Integrated Study of Air Pollutant Emissions from Different Sources in Isfahan City of Iran

**Tayeb Yousefi · Javad Varvani ·
Bahman Shams Esfand Abad · Abbas Ahmadi ·
Nourollah Abdi**

Abstract Air pollution is a significant environmental problem in Isfahan City, Iran, with detrimental effects on human health and ecosystems. It comes from various sources, including the asphalt industry, motor vehicles, power plants, industry, and natural events such as forest fires and dust storms. The data used in the study was obtained through a combination of different methods and strategies. Reliable laboratory information besides reports from the European Environmental Protection Organization, American Environmental Protection Organization, and Australian Environmental Protection Organization, standards from environmental organizations were used to determine emission coefficients. Questionnaires were prepared and referred to trade and industrial units to gather information on production and air pollutant emissions. Finally, statistical analysis and grouping methods were used to analyze the data. Based on average data of emission rate of different sources, prioritizing resulted in the identification of five main sources of gaseous pollutant including chemical industries, synthetic textiles, and pharmaceutical industries (7.36%), burning garden waste outdoors (7.68), brick kilns (12.43%), garbage center (15.78), and digestion of humans (45.68). Other 30 sources contribute less than 3%. Based on the results, it is obvious that CH_4 only contributes 44% in gas emissions of Isfahan City followed by CO (23%), TSP (13%), MVOCS (9%), PM10 (2.17%), NH3 (1.96%), non-methane volatile organic compounds (1.89%), Nox (1.70%), PM2.5 (1.36%), SOx (0.89%), VOC (0.76%), and PM (0.03%).The results of the paper provide information on the major sources of air pollutant emissions in Isfahan City, including chemical industries, burning garden waste outdoors, brick kilns, garbage centers, and digestion of humans. It presents the average data of emission rates from different sources, helping in prioritizing and targeting specific sectors for reducing emissions. The study highlights the importance of considering both natural and anthropogenic sources of air pollution and the need for implementing strategies to obtain accurate information on emissions. The research contributes to the understanding of air pollution sources in Isfahan City, which can aid in developing effective measures for reducing pollution and improving air quality.

Keywords Air pollutant · Emissions · Isfahan City · Anthropogenic sources

T. Yousefi · J. Varvani (✉) · B. S. E. Abad · A. Ahmadi · N. Abdi
Department of Natural Resources and Environment, Islamic Azad University, Arak Branch, Arak, Iran
e-mail: Varvani_55@yahoo.com

J. Varvani
Research Center of Applied Plant Science, Islamic Azad University, Arak Branch, Arak, Iran

1 Introduction

Air pollution is a change in the natural characteristics of the atmosphere due to chemical substances, dust, or biological agents. The atmosphere is a dynamic and complex natural gas system to which life on planet earth depends. Depletion of the ozone layer of the stratosphere due to air pollution has long been known as a danger to the health of people and the earth's ecosystems. Due to its harmful consequences, air pollution has become one of the most tangible environmental problems of urban area especially in Isfahan, a major city in the center of Iran. Statistics show that the number of respiratory patients increases on days of increased air pollution. The most important factor related to the aggravation of cardiovascular, vascular, and pulmonary diseases is the increase in sulfur dioxide, suspended particles, and carbon monoxide pollutants. (Abderrezak, Khelfi, 2018, Binglin Zhang et al., 2023; Tan and Yan, 2021). This air pollution may be natural (such as the activity of volcanoes) or artificial. Artificial pollution is mainly caused by the activity of vehicles and factories. Every day, various pollutants enter the air through industrial units, different trades, factories, and different urban sectors. If the release and contribution of each pollutant source in the country, regions, and different urbanized areas that have air pollution problems are not determined, any design and planning to manage the air pollution of that country and city areas will be fruitless. The activity of industries, residential and commercial buildings, small industries, and other air-polluting industries, if they are categorized and their pollution is examined and researched together, could be effective in crisis management in urbanized areas. The discussion of air pollution in large cities of Iran and the legislation about it go back to the municipal law in 1955 in that the issue of air pollution reduction became a matter of serious importance. But this issue, since 1995 when the pollution reached the extreme limit, consolidated and caused the law on how to prevent air pollution to be approved and established this year. In 2013, other activities such as compiling the first standard for vehicle exhaust gas emission, fueling motor vehicles, and technical inspection of cars were established. This year, the results of the preliminary research of the Japanese JICA group stated that the share of mobile sources is 77% of the total pollution in Tehran. Between 1995 and 2000, a plan was implemented under the title of reducing air pollution caused by transportation. In this research plan, after reviewing the current situation and referring to the necessary information about the city of Tehran, implementation plans to reduce air pollution in the short term (5 years), medium term (10 years), and long term (20 years) along with evaluation the economy of each program were discussed. The results of this project estimated the amount of emissions of pollutants in 2015 from fixed sources for greenhouse gases in terms of CO_2 equivalent to about 41 million tons and for suspended particles 5300 tons, which 45% of gases and 38% of particles from energy consumption in domestic and commercial use. This research measured the total emissions from mobile sources in this year of 9.4 million tons of greenhouse gases and 20,500 tons of suspended particles, and heavy vehicles produced 36% of greenhouse gases and 42% of suspended particles. While the traffic measured for these devices in terms of kilometers was estimated to be 8% of the total traffic. From 1995 to 1997, a comprehensive research was conducted with the cooperation of the Japan International Cooperation Organization (JICA) under the title "Comprehensive Plan of Air Pollution Control in Tehran", which resulted in infrastructure and long-term solutions and a schedule and price estimation to reduce the pollution of the city of Tehran. In this research, the study area of which was over 2500 square kilometers, field activities were carried out in three consecutive seasons: (1) sampling of the chimneys of large industrial units and measuring the concentration of air pollutants in 31 points from the city, (2) studying and editing the driving pattern in the city of Tehran, recording the traffic volume by car type in 20 main and busy intersections of Tehran, and (3) measuring the concentration and type of metallic and non-metallic elements forming suspended particles. According to the results of this research, in 2016, contribution of the transportation sector in the production of total pollutants was 71.2%, and out of the 28.8% share of fixed sources, 21.8% was the industry sector, 4.6% was the household sector and general, and 5.9% were produced by Tehran power plants and refinery. In 2016, the project "Measurement of metallic elements, ions, and cyclic hydrocarbons" was carried out in the air of Tehran City. In this research, every 4 days, a sample was taken from five different stations in the city, and the amounts of four metal elements including lead,

cadmium, nickel and chromium, dioxide sulfate and nitrate, PAH, acidity, and total solid particles of the samples were measured. This research is unique in its kind due to the measurement of elements at the city level. The results of this research were presented in the form of a statistical study of spatial and temporal changes of the parameters measured during 2016 and in the city of Tehran. In 2013, in line with the continuation of air pollution research based on the comprehensive air pollution control plan of Tehran, two researches out of seven experimental researches proposed by JICA were dedicated to the classification and contribution of the role of stationary and mobile sources in the production of various types of air pollutants. And their implementation was handed over to the air quality control company. In these two researches, despite the presentation of the amount of urban pollutant production from each of the analytical sources, the obtained results have not been presented. Since 1997, a 10-year comprehensive program to reduce air pollution in Tehran and other big cities has been implemented, and due to the importance of the issue, it has been specifically addressed to the issue of air pollution in Tehran and the big cities of Arak, Mashhad, Isfahan, and Karaj.

Jafarzadeh et al., (2014) investigated the distribution of mobile devices in the province of Khuzestan in their study. The results showed that energy products across the state were analyzed and then compared to electrical products and fuel oil in the region. Nazari et al. (2009) conducted a study on CO_2, SO_2, and NOX pollution in Iran's electricity industry. As a result of this study, emission factor values for the above pollutants were obtained from empirical relationships. The CO_2, SO_2, and NOX emission factor values obtained are 650, 2.57, and 2.31 g per kW electricity, respectively. Considering the results obtained for CO_2, SO_2, and NOX pollution, the emission value is 125. AlKheder and Almusalam, (2022) investigated air pollution from the energy industry in Kuwait, which was 34, 0.552, and 0.465 Tg per year. The aim of this study is to investigate NOX, SO_2, CO, and CO_2 pollutant emissions according to fuel type, power consumption, and power consumption. The results show that from 2010 to 2015, apart from PM10 and SO_2 pollution, the pollution of other pollutants increased gradually from 2010 to the gas and liquid used. They switched from liquid to carbon in 2015. As a result, the level of sulfur dioxide

emissions decreased by 13% compared to 2010, while carbon monoxide pollution which increased by 41.9% passes through other pollutants. Carbon monoxide is the second largest nitrogen oxide pollutant after carbon monoxide, and its emissions growth is second, with annual increase of 35.7%. McLaren, (2020) worked to update the release of the City of Auckland. This study investigates the emission rate of pollutants related to pollution from the elements. The study found that air pollution can be reduced by recycling and refurbishing equipment. Han et al., (2019) conducted a study to determine the VOC emissions of one of the largest petrochemical industries in China to assess the impact of the presence of VOCs in the air during 2.5 h of the night. The industry is divided into three segments: refining, aromatic production, and paraffin production. In 2018, research was conducted on the list update published by the energy industry of Jiangsu Province of Turkey. The purpose of this study is to investigate emissions from the power generation industry in Jiangsu Province. Contaminants covered in this report include PM2.5, PM10, SO_2, and NOX, details of which are obtained from online business data. Pollutants such as sulfur dioxide (SO_2), hydrogen sulfide (H2S), and nitrogen oxides (NO_2 and NO) affect plant cell physiology and different levels of PSM (Chandawat et al., 2014). Sulfur is an important compound that plays an important role in many physiological and biochemical processes in plant growth (Li et al., 2022). SO_2 is a major pollutant released into the atmosphere by the commercialization of oil or coal power generation (Ziegler, 1975). Considered at the ecosystem level, SO_2 pollution can lead to the loss of sensitive plants (such as lichens and bryophytes), so SO_2 has an impact on species (Varshney et al., 1979). H2S is an important pollutant found in high concentration in many parts of the atmosphere. H2S can cross cell membranes and cause many responses to various stressors such as heat stress, high pressure, osmosis, heavy metals, and many other stressors. The high content of nitrogen dioxide (NO_2), one of the most harmful and harmful gases, can cause plant oxidation (Li et al., 2023; Sheng and Zhu, 2019). High nitrogen oxides in the air cause an increase in ozone concentrations and the flux of nitrogen oxide compounds from the air to the surface, which damages the photosynthetic apparatus and is therefore bad for the growth of plants. Nitric oxide (NO) is very

important. A small amount of radiation causes disruption of biochemical events that make plants more resistant to environmental stress (Dan et al. 2018; Le et al. 2021; Shivaraj et al., 2020; Goyal et al., 2021; Pandey et al., 2021).

de Miranda et al., (2012) focused on the identification and analysis of air emissions from permanent residences with significant environmental impact in Belo Horizonte, Brazil. This study provides information on the emission of pollutants such as NOX, CO, TSP, PM10, PM2.5, SO_2, and VOC, which is useful for air diagnosis, modeling, and management. Summary of a short report on outdoor air pollution and its impact on human health explained that air pollution is a mixture of harmful substances and gases produced by human activities and natural events, and that certain groups of people, such as pneumonia, are at high risk of experiencing health problems due to exposure to outdoor air. Song et al. (2021) noted that air pollution is caused by human activities and natural events such as forest fires, electrical fires and storms, and more pollution than the nearest source of emissions. Zhou et al., (2017) reported biomass emissions from burning in homes and fields in mainland China in 2012, including hay burning, wildfires, livestock burning, and forest and grass fires. The product was developed using geographic information systems (GIS) techniques and includes the main parameters of pollutants, carbon monoxide, and heavy metals released from biomass combustion. Recently, off road mobile sites have gained attention for their contribution to air pollution and climate change. Many literatures have taken this into account (Campbell et al., 2018; McDonald et al., 2018). Non-road vehicles in my country have become significant sources of nitrogen oxide (NOx) and particulate matter (PM) emissions due to their long service life and stringent inspection compared to transport vehicles (Yifeng Xue et al. 2022; Chen et al., 2021; Zhong et al., 2018; Ying et al. 2016). Chapter (2021) studies show that CO, HC, and NOx emissions from excavators and loaders are highest in operating mode and decrease with stringent emission standards. However, the study of CO_2 emissions is far from sufficient; there are only a few studies on CO_2 emissions in different operations. Yao et al. 2022 analyzed the emission characteristics of pollution from construction machinery and the operation of the control system in Beijing based on the registration data of the information system, and the results showed the following: (1)

According to the registration data of the code, there are 37,000 oil-only construction machinery, and the largest share of them is excavators (56%, loaders and forklifts also make up a large share (19% and 15%), representing the main type technology. (2) The registration data can reflect the actual situation of construction technology emissions than the above system; air pollution of large NOx, PM2.5, and VOCs is 12,000 tons, 600 tons, and 1000 tons, slightly overvalued under the top-down rule. (3) Emissions from loaders and excavators are a major contributor, accounting for 80–91% of our pollution emissions; the number of national standard machines is relatively large, accounting for 64 to 68% of pollution emissions; low-energy areas where high-efficiency generators are used are effective in reducing air pollution, but these areas still use high-energy generators and require more attention. (4) In the future, the prohibition of the use of high-voltage machinery and control systems in these areas should be expanded, the supervision and regulation legislation should be strong, and standards and reform of energy saving and emission reduction should be made. Mechanical engineering must be strong. Encourage and implement measures such as the use of electricity in some lighting systems and continue to reduce pollution. Yang Gao et al., (2022) presented characteristics of the location and functioning of industrial high carbon dioxide and air pollutants in China. The main sources of CO_2 and other greenhouse gas emissions are electricity and industry. Among the different sub-sectors of the economy, detailed analysis shows that cement, iron, and steel are the main sub-sectors with CO_2 emissions and the most pollutants. High-resolution spatial distribution analysis showed that 5% of the grid for CO_2 accounted for 90% of all CO_2 emissions and showed spatial heterogeneity. These power lines are also important sources of pollutant emissions such as, for example, emissions of SO_2 reach 73% and emissions of volatile organic compounds (VOC), CO, NOx, PM10, and PM2.5 exceed 50%, indicating that emissions of greenhouse gases and pollutants are imminent. Most emissions are concentrated in relatively low power grids, which means there is the possibility of mutual control of greenhouse gas emissions and pollution emissions, which is especially beneficial for future policies to achieve carbon neutrality and air quality.

Guo et al. (2023) in its carbon emission trading pilot study (CETP) in 2023, pointed out that the

carbon emission trading pilot policy is an important measure to ensure economic cooperation and the environment. Based on data from 268, cities in China from 2006 to 2020, two time-varying models to examine the impact of the carbon emissions trading pilot policy on urban innovation capital were used. Research shows that the use of CETP improves urban innovation capacity and that the impact of policies on improving urban innovation capacity differs between types of innovation and city branding. Utility model patents and city branding have a strong incentive for innovation. The implementation of CETP has a positive impact on the development of urban infrastructure and can stimulate the development of new resources in surrounding cities. The carbon emissions trading pilot policy actively promotes new cooperation between green and urban areas. There are different patterns in the impact of carbon emissions trading pilot policy on green innovation collaboration. Compared with cities with high openness, cities with low openness have a better impact on urban sharing and urban green cooperation policies. Likewise, although the results of cities with different jurisdictions and environmental management studies on cooperation in the new green city are still similar, the support for cooperation in the new green city is stronger. These findings highlight important differences in the impact of carbon emissions trading pilot policy across different urban contexts. The relationship between the carbon emissions trading pilot policy and green innovation cooperation is partially mediated by two factors: business model reform and digital financial services. Optimization of business models is driving the evolution of urban green innovation, and digital financial services are supporting the transformation of urban carbon emissions and ensuring the effectiveness of policies and procedures. The government should take a different approach to low carbon, based on openness characteristics and environmental management efforts. For cities that are less open, the government should encourage companies to respect opening hours and encourage water flow in the area. Environmental management should be directed and managed in a way that forces companies to carry out R&D and production activities. Environmental protection businesses will encourage businesses to save energy, reduce emissions, and make environmentally friendly innovations. For cities with less command- and control environmental policies, the government

should use two different environmental regulations to extend the benefits of the carbon emissions trading pilot policy of green innovation cooperation. Although this study has certain theoretical value and practical significance, there are still some limitations that future research can improve. The research object of this study is the level of green innovation cooperation at the city level, so we adopt the panel data of prefecture-level cities. Future studies can be further refined as data collection becomes more detailed. First, green innovation cooperation can be further subdivided into school–enterprise and enterprise–enterprise cooperation. Second, a shift from static to dynamic research can make the results have a more far-reaching impact. Third, environmental regulation policies may produce different effects in different industries. Therefore, future research will evaluate the effects of carbon emission trading policies on different industries. Fourth, we will collect more detailed data, such as cooperation data on green services and products, to measure green innovation cooperation more comprehensively. Chen et al., (2023) demonstrate that there are few studies on the correlation between PM2.5 and meteorological factors. Their study investigates the correlation between six meteorological factors (temperature, dew point, humidity, barometric pressure, wind speed, and visibility) and hourly PM2.5 concentration in Beijing. Pearson correlation analysis was used to analyze and found that meteorological factors had a stable non-linear effect on the change in PM2.5 concentration. Additionally, a BP neural network model was employed to examine the influence of meteorological conditions on hazy weather, considering both univariate and multifactorial aspects. Experimental results reveal a strong correlation between PM2.5 concentration and the four seasons, exhibiting minimal deviation and varying prediction errors throughout the seasons, confirming the seasonal association with haze weather. Consequently, the utilization of the BP neural network model for air quality index prediction is considered feasible. This research serves as a valuable reference for understanding the formation mechanism, implementing control methods, and establishing a haze prediction system to effectively manage urban air quality. In their study, Barlam et al., (2023) have assessed the concentrations of black carbon (BC) measured using aethalometer during different cooking periods in five different types of kitchens

and different fuels in the tribal villages of east India. The BC mass concentrations were 397.24 ± 129.28, 403.49 ± 204.02, 463.45 ± 196.83, 458.77 ± 181.81, and 445.43 ± 193.67 µgm^{-3} for the indoor built kitchen (K1), indoor built kitchen but stoves situated in living area (K2), outside built kitchen (K3), semi-open kitchen (K4), and open cooking (K5), respectively. It is noted that the kitchen structure also significantly influences the accumulation of BC particles. Despite no connection between study area and from industrial site, it is observed that more tremendous amount of BC concentration. It shows that solid biomass fuel is responsible for increasing the concentrations level of BC in the atmosphere. The health risks were higher in K3 and K4 types of kitchens than in other types of kitchens. Their results indicate a requirement for a comprehensive study to thoroughly investigate the impact of household BC pollutants on the health risk assessments in the villages of east India. Zhao et al. (2023) in study of simulation of carbon sink calculation for urban buildings demonstrate that cement and other cementitious materials in buildings can react with CO_2 in atmosphere, leading to the carbonization. Predicting the precise uptake of CO_2 of urban buildings is crucial to addressing the loss of carbon sinks.

Based on mentioned issues and importance of air quality in local and worldwide level, the aim of this research is to finding main gas emission from different kinds of industries and sources to the Isfahan air system and prioritizing the main sources of the gas emission. Identifying the major sources of air pollution in the specific area or city through comprehensive studies and data analysis, prioritizing the sources based on their contribution to pollutant emissions, and focusing on the ones with the highest emissions rate are of the other purposes that might be interested.

2 Methods

2.1 Study Area

The scope of the project in this research is the 15 districts of Isfahan City, one of the major well developed cities in the central part of Iran (Fig. 1). Since some industries and small industries outside the city of Isfahan, including brick kilns and foundries, are considered by the residents of Isfahan, the amount of pollutants produced by them has also been investigated
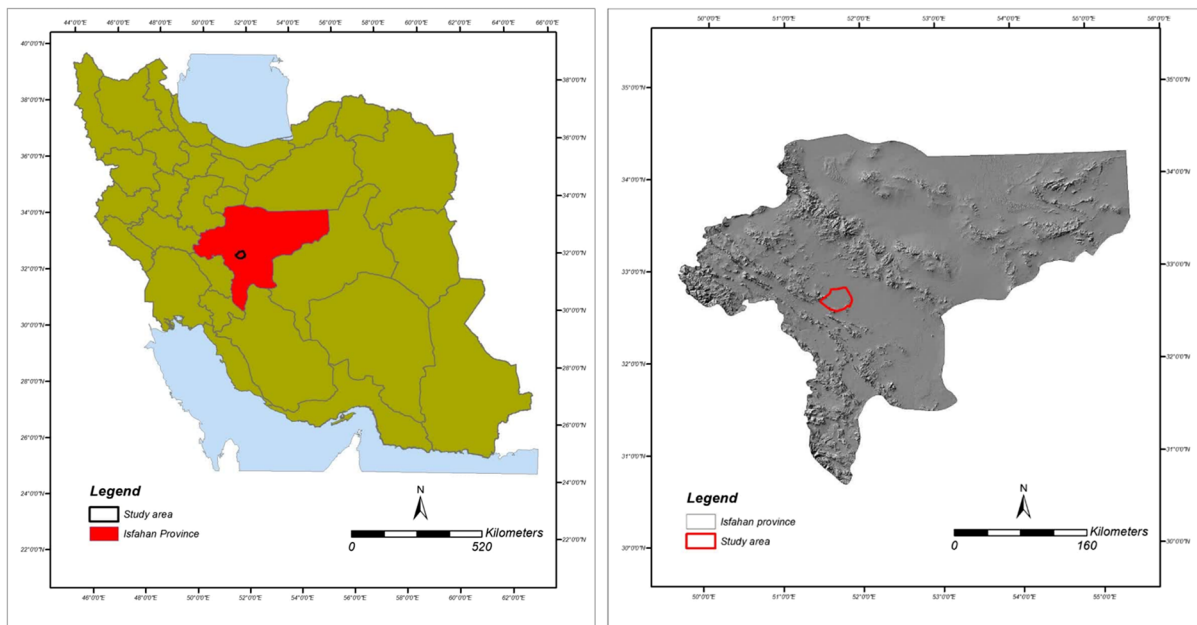

Fig. 1 Map of study area in country (Iran) and Isfahan Province

and given importance. Also, in order to influence part of the outskirts of the city, Sajzi, Daulat Abad, Habib Abad, and Jay Industrial town have also been added to it.

2.2 Procedures for Preparing the List of Gas Pollutant Emissions of Small Manufacturing Industries and Trades

Department of Environment and Conservation of Iran, Approved Methods for the Sampling and Analysis of Air Pollutants (DECI, 2023), environment protection legislation, in accordance with the approval procedures set out by EPA, and other worldwide standards were considered in sampling and analyzing of air pollutants in Isfahan City. To assess air pollution by stationary sources, parameters (TSP, O3, CO, CO_2, NO, NO_2, NOx, SO_2, H2S, CxHy, and dioxin) were measured by using particle measuring device, gas measuring device and GC. Technical instructions provided by EPA were applied. Also in some cases, portable devices with electro chemical sensor were used to collect gaseous pollutants (DECI, 2023). All this procedures carried out by reference laboratory located in environmental organization with numerous engineering consultant companies that are responsible to collect air pollution data periodically from different active urban units. The different steps of preparing the list of air pollution emissions of manufacturing industries and industries are as follows:

2.2.1 Identification and Classification of Guilds and Industrial Units

To prepare the release list of units, polluting sources are first identified and classified. The purpose of classification is to determine a group of industries and classes that have a similar activity or pollution emission rate compared to each other. For example, chemical manufacturing industries are introduced in one class, because most of them emit volatile organic substances.

2.3 Collecting Data that Can Be Used to Determine the Rate of Publication of Resources from Reference Organizations

One of the main steps of preparing the publication list of trades is to determine the number of active trades and small industries in the city and their activity level. The main problem for preparing the publication list is not having the required information. Therefore, various strategies were implemented to obtain the types of information used and in some cases, several methods were tested.

2.4 Information and Data of Organization of Industry, Mining, and Trade

Isfahan Province has two data systems: the first related to small industries located in towns and industrial areas, and the second, data of guilds. According to the data of this organization, about 6151 active industrial units are operating in Isfahan City, and the type of activity and the amount of products produced per year are specified in these data.

2.5 Business Information and Data

The most complete information related to the categories is business data. The number of classes in the 15 districts of Isfahan is about 135,816. This data includes many active classes. In this data, classes are classified based on the type of activity. This data includes the trade unions of the entire city of Isfahan (with industrial areas such as the industrial towns. In addition to the type of activity, the area of trade union units is given and they are classified based on quality.

2.6 Trade Unions and Associations

More than 105 unions and trade associations have been registered in Isfahan City, and unions are the most important source of information. The information of these unions is limited only to their addresses.

2.7 Information and Data Provided by Official Sources

In this research, information and data from official sources were used to find out about the performance of some classes and small industries. These sources are highway police, industry and mining organization, gas company of Isfahan Province, water and sewage organization, national oil products distribution company of central Isfahan region, commerce department, general grain department of the 10th region of the country, Jihad agriculture organization, etc.

Another source of information used in this research is the statistical booklet "Isfahan Metropolis Atlas" which is published every year; this atlas collects and publishes the data of population and housing, energy and fuel, transportation, industry and mining, construction, and agriculture of Isfahan City from the relevant official authorities.

2.8 Field Investigation and Questionaries

Only the organization of industry, mining, and trade stated the data of the production of industrial units. For this reason, questionnaires have been prepared and referred to trade and industrial units and asked them about their production or fuel consumption. In many cases, the number of trade and production units are large, and many of their managers avoid giving information due to concerns about taxes, duties, and the environment. For this purpose, methods are used to determine their activity percentage, and it is generalized for the whole trade union.

2.9 Determination of Diffusion Coefficient

The emission coefficient is the ratio of the emission rate of the pollutant to the activity level of the system. To determine the diffusion coefficient, there are three basic methods:

2.9.1 The Use of Authentic Reports Approved by the Countries' Environmental Organizations

The European Environmental Protection Agency (EEA), the American Environmental Protection Agency (EPA), and the Australian Environmental Protection Agency (NPi) used as standards for determining the emission rate of industrial pollutants. And they have proposed classes that are very similar in many cases. The selection of the type of standard depends on the technology and also the accuracy of the activity level data.

2.9.2 Direct Measurement

For this purpose, it is necessary to measure the concentration of the desired pollutant, the volume flow rate of the total output material, and the output temperature.

2.9.3 Using the Law of Conservation of Mass

In some cases, by having some inputs and outputs, and by applying the law of conservation of mass to the system, it is possible to obtain the emission rate of the desired pollutant. The emission coefficient is a practical and basic tool to control air quality. By comparing the emission coefficient obtained and for the source in question with the standard values, it is possible to benefit from the working status of the system from an environmental point of view. Direct measurement is the most accurate method from the point of view of the certainty of the data of the release list. The material balance method can be used if the required input information is available with appropriate certainty. Despite the high confidence factor, this method has a lower cost than direct measurement, but its use is limited. The use of modeling methods and written software in this field to calculate the diffusion coefficient is very useful. This method is used in industries and areas where measurement is not possible or sufficient funds are not available for this purpose. To use each of these methods, different information is required. Collecting this information with optimal accuracy in each method requires different time and cost. The important factors for choosing the method of determining the diffusion coefficient are as, feasibility and accessibility to the information of classes and industries, technology used, accuracy, economic cost, and time.

The selection of the emission coefficient depends a lot on the information on the activity rate and fuel consumption of trade and industrial units. The emission coefficient of the international standard sources has good accuracy, but its use to prepare the pollution emission list requires the details of the production process. Despite the details of different parts of the asphalt factory, it is possible to calculate their pollution emission rate; since the production rate of the entire factory is available, only the total emission rate can be obtained without having production details. The technology used in the production of the product also affects the selection or determination of the emission coefficient.

2.9.4 Selection of Methods for Determining the Diffusion Coefficient and Activity Rate

If the reliable laboratory information is available, the measurement is used for the diffusion coefficient.

Regarding brick kilns, which is very important and little information was available, ten items were sampled, and their emission coefficient was obtained. In most cases, the reports of the European Environmental Protection Organization and the American Environmental Protection Organization and, in limited cases, the Australian Environmental Protection Organization have been used to determine the emission coefficient. The choice of the type of standard depends a lot on the compatibility of the technology of that country with the technology of the industry used in Iran, as well as the information on the activity rate of trades and industries. It is possible that the emission coefficient proposed in the standard is based on the production rate of the trade unit or based on the type and fuel. To be consumed since the accuracy of fuel consumption information is more, it has been tried to use the emission coefficients based on fuel consumption. The European Environmental Protection Organization expresses more reliance on used fuel. In cases where the diffusion coefficient has not been established in these standards, other standards or authoritative reports and articles have been used. Regarding the selection of standards, depending on the type of trade and industrial units, the necessary explanations are given in the sections of the report related to each class of trade. Despite the accuracy used in obtaining the data of production, activity level, fuel consumption, and pollution emission coefficient, the list of pollutant emission of classes is error-free. It has been tried that this project for different classes is aware of it, and the environment is shared to have the least error. The more the percentage of pollution of a certain class increases, the more accurate the information will be. Since the information on the activity rate of some trade units is not available or there may be a large error in their collection, their pollution emission rate is calculated based on their fuel consumption. The standards of environmental organizations have stated the emission coefficient of many small industries based on the amount of consumption and type of fuel. This part is titled as small burns.

After determining the emission coefficient and activity rate of trade and industrial units, their emission rates are calculated from the following equation:

$$E = A \times EF \times (1 - ER/100) \tag{1}$$

In the above equation, E is the amount of pollutant emission, A is the activity rate of the industrial unit,

EF is the emission coefficient (the amount of emitted pollutant mass per amount of production product or activity rate), and ER is the overall percentage of low emission, which if the systems are not used, the pollutant reduction of this value is zero. The emission rate has been proposed for two hot and cold half of the year. The warm half-year is considered from the first of April to the end of September, and the cold half-year is considered from the first of October to the end of March. In principle, the amount of activity of trade and industrial units exists throughout the year, and both hot and cold half-years have similar pollution emission rates. In some cases, with fuel consumption in different half-years, the pollution emission rates are separated in these two half-years.

3 Summary of the Publication List Preparation Method

In the diagram of Fig. 2, the details of the process of preparing the publication list of small industrial units of Isfahan City are shown.

4 Result and Discussion

Table 1 shows the descriptive statistics of different gaseous pollutants and different units that studied in this research. In Table 2, ANOVA of different gaseous pollutants production values (kg/year) in different units are summarized. Based on the result of ANOVA table, homogenous groups of units in the form of different subsets in Table 3 have been indicated. Also for better understanding of the result, different industrial and activity units with statistical code in Table 4 are explained. In Figs. 3, 4, 5, and 6, values of gaseous pollutants in different industrial and non-industrial units of Isfahan City have been depicted.

Homogenous subsets with same amount of emission using statistical analysis are as follows:

4.1 Non-Methane Volatile Organic Compounds Units

Based on statistical analysis and grouping methods (Table 4), non-methane volatile organic compound units include in two subsets. Subset 1—covering all

Fig. 2 Flow chart of research process and algorithm used in study
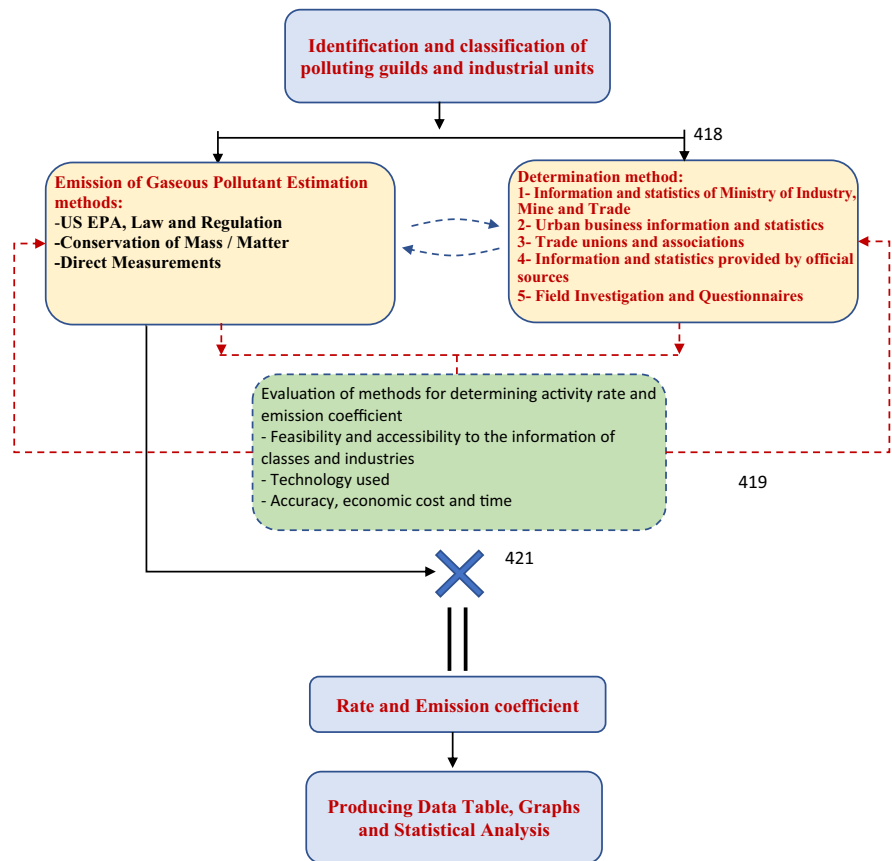
studied unit except unit of 35 that is evaporation of gasoline in gas stations (ordinary and super gasoline).

4.2 CH4-Producing Units

This kind of gaseous pollutants belongs two subsets of effective units. In subset 2, processes of digestion of human (29) placed and other units placed in subset 1.

4.3 VOC-Producing Units

Units of garbage center (23) and small burns unit (30) statistically produced different amounts of VOC and placed in two subsets of 2 and 3, and other units placed in subset 1.

4.4 PM-Producing Units

Animal and poultry feed production factories (14) produce different amounts of PM gaseous pollutant than other industrial and active units in Isfahan City.

4.5 NH3-Producing Units

Processes of digestion of human (29) stay on different subset from other studied gaseous pollutant units considering NH3-producing units.

4.6 PM2.5-Producing Units

Units of traditional sandblasting (11), residue of construction debris (24), and burning garden waste outdoors (27) stay of different subset (1–3) considering PM2.5-producing activities from other studied units.

4.7 PM10-Producing Units

In this study, PM10-producing units form eight different subsets in which building stone (3), gas consumption in the industrial areas of Isfahan (34), livestock units of Isfahan (28), and small burns (30) placed in same subset. Coal consumption (31),

Table 1 Descriptive statistics of different gaseous pollutants under examination

	N	Range	Minimum	Maximum	Sum	Mean		Std. deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. error	Statistic	Statistic	Statistic	Std. error	Statistic	Std. error
Non-methane volatile organic compounds	35	2,143,000.00	0.00	2,143,000.00	2,143,000.00	61,228.57	61,228.57	362,233.11	131,212,828,571.43	5.92	0.40	35.00	0.78
CH	35	49,614,300.00	0.00	49,614,300.00	50,314,300.00	1,437,551.43	1,417,104.21	8,383,701.57	70,286,452,077,865.50	5.91	0.40	34.98	0.78
VOC	35	620,000.00	0.00	620,000.00	863,827.00	24,680.77	18,840.71	111,463.16	12,424,035,127.89	4.98	0.40	25.80	0.78
PM	35	31,506.00	0.00	31,506.00	31,506.00	900.17	900.17	5325.49	28,360,801.03	5.92	0.40	35.00	0.78
NH3	35	2,183,029.00	0.00	2,183,029.00	2,224,292.00	63,551.20	62,343.13	368,826.95	136,033,316,626.46	5.91	0.40	34.99	0.78
$PM_{2.5}$	35	988,982.00	0.00	988,982.00	1,541,810.00	44,051.71	29,689.69	175,646.57	30,851,718,556.39	5.01	0.40	26.45	0.78
PM_{10}	35	1,013,235.00	0.00	1,013,235.00	2,462,254.00	70,350.11	35,500.55	210,024.07	44,110,109,379.75	3.84	0.40	14.71	0.78
TSP	35	12,079,537.00	0.00	12,079,537.00	14,949,308.00	427,123.09	344,976.74	2,040,909.92	4,165,313,319,067.79	5.80	0.40	34.01	0.78
NMVOCs	35	8,348,699.00	0.00	8,348,699.00	10,386,631.00	296,760.89	238,840.88	1,413,001.67	1,996,573,725,937.69	5.77	0.40	33.73	0.78
SO_x	35	722,540.00	0.00	722,540.00	1,009,718.00	28,849.09	20,951.72	123,952.05	15,364,111,251.02	5.50	0.40	31.19	0.78
CO	35	170,00000.00	0.00	170,00000.00	25,543,704.00	729,820.11	500,213.79	2,959,304.68	8,757,484,218,159.81	5.26	0.40	28.92	0.78
NO_x	35	620,357.00	0.00	620,357.00	1,922,379.00	54,925.11	23,341.39	138,089.54	19,068,720,157.75	3.35	0.40	11.06	0.78
Valid N (listwise)	35												

Table 2 ANOVA of different gaseous pollutants in study units

		Sum of squares	df	Mean square	*F*	Sig
H4	Between groups	14,868,998,193,157,800	34	437,323,476,269,347	332.511	0.000
	Within groups	230,162,395,000,407	175	1,315,213,685,717		
	Total	15,099,160,588,158,200	209			
Non-methane volatile organic compounds	Between groups	27,757,885,812,565	34	816,408,406,252	332.787	0.000
	Within groups	429,317,440,683	175	2,453,242,518		
	Total	28,187,203,253,248	209			
VOC	Between groups	2,628,286,712,164	34	77,302,550,358	326.116	0.000
	Within groups	41,482,002,930	175	237,040,017		
	Total	2,669,768,715,094	209			
PM	Between groups	5,999,708,001	34	176,462,000	332.737	0.000
	Within groups	92,808,719	175	530,336		
	Total	6,092,516,720	209			
NH3	Between groups	28,777,652,200,199	34	846,401,535,300	332.416	0.000
	Within groups	445,587,051,202	175	2,546,211,721		
	Total	29,223,239,251,401	209			
PM2.5	Between groups	6,526,638,921,453	34	191,959,968,278	321.742	0.000
	Within groups	104,409,674,356	175	596,626,711		
	Total	6,631,048,595,809	209			
PM10	Between groups	9,331,403,970,570	34	274,453,057,958	307.047	0.000
	Within groups	156,423,328,453	175	893,847,591		
	Total	9,487,827,299,023	209			
TSP	Between groups	881,165,914,594,120	34	25,916,644,546,886	327.793	0.000
	Within groups	13,836,224,972,004	175	79,064,142,697		
	Total	895,002,139,566,124	209			
NMVOCs	Between groups	422,372,247,635,209	34	12,422,713,165,741	327.693	0.000
	Within groups	6,634,186,832,332	175	37,909,639,042		
	Total	429,006,434,467,540	209			
Sox	Between groups	3,250,256,420,481	34	95,595,777,073	324.482	0.000
	Within groups	51,556,815,537	175	294,610,374		
	Total	3,301,813,236,018	209			
CO	Between groups	1,852,633,236,595,120	34	54,489,212,841,033	322.391	0.000
	Within groups	29,577,825,544,459	175	169,016,145,968		
	Total	1,882,211,062,139,580	209			
Nox	Between groups	4,033,959,968,411	34	118,645,881,424	294.598	0.000
	Within groups	70,479,220,824	175	402,738,405		
	Total	4,104,439,189,235	209			

constructions of the urban areas of Isfahan (21), animal and poultry feed production factories (14), and paper and pulp industries (12) grouped in one subset. Production of asphalt and road asphalt (7), constructions of the urban areas of Isfahan (21), animal and poultry feed production factories (14), and paper and pulp industries (12) grouped also in another subset. Units of traditional sandblasting (11) and suspended particles of Isfahan flour factories (15) stay in another subset. Traditional castings (9), residue of construction debris (24), and burning garden waste outdoors (27) stay of different subsets.

Table 3 Different industrial and non-industrial units suspected to gaseous pollutant in Esfahan City

Row	Kind of activity	Unit no	Code in Statistical Analysis
1	Gold making	801	1
2	Textile	923	2
3	Building stone	377	3
4	Plaster production	87	4
5	Glass production	15	5
6	Cutting wood	1830	6
7	Production of asphalt and road asphalt	3	7
8	Brick kilns	313	8
9	Traditional castings	103	9
10	Industrial foundries	40	10
11	Traditional sandblasting	20	11
12	Paper and pulp industries	37	12
13	Chemical industries, synthetic textiles, and Pharmaceutical Industries	149	13
14	Animal and poultry feed production factories	7	14
15	Suspended particles of Isfahan flour factories	9	15
16	The inner city terminals of Isfahan	10	16
17	Isfahan suburban terminals	5	17
18	Small scale power generators	16	18
19	Dry cleaners	267	19
20	Gaseous pollutants of bakeries	947	20
21	Constructions of the urban areas of Isfahan	2,905,953	21
22	Compost	1	22
23	Garbage center	2	23
24	Residue of construction debris	2	24
25	Waste Water Treatment units	5	25
26	Coal production furnaces	1000	26
27	Burning garden waste outdoors	3000 (ha)	27
28	Livestock units of Isfahan	700	28
29	Digestion of humans	1,984,572	29
30	Small burns	2900	30
31	Coal consumption	5 kg	31
32	Tobacco use	180 (g/year)	32
33	Gas consumption in residential, commercial Buildings, Public Places and Other Industries	3,000,000	33
34	Gas consumption in the industrial areas of Isfahan	10	34
35	Non-methane volatile organic compounds resulting from the evaporation of gasoline in gas stations (ordinary and super gasoline)	69	35

4.8 TSP-Producing Units

Subset of burning garden waste outdoors (27) and coal production furnaces (26) and subset of brick kilns (8), two different subset could be observed in TSP-producing units in Isfahan City based on statistical analysis.

Table 4 Grouping different industrial units suspected to gaseous pollutants

Gaseous pollutants	Alpha level	Subset 1	Subset 2	Subset 3	Subset 4	Subset 5	Subset 6	Subset 7	Subset 8	Subset 9
Non-methane volatile organic compounds	0.05	1–34	35							
CH4	0.06	1–28, 30–35	29							
VOC	0.06	All except 30–23	30	23						
PM	0.06	All except 14	14							
NH3	0.07	All except 29	29							
PM2.5	0.08	All except 11–24–27	11	24	27					
PM10	0.08	All except subset (2–9)	30–28–34–3	31–14–12–21	14–12–21–7	15–11	9	24	27	
TSP	0.06	All–26–27–8	26–27	8						
NMVOCs	0.06	All except 26–13	26	13						
Nox	0.08	All except subset (2–9)	10–7–31	31–5–12	5–12–27–20	27–20–26	30	8	34	33
Sox	0.08	All except subset (2–5)	12.00	5.00	30	27				
CO	0.08	All except subset (2–5)	26	8	27	23				

4.9 NMVOCs-Producing Units

Coal production furnaces (26) and synthetic textiles and pharmaceutical industries (13) behave different from other units considering NMVOCs production.

4.10 NOx-Producing Units

Nine subsets could be recognized considering **NOx** production. Production of asphalt and road asphalt (7), industrial foundries (10), and coal consumption (31) units placed in the same subset. Glass production (5), paper and pulp industries (12), and coal consumption (31) form another subset. Glass production (5), paper and pulp industries (12), subset of burning garden waste outdoors (27), and gaseous pollutants of bakeries (20) placed in the same subset.

Coal production furnaces (26), subset of burning garden waste outdoors (27), and gaseous pollutants of bakeries (20) form another subset. Four different subsets belong to brick kilns (8), small burns (30), gas consumption in residential, commercial buildings, public places, and other industries (33), and gas consumption in the industrial areas of Isfahan (34).

4.11 SOX-Producing Units

Small burns (30), burning garden waste outdoors (27), glass production (5), and paper and pulp industries (12), are for different subsets considering SOX-production from other units.

4.12 Co-Producing Units

Brick kilns (8), garbage center (23), coal production furnaces (26), and burning garden waste outdoors (27) are different subsets considering co-production.

4.13 Prioritizing Source of Emission of Gaseous Pollutants

Based on average data of emission rate of different sources of gaseous pollutant, prioritizing carried out as Table 5. In this table, there are five main sources of gaseous pollutant including chemical industries, synthetic textiles and pharmaceutical industries (7.36%), burning garden waste outdoors (7.68), brick kilns (12.43%), garbage center (15.78), and digestion of humans (45.68).

Fig. 3 Values of VOC, CO, and CH4 in different industrial units of Isfahan City
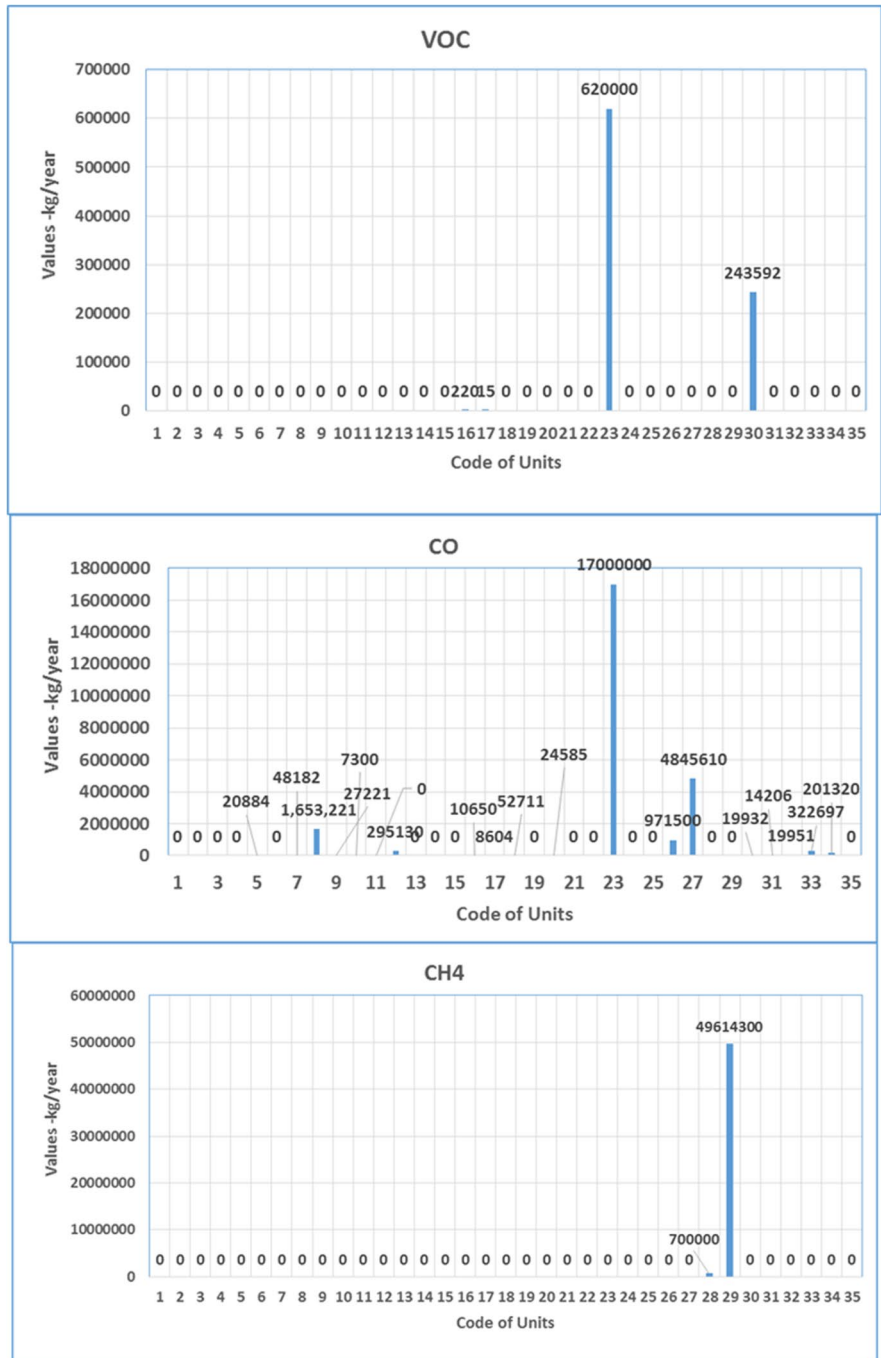
Other 30 sources contribute less than 3%. In Fig. 7, percent of contribution of each gaseous pollutant in total air pollution of Isfahan City depicted. Based on this graphs, it is obvious that CH4 only contribute 44% in gas emissions of Isfahan City followed by CO (23%), TSP (13%), NMVOCS (9%), PM10 (2.17%), NH3 (1.96%), non-methane volatile organic compounds (1.89%), Nox (1.70%), PM2.5 (1.36%), SOx (0.89%), VOC (0.76%), PM (0.03%), methane (CH4) one of the primary component of natural gas, and greenhouse gas (GHG); so, its presence in the atmosphere affects the earth's temperature and

Fig. 4 Values of PM10, NH3, and non-methane volatile organic compound units, in different industrial units of Isfahan City
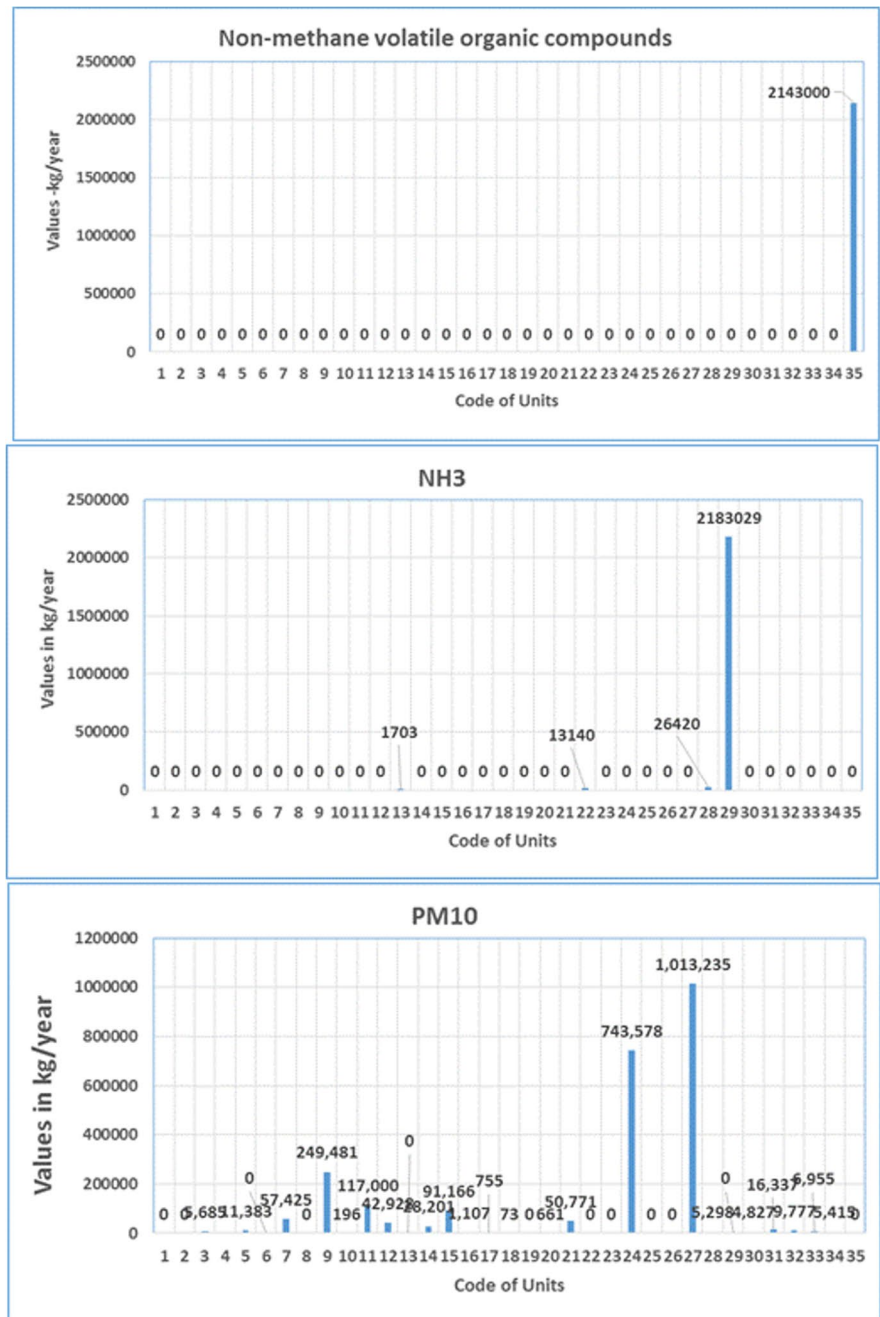
climate system. It is emitted from human-influenced or anthropogenic sources as well as natural sources. Anthropogenic emission sources in this study include digestion of human (98%) and livestock unit of Isfahan (~2%). Because methane is both a powerful greenhouse gas and short-lived compared to carbon dioxide, achieving significant reductions would have a rapid and significant effect on atmospheric warming potential. Co-producing guilds include garbage center (66.5%), burning garden waste outdoors (18.97), brick kilns (6.47%), and coal production furnaces (3.8%), and the remained percentage belong to other studied guilds. Considering TSP criteria, brick kilns (80.80), burning garden waste outdoors (7.10), coal

Fig. 5 Values of PM2.5, NMVOCs, and SOx in different industrial units of Isfahan City
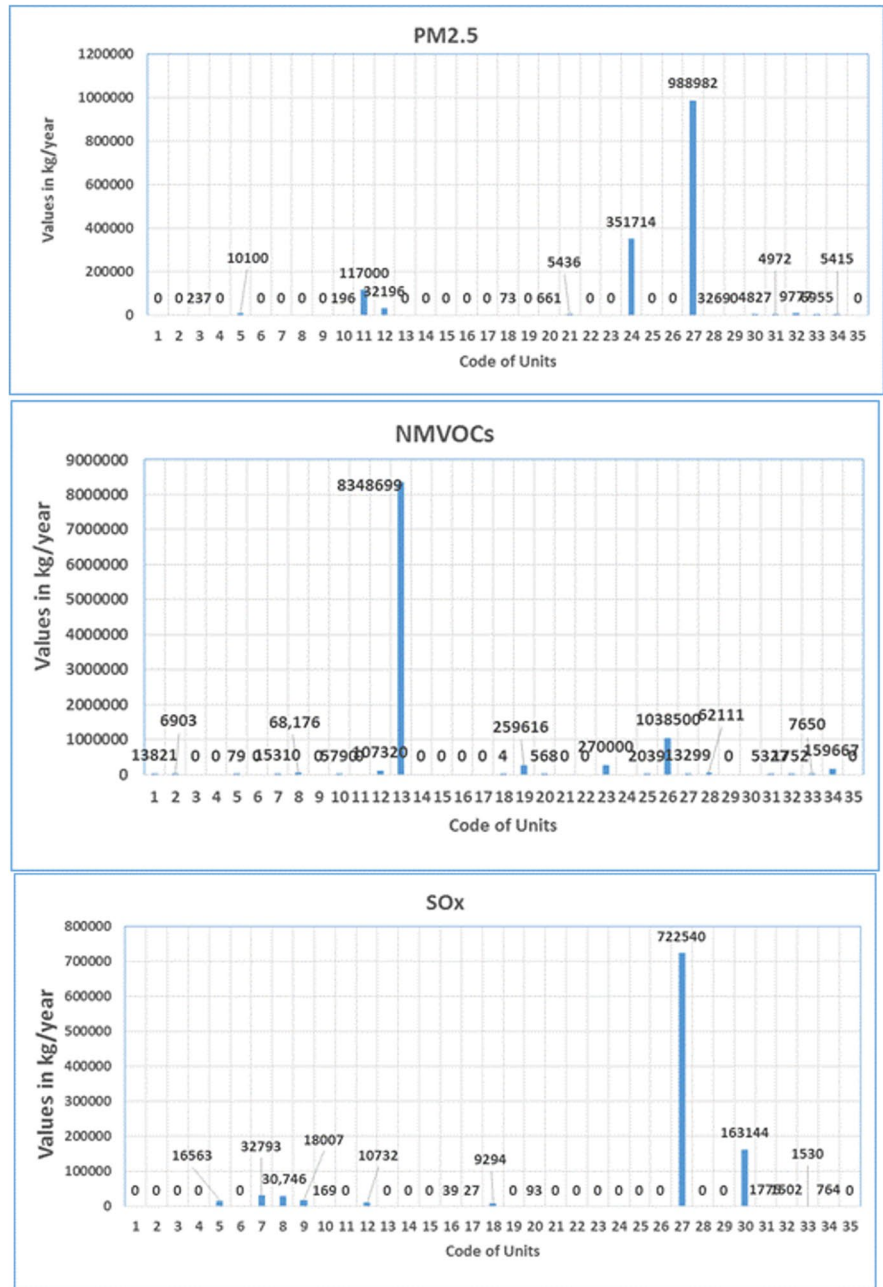
production furnaces (6.05), traditional sandblasting (1.63), production of asphalt and road asphalt (1.30), suspended particles of Isfahan flour factories (1.22), cutting wood (0.64), paper and pulp industries (0.36), plaster production (0.35), coal consumption (0.11), Building stone (0.09), glass production (0.08), and livestock units of Isfahan (0.08), tobacco use (0.07), gas consumption in residential, commercial buildings, public places, and other industries (0.05), gas consumption in the industrial areas of Isfahan (0.04), and small burns (0.03) contribute in its production. NMVOCs-producing sources include chemical industries, synthetic textiles and pharmaceutical industries (80.38%), coal production furnaces (10.00%), garbage

Fig. 6 Values of PM, NOx, and TSP in different industrial units of Isfahan City
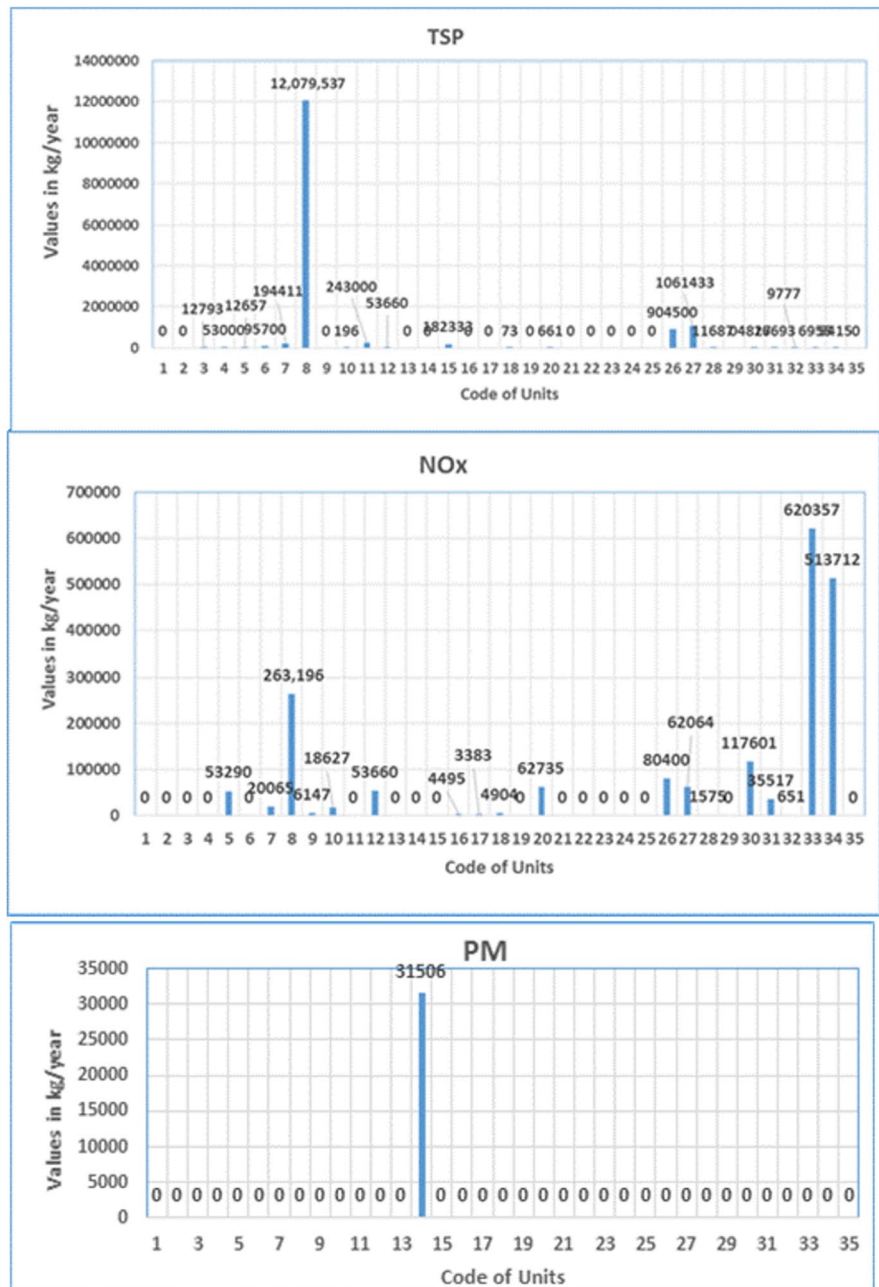
center (2.60%), air pollution of dry cleaners (2.50%), gas consumption in the industrial areas of Isfahan (1.54%), paper and pulp industries (1.03%), brick kilns (0.66%), livestock units of Isfahan (0.60%), production of asphalt and road asphalt (0.15%), gold making (0.13%), burning garden waste outdoors (0.13%), gas consumption in residential, commercial buildings, public places, and other industries (0.07%), textile (0.07%), industrial foundries (0.06%), coal consumption (0.05%), refineries of Isfahan houses (0.02%), tobacco use (0.02%), and gaseous pollutants of bakeries (0.01%) in the Isfahan City of Iran. The studied gases mainly have a large share in the total emission of gas emissions in Isfahan. The rest of the gases had a small share in the total emission, the details of which are given in the relevant graphs and tables.

Table 5 Percent of contribution of each sources in total gaseous pollutant

Description of units	% of total gaseous pollutant
Waste water treatment units	0.00
Textile	0.01
Isfahan suburban terminals	0.01
Compost	0.01
Gold making	0.01
The inner city terminals of Isfahan	0.01
Building stone	0.02
Industrial foundries	0.03
Plaster production	0.05
Tobacco use	0.05
Constructions of the urban areas of Isfahan	0.05
Animal and poultry feed production factories	0.05
Small scale power generators	0.06
Gaseous pollutants of bakeries	0.08
Coal consumption	0.08
Cutting wood	0.08
Glass production	0.11
Dry cleaners	0.23
Flour factories	0.24
Traditional castings	0.27
Production of asphalt and road asphalt	0.32
Traditional sandblasting	0.42
Small burns	0.49
Paper and pulp industries	0.53
Livestock units of Isfahan	0.71
Gas consumption in the industrial areas of Isfahan	0.79
Gas consumption in residential, commercial buildings, public places and other industries	0.86
Residue of construction debris	0.97
Non-methane volatile organic compounds resulting from the evaporation of gasoline in gas stations (ordinary and super gasoline)	1.89
Coal production furnaces	2.64
Chemical industries, synthetic textiles and pharmaceutical industries	7.36
Burning garden waste outdoors	7.68
Brick kilns	12.43
Garbage center	15.78
Digestion of humans	45.68

5 Conclusion

Due to its harmful consequences, air pollution has become one of the most tangible environmental problems of urbanized area. Air pollutant emissions come from various sources, including the asphalt industry, motor vehicles, power plants, industry, and natural events such as forest fires and dust storms. Overall, air pollution arises from a wide range of natural and anthropogenic sources, with emissions of primary and secondary pollutants affecting human health and the environment. This paper discusses the issue of air pollution in urban areas, particularly in Isfahan City of Iran and explains that

air pollution is caused by chemical substances, dust, or biological agents, and can be natural or artificial. The paper emphasizes the importance of identifying and researching the sources of air pollution in different sectors, such as industries, residential and commercial buildings, and small industries, to effectively manage air pollution in urban areas. Based on average data of emission rate of different sources of gaseous pollutant, prioritizing carried out as Table 5. In this table, there are five main sources of gaseous pollutant including chemical industries, synthetic textiles, and pharmaceutical industries (7.36%), burning garden waste outdoors (7.68), brick kilns (12.43%), garbage center (15.78), and digestion of humans (45.68). Other 30 sources contribute less than 3%. Based on the results, it is obvious that CH_4 only contributes 44% in gas emissions of Isfahan City followed by CO (23%), TSP (13%), NMVOCS (9%), PM10 (2.17%), NH3 (1.96%), Non-methane volatile organic compounds (1.89%), Nox (1.70%), PM2.5 (1.36%), SOx (0.89%), VOC (0.76%), and PM (0.03%).

The paper provides a comprehensive study of air pollutant emissions from different sources in Isfahan City of Iran, which can help in designing and planning effective measures to manage air pollution in the city. Also it highlights the harmful consequences of air pollution on human health and the environment, which can create awareness among policymakers and the general public about the need for taking action to reduce air pollution. The results identify the major sources of air pollution in the city, such as industries, residential and commercial buildings, and transportation, which can help in targeting specific sectors for reducing emissions. Importance of conducting regular monitoring and measurement of air pollutants can help in tracking the progress of air pollution reduction measures and making necessary adjustments to achieve the desired outcomes emphasized in this paper.

Air pollution is a significant environmental problem in urban areas and can have harmful consequences on human health. The increase in sulfur dioxide, suspended particles, and carbon monoxide pollutants can aggravate cardiovascular, vascular, and pulmonary diseases. Air pollution can be caused by natural sources such as volcanic activity or artificial sources such as vehicles and factories. To effectively manage air pollution, it is essential to determine the contribution of each pollutant source in the country, regions, and different urbanized areas. The activity of industries, residential and commercial buildings, small industries, and other air-polluting industries, if categorized and researched together, could be effective in crisis management in urbanized areas.

5.1 Limitation of the Research

The paper does not explicitly mention any future works or recommendations for further research. However, some potential areas for future research could include conducting more detailed studies on the health effects of air pollution in Isfahan City, including the effects on vulnerable populations such as children and the elderly, investigating the effectiveness of previous policies or interventions aimed at reducing air pollution in Isfahan City and identifying areas for improvement, and examining the potential for renewable energy sources and other sustainable practices to reduce air pollution in Isfahan City and other urban areas in Iran.

Declarations

Conflict of Interest   The authors declare no competing interests.

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