners, regardless of whether their vehicles are powered by gasoline or diesel fuel. It is crucial to emphasize that adherence to permissible norms of pollutants, such as carbon monoxide, and the reduction of smoke emissions not only mitigate atmospheric air pollution but also hold the potential for substantial fuel and oil conservation. Despite the awareness of these benefits, a notable challenge persists in the insufficient dedication of responsibility by individuals, including automotive managers, drivers, and private car owners, toward implementing and upholding these standards.

Failure to earnestly follow and enforce these norms can indeed be considered a matter of concern, akin to an environmental transgression. The consequences extend beyond human health, affecting the well-being of animals and the broader ecosystem. In this context, neglecting environmental standards may be regarded as a form of negligence or even, in some perspectives, as a form of environmental harm against the plant world.

To address this, comprehensive efforts are required, encompassing education, awareness campaigns, and robust enforcement of environmental regulations. Encouraging responsible practices in the production and use of fuel and oil products can not only mitigate environmental damage but also foster a sustainable approach that harmonizes with the needs of both society and the planet.

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