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Research Article

Evaluation of the effects of sustainable development goals on improvement of air quality in cities

Şahin KORKMAZ[1], Damla MUSTAFAOĞLU[1,*], Zeynep CEYLAN[1]

[1]*Department of Environmental Engineering, Atatürk University, Erzurum, 25240, Türkiye*

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ABSTRACT

In parallel with the rapid population growth, air pollution has become one of the most important problems in cities, along with water pollution, soil pollution, nuclear pollution and other pollution (noise-light pollution). Pollution elements, which have many negative effects on the natural environment and human health, and which have increased in recent years and cause serious air pollution, need to be reduced in the urban atmosphere and even eliminated at the source. With effective air quality policies to be implemented in the city, the amount of emissions of these pollutants to the atmosphere can be reduced and the emissions of these emissions can be solved at their sources thanks to clean technologies. In this context; effective implementation of the sustainable development goals will improve air quality by aiming to reduce pollutant emissions in cities. This study reveals which of the sustainable development goals can be used to minimize air pollutants in cities within the scope of sustainable environment in line with sustainable development goals and how these goals can have a positive impact on air quality. In order to investigate the impact of Sustainable Development Goals on air quality in cities, one-on-one interviews were conducted with expert academic staff from the environmental engineering department of our university and the collected data were presented.

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INTRODUCTION

Globally, air pollution is one of the most important environmental problems in cities. Worldwide, emissions from production, consumption processes and logistics activities degrade urban air quality. In order to solve this problem, it is necessary to identify air pollutants, investigate emission sources and reduce or even eliminate pollutants released into the atmosphere at the source [1].

Problems of global dimension emerged especially after the industrial revolution in the 19th century when fossil fuels such as coal and oil started to be used in energy production. Concentrations of pollutants such as Carbon dioxide (CO_2), sulfur dioxide (SO_2) and Particulate Matter (PM) gradually increased in the atmosphere, and this increase, together with the increase in greenhouse gases (methane, chlorofluorocarbons, etc.) after the second half of the 20th

***Corresponding author.**
*E-mail address: damlamustafaoglu83@gmail.com

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century, caused problems such as global warming and ozone depletion on a global scale. This worldwide problem has caused problems such as acid rain in various parts of the world on a regional scale, while on a local (urban) scale, it has caused serious air pollution in large residential areas and industrial zones [2].

If we consider air pollution as a system with three basic components; (Fig. 1) these components are; Pollutant Source, Carrier Environment and Receiving Environment. The urban atmosphere is the environment where these three components are together. Air pollutant emissions generated as a result of production processes in industrial areas of cities affect other parts of the city, especially these areas. In addition, other pollutants from traffic and residential heating also participate in this process and negatively affect urban air quality.

The most important air pollutants in the urban atmosphere are inorganic in origin; carbon oxides (CO/CO_2), sulfur oxides ($SO/SO_2/SO_X$), nitrogen oxides ($NO/NO_2/NO_X$), ozone (O_3), heavy metals and particulate matter (especially $PM_{2.5}$ and PM_{10}), and organic ones, volatile organic compounds (BTX/VOCs), polyaromatic hydrocarbons (PAHs), dioxin and dibenzo-p-dioxin derivatives, hydrocarbon (HC) and chlorofluorocarbons (CFCs), etc.

Substances released into the atmosphere in cities and affecting air quality may undergo transformation through chemical/photochemical reactions and meteorological factors such as wind vector, relative humidity, temperature, temperature variation with height, pressure, precipitation may affect horizontal/vertical transport (advection/convection), dispersion and deposition (Fig. 2). Control methods should be used effectively in all of the main topics of source, urban atmosphere and impacts [3-4].

Air pollutants in the urban atmosphere have adverse effects on visibility, materials, plants and animal health, especially human health. Aerosols, a gaseous mixture of

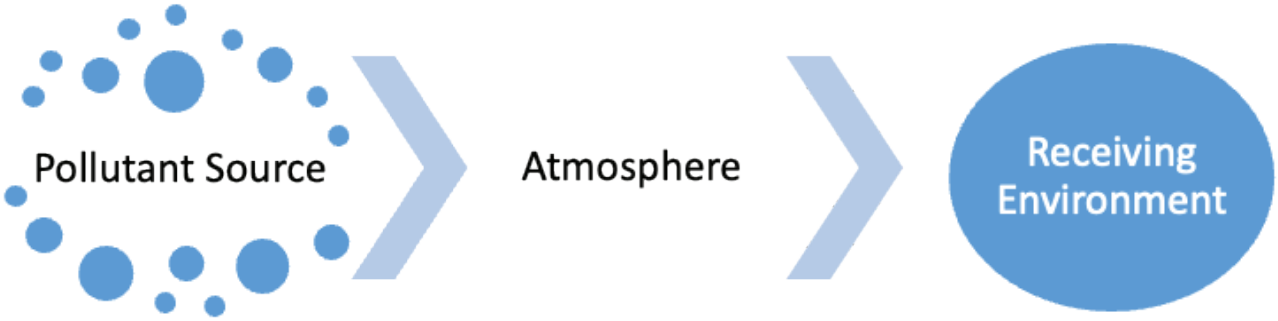

Figure 1. Components of air pollution.

Figure 2. Processes in air pollution.

Table 1. Common air pollutants and greenhouse gases and their impacts on climate, human- environmental health and ecosystems.

Air pollutant	Life time	Domain	Effect on global warming	Environmental ımpacts
Carbon dioxide (CO_2)				
Sulfur dioxide (SO_2)				
Methane (CH_4)				
Nitrogen oxide (NO_X)				
Nitrous oxide (N_2O)				
Tropospheric ozone (O_3)				
Volatile organic Compounds (VOC)				
Carbon monoxide (CO)				
Chloro fluoro carbons (CFC)				
Particulate matter (pm_{10})				
Particulate matter ($pm_{2.5}$)				
Impact indicators		Local		
		Global		
		Increase in global temperature		
		Decrease in global temperature		
		Effective on human health		
		Effective on ecosystems		
		It has no direct impact on human, environmental health and ecosystems.		

solid and liquid particles resulting from incomplete combustion of carbonaceous materials such as solid fuels and fuel oil, are a form of air pollution and have a visibility-reducing effect. Air pollution has a destructive and deforming effect on artistic and architectural structures (especially historical monuments). In plants, it can kill and inhibit growth by closing leaf stomata. The effects of air pollution on human health are caused by inhalation of high amounts of harmful substances in the atmosphere. These pollutants are known to have both acute and chronic effects on human health in urban areas and affect many organs, especially the respiratory tract. It causes many health problems such as upper respiratory tract irritation, chronic respiratory and heart disease, lung cancer, acute respiratory infections in children, chronic bronchitis in adults, adverse effects on pre-existing heart and lung diseases and asthma attacks. In a statement made at the United Nations Climate Change Conference (COP26) held in Glasgow, England, between October 31 and November 12, 2021, it was emphasized that 7.8 million people a year suffer from different types of cancer due to air pollution [5-8].

Urban air pollutants should be measured and controlled by developing effective urban policies, pollutant emissions should be reduced, health effects should be determined and their effects should be eliminated with regulations and objectives (SDGs). Reducing all the negative effects of these pollutants on the environment and human health is directly and indirectly linked to the effective implementation of SDG targets in cities (Table 1).

The concept of sustainability, which is frequently used in many fields, is defined as a participatory process [9-10] that ensures the careful use of all of society's social, cultural, scientific, natural and human resources and creates a social perspective based on respect for them. It can be said that sustainability began to manifest itself concretely in the literature in the early 19th century and emerged as a specific notion in renewable resources such as agriculture, forests and fisheries. The main feature of the concept, which is used in different fields, is that it deals with the human future and includes the protection of the resources of the area in which it is used. When the concept is viewed from this perspective, it is seen as a concept that combines economics, social justice, environmental science and management, business management, politics and law [11-14].

"Sustainable Development (SD)", which is the translation of the English concept of "Sustainable Development" into Turkish, is defined in the dictionary as "ensuring economic development without sacrificing the principle of using environmental values and natural resources in a rational way that does not lead to wastefulness, taking into account the rights and benefits of present and future generations." [15-16]. Almost all of the economic development models adopted today are models developed without taking into account environmental quality and the deformation of natural resources. "Sustainable development", which is seen as the only long-term development model that takes into account environmental quality and human capital and aims at the optimum use of resources, has been frequently used in the economic literature in recent years [17]. The transformation of SD into a globally active policy was realized with the "United Nations Conference on Environment and Development" (1992 Rio Conference) held in Rio de Janeiro, Brazil on June 3-4, 1992 with the participation of 178 heads of state or government of 178 countries. At the conference,

Figure 3. Sustainable development goals (UNDP 2024).

it was accepted that humans beings are at the center of SD and have the right to a healthy, harmonious and productive life with nature. The conference adopted two fundamental documents, the Rio Declaration and Agenda 21. With this conference, the content of the concept of SD has expanded considerably and has started to be used frequently in many disciplines [14,18-22].

A total of 17 Sustainable Development Goals (SDGs) have been defined under the 2030 Agenda, which envisages shifting the direction of global development to a more sustainable course (Fig. 3). With a total of 169 targets, sustainable development covers all economic, social and environmental dimensions [23-26]. Sustainable development goals are defined below:

Goal 1. No Poverty

It aims to end extreme poverty in all its forms (income below USD 1.90 per capita per day), achieve income justice for all and improve access to economic resources.

Goal 2. Zero Hunger

The goal of ending global hunger and malnutrition and ensuring access to safe, nutritious and sufficient food for all by promoting sustainable agricultural methods and food systems.

Goal 3. Good Health and Well-being

It aims to make global progress on issues such as infectious diseases, maternal and child health and mental health by promoting a healthy life for people of all ages and improving health systems.

Goal 4. Quality Education

Efforts are made to promote lifelong learning opportunities by providing inclusive, equitable and quality education opportunities for all.

Goal 5. Gender Equality

It targets the transformations necessary to end all forms of discrimination against women and girls and to ensure their equal participation in society, economy and politics.

Goal 6. Clean Water and Sanitation

Promotes the efficient use of water resources to ensure access to clean and safe water for all and sustainable sanitation practices.

Goal 7. Affordable and Clean Energy

It aims to guarantee access to modern, secure, sustainable and affordable energy sources for all.

Goal 8. Decent Work and Economic Growth

It promotes inclusive and sustainable economic growth, full employment and the creation of decent work opportunities.

Goal 9. Industry, Innovation and Infrastructure

It aims to create a global system that promotes sustainable industrialization, supports innovative solutions and builds resilient infrastructures.

Goal 10. Reduced Inequalities

It aims to reduce inequalities in income and opportunity between and within countries.

Goal 11. Sustainable Cities and Communities

It works to create inclusive, safe, resilient and sustainable cities and to improve the quality of urban life.

Goal 12. Responsible Consumption and Production

It supports responsible production and consumption through the efficient use of natural resources, waste management and the promotion of sustainable consumption patterns.

Goal 13. Climate Action

It aims to strengthen action to reduce carbon emissions and limit global temperature rise by taking urgent measures to combat climate change.

Goal 14. Life Below Water

It aims to protect underwater ecosystems by promoting the sustainable use of oceans, seas and marine resources.

Goal 15. Life on Land

It aims to protect forests, combat desertification, conserve biodiversity and ensure sustainable management of terrestrial ecosystems.

Goal 16. Peace, Justice and Strong Institutions

It promotes access to justice for all, building peaceful and inclusive societies, and building effective, accountable institutions.

Goal 17. Partnerships for the Goals

It aims to strengthen global cooperation, increase financial resources and facilitate information sharing to achieve sustainable development goals.

In Türkiye, the "Türkiye's Current Situation Analysis Project on Sustainable Development Goals" supports the development of policy, legislation, institutional framework and project development for Türkiye in the context of sustainable development goals. Within the scope of the project, Türkiye's current situation was assessed for each SDG, and gaps and areas in need of improvement were identified in line with the findings and determinations made (Sustainable Development Goals Assessment report 2019).

There are three important factors affecting environmental sustainability. These are industrialization, urbanization and rapid population growth. The rapid increase in population started in the 18th century and today, urbanization has brought environmental problems in cities with unpreventable migration. With the development of technology, the use of natural resources has increased. Natural resources, which were previously considered unlimited and free, have turned into a limited capital with increasing production activities in contemporary societies [27].

The environment has been greatly affected by exploitation, which is referred to as an economic- based attack, especially after the Industrial Revolution. From this period until the 1960s, the damage to the natural environment was seriously ignored [28]. However, after the 1970s, it is seen that this situation will not continue, there is no sustainability and environmental problems have started to emerge on a global scale. In terms of the sustainability of the environment and the ecosystem, within the framework of renewable resources; the level of use of resources should never exceed the level of regeneration of resources [18,29].

Especially developing countries have to develop and use their natural resources while doing so. Intensive use of natural resources creates the risk of destroying these resources and destroying environmental values. At the time, this was considered an inevitable consequence of development. Since the 20th century, rapidly developing countries have achieved social welfare, completed their economic development and developed an environmentally sensitive development policy. However, the infinity of human needs has necessitated the infinity of demands, and new demands and unstoppable consumption frenzy continue to harm the environment. In response to the limited natural resources and the rapid increase in the world population, natural resources have started to decrease and environmental pollution has started to increase. Rapid industrialization, urbanization, modernization of agriculture, developments in technology and economy have disrupted the resource-need balance, and efforts to achieve social welfare have begun to threaten the future of humanity. Thus, the concept of SDGs was developed in order to develop socio-economically, protect environmental values and stop the rapidly approaching global climate crisis [30-31].

Among the SDGs, which take measures on many issues and call for global action, there are some goals directly related to the environment. Goal 6 (Clean Water and Sanitation), Goal 7 (Affordable and Clean Energy), Goal 9 (Industrial Innovation and Infrastructure), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Production and Consumption), Goal 13 (Climate Action), Goal 14 (Life in Water) and Goal 15 (Life on Land) directly contribute to solving environmental problems, mitigating the impacts of climate change and creating a sustainable world ecosystem. Within these goals, some goals and sub-goals directly address air quality in cities and reduce the negative impacts of air pollutants on the environment and human health.

MATERIALS AND METHODS

In this study, the effects of sustainable development goals on the improvement of air quality in cities were evaluated by our expert team by examining the SDGs in detail through literature reviews. The study was developed in two steps. In the first step, SDGs directly related to the environment were identified. Following this identification, in the second step, it was examined which SDGs and sub-goals can improve air quality in cities. While performing these two steps, academic databases were scanned in detail. In this study, one-on-one interviews are conducted with 19 academic staff from the environmental engineering department of our university in order to investigate the impact of SDGs on air quality in cities. The data collected as a result of these interviews are presented in the Results and Discussion section.

RESULTS AND DISCUSSION

The effects of SDGs and their sub-objectives on air quality in cities have been revealed as a result of the studies. The relationship between SDGs and air quality is interpreted through the effects of these objectives on air quality components. Afterward, it is discussed which SDGs and sub-objectives can be used to improve air quality in cities.

Relationship Between Scalars and Urban Air Quality

Improving air quality in cities is linked to the effective implementation of the SDGs and has received considerable attention in recent years (Fig. 4). Understanding the extent to which air pollution also affects the process of achieving the SDGs can help to estimate the benefit of reducing air pollution to improve sustainable development and assess the necessity and urgency of reducing air pollutants and improving air quality [32]. Clearly, air pollution, urban air quality and SDGs mutually influence each other [33,34].

Reducing air pollution can improve the progress of sustainable development in several ways. First and foremost, air pollution changes the composition of the atmosphere, causing global warming by affecting greenhouse gas emissions and generating significant amounts of potentially health-threatening carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx) and particulate matter. Second, air pollutants can enter water and soil and be taken up by plants and grazing animals, thus affecting the entire ecosystem [29, 35-38].

Air pollution causes adverse health effects that have been widely researched in recent years. These health impacts include increased mortality and hospitalization

Figure 4. Relationship between air pollution and urban air quality and SDGs.

Table 2. Relationship between Air Pollution and SDGs

SDG	Effect on air pollutants sources	Air quality	Effects on human and environmental health
SDG 1	Neutral	Neutral	Ineffective
SDG 2	Neutral	Neutral	Ineffective
SDG 3	Reduces	Increases	Positive Impact
SDG 4	Neutral	Neutral	Ineffective
SDG 5	Neutral	Neutral	Ineffective
SDG 6	Neutral	Neutral	Ineffective
SDG 7	Reduces	Increases	Positive Impact
SDG 8	Neutral	Neutral	Ineffective
SDG 9	Neutral	Neutral	Ineffective
SDG 10	Neutral	Neutral	Ineffective
SDG 11	Reduces	Increases	Positive Impact
SDG 12	Neutral	Neutral	Ineffective
SDG 13	Reduces	Increases	Positive Impact
SDG 14	Reduces	Increases	Positive Impact
SDG 15	Reduces	Increases	Positive Impact
SDG 16	Neutral	Neutral	Ineffective
SDG 17	Neutral	Neutral	Ineffective

Indicators
Effect on Air Pollutants Sources: Increases-Neutral-Reduces
Air Quality: Increases-Neutral-Reduces
Effects on Human and Environmental Health: Positive Effect- Ineffective-Negative Effect

more chronic and respiratory diseases such as diseases of the nervous system, heart, brain, vascular diseases, reduced lung function and exacerbation of asthma and exercise-induced bronchoconstriction, chronic obstructive pulmonary disease and acute lower respiratory tract infections. Efforts to reduce air pollution can improve these conditions and thus benefit the achievement of the SDGs (Table 2). However, as a product of human activities, air pollution is associated with major social economic sectors, such as agriculture, industry, housing, and transportation sectors, which increase a country's Gross Domestic Product (GDP).

SDGS Effective in Improving Air Quality

Reducing urban air pollution and improving air quality is possible through the effective implementation of environmental SDG targets 3-7-11-13-14-15. Improving air quality will also positively affect SDG achievement as a positive feedback.

Among the SDGs, there are 13 targets under SDG 3 (Ensure a healthy and quality life at all ages).

These objectives are:

Sub-target 3.9 "By 2030, significantly reduce deaths and illnesses caused by hazardous chemicals and air, water and soil pollution and contamination with hazardous chemicals" and sub-target 3.d "Strengthen early warning, mitigation and risk management capacities of all countries, in particular developing countries, against national and global health risks" directly contribute to reducing air pollution.

SDG 7 (Ensure access to affordable, reliable, sustainable and modern energy for all) includes five targets, including;

Sub-target 7.1 "By 2030, ensure universal access to affordable, reliable and modern energy services", sub-target 7.2 "By 2030, significantly increase the share of renewable energy in the global energy mix", sub-target 7.3 "By 2030, double the global rate of improvement in energy efficiency", sub-target 7.a "By 2030, scale up international cooperation to facilitate access to clean energy research and technologies, including renewable energy, energy efficiency, advanced and cleaner fossil fuel technologies, and support investments in energy infrastructure and clean energy technologies" sub-target 7.b "By 2030, expand infrastructure and upgrade technologies in all developing countries, especially in the least developed countries, small island developing States and landlocked developing countries, to provide modern and sustainable energy services for all", the use of renewable and clean energy and the reduction of fossil air pollutants can be achieved.

SDG 11 (Making cities and human settlements inclusive, safe, resilient and sustainable) has 10 targets. These targets include;

Sub-target 11.2 "By 2030, ensure access to safe, affordable, accessible and sustainable transport systems for all,

with particular attention to the needs of vulnerable people, women, children, persons with disabilities and the elderly, by improving road safety and improving public transport systems in particular" and sub-target 11.4 "Strengthen efforts to protect and preserve the world's cultural and natural heritage" will reduce traffic-related emissions in cities and improve air quality around historical monuments through sustainable transport systems. In addition, sub-target 11.6 "By 2030, reduce negative environmental impacts per capita in cities, with particular attention to the management of municipal and other waste and air quality", sub- target 11.7 "By 2030, ensure universal access to safe, inclusive and accessible green and public spaces, especially for women, children, older people and persons with disabilities" and sub- target 11.7 "By 2030, ensure universal access to safe, inclusive and accessible green and public spaces, especially for women, children, older people and persons with disabilities", and sub- target 11.7.a "Promote positive economic, social and environmental relations between urban, peri-urban and rural areas through strengthening national and regional development planning", air quality can be given special attention, air pollutants can be reduced and positive environmental relations can be increased by increasing green areas within the city.

There are 5 targets under SDG 13 (Taking urgent action to combat climate change and its impacts). Among these; sub-target 13.1 "Strengthen resilience and adaptive capacity to climate change-related hazards and natural disasters in all countries", sub-target 13.2 "Incorporate climate change measures into national policies, strategies and planning processes", sub-target 13.3 "Develop training, awareness, individual and institutional capacity on climate change prevention and mitigation, climate change adaptation and early warning", sub-target 13.a "In order to meet the needs of developing countries in the context of meaningful mitigation actions and transparency in implementation, to ensure that developed countries that are parties to the United Nations Framework Convention on Climate Change realize their commitments to jointly mobilize USD 100 billion annually from all sources by 2020 and to operationalize the Green Climate Fund by completing the capital formation as soon as possible" sub-target 13.b "Promote mechanisms to increase planning and management capacity for climate change, including a focus on women, youth and local and marginalized communities in least developed countries and small island developing States".

SDG 14 (Protecting and sustainably using the oceans, seas and marine resources for sustainable development) has 10 targets. These include;

14.1 "By 2025, prevent and significantly reduce all forms of marine pollution, particularly from land-based activities, including marine litter and nutrient pollution", sub-target 14.2 Sub-target

14.1 "By 2020, manage and protect marine and coastal ecosystems sustainably, including by increasing their resilience, to avoid significant adverse impacts, and take action to restore ecosystems for healthy and productive oceans", sub-target 14.3 "Address and, as far as possible, reduce the impacts of ocean acidification, including through enhanced scientific cooperation at all levels", sub-target 14.a "Increase scientific knowledge, strengthen research capacity and transfer marine technologies to improve ocean health and enhance the contribution of marine biodiversity to the development of developing countries, in particular small island states and least developed countries, in line with the Criteria and Guidelines of the Intergovernmental Oceanographic Commission on the Transfer of Marine Technology", sub-goal 14.a; and sub- goal 14.c "As stated in paragraph 158 of "The Future We Want" The sub-objective 14.c "Improve the conservation and sustainable use of oceans and ocean resources by applying international law as enshrined in the United Nations Convention on the Law of the Sea, which sets out the legal framework for the conservation and sustainable use of oceans and ocean resources, as set out in paragraph 158 of the "The Future We Want" document" will enhance marine and ocean health and improve air quality globally.

There are 12 targets under SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems; ensure sustainable forest management; combat desertification; halt and reverse land degradation; prevent biodiversity loss). Among these targets; sub-target 15.1 "By 2020, in line with obligations under international agreements, ensure the protection, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands" will reduce air pollutants from acid rain and forest fires. 15.2 The sub-target 15.2 "By 2020, promote the practice of sustainable management for all forest types, halt deforestation, restore degraded forests, and substantially increase reforestation and reforestation globally" is to reduce greenhouse gas emissions by preventing climate change. Sub-target 15.3 "By 2020, combat desertification, restore degraded lands and soils, including lands affected by desertification, droughts and floods, and strive to achieve a world free from soil degradation" and sub-target 15.b "mobilize all resources at all levels to a significant extent to finance sustainable forest management and provide adequate incentives for developing countries to further sustainable forest management, including conservation and reforestation" improve air quality by protecting forest areas.

CONCLUSION

With the industrial revolution in the twentieth century, there has been an increase in human interaction with the environment and ecosystems. The desire of human beings to meet their unlimited needs has caused them to utilize nature, which they see as an unlimited resource, to misuse it and to pollute the environment as a result of this relationship. The fact that environmental pollution has reached great dimensions especially after the 1970s has brought to the agenda the sustainable development policy, which,

instead of growing no matter what, attaches importance to human beings, considers the interests of current and future generations, envisages the optimum use of natural and cultural resources, and advocates the harmony of economic and social policies with environmental policies at every stage of development. With this policy, economic and environmental problems have moved to an international dimension. Following the SDG policy, which brings a new dimension to the relationship between economic development and the environment, will ensure the establishment of a sustainable relationship with the environment.

In recent years, many studies have been conducted and published on air pollution, which causes significant health and environmental problems throughout our country. By increasing the number of studies, pollutant sources can be better identified, emission sources can be monitored, and their effects on the environment and human health can be better investigated. Identifying the sources of pollutants is possible by implementing the necessary measures and Sustainable Development Goals to eliminate pollutants at the source and in the urban atmosphere. Reducing pollution with a mechanism that affects each other will ensure that these goals are fulfilled more healthily.

As a result; full implementation of SDGs that are directly and indirectly related to air quality will contribute to the reduction of pollutants in the urban atmosphere and indirectly improve urban air quality. It should be noted that all stakeholders who are trying to implement relevant SDGs effectively in improving air quality within the city contribute to the process.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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