ISSN: 2181-8150 Vol.119, №4 (2026)
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10.63241/AKHVvol119y2026iss4m12

TREND ANALYSIS OF NITROGEN OXIDE (NO) AND NITROGEN DIOXIDE (NO_2) CONCENTRATION IN TASHKENT CITY (BASED ON MANN-KENDALL TEST)

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Abstract. In this study, from January 2012 to December 2022, the long-term average values of the concentration of Nitrogen oxide (NO) and Nitrogen dioxide (NO_2) in the air of the city of Tashkent were analyzed using the MS Excel program. The dynamic of change was statistically analyzed based on the Mann-Kendall trend test. According to the result of the trend test, it was found that the significant change was in October (Z=2.26), these results were respectively for NO (Z=2.02) and for NO_2 (Z=2.26). On the basis of these results, the necessary conclusions were drawn regarding the monitoring of atmospheric air in the future.

Keywords: Atmospheric air, air pollutants, Nitrogen oxide, Nitrogen dioxide, statistical analysis, Mann-Kendall test, Sen's slope estimator, Tashkent city.

Annotatsiya. Ushbu tadqiqotda, 2012-yil yanvaridan 2022-yil dekabrigacha, Toshkent shahri havosidagi azot oksidi (NO) va azot dioksidi (NO2) konsentratsiyasining uzoq muddatli o'rtacha qiymatlari MS Excel dasturi yordamida tahlil qilindi. O'zgarish dinamikasi Mann-Kendall trend testi asosida statistik tahlil qilindi. Trend testi natijalariga ko'ra, sezilarli o'zgarish oktyabr oyida (Z=2.26) bo'lganligi aniqlandi, bu natijalar mos ravishda NO (Z=2.02) va NO2 (Z=2.26) uchun edi. Ushbu natijalar asosida kelajakda atmosfera havosini monitoring qilish bo'yicha zarur xulosalar chiqarildi.

Kalit so'zlar: Atmosfera havosi, havo ifloslantiruvchi moddalar, Azot oksidi, Azot dioksidi, statistik tahlil, Mann-Kendall testi, Senning qiyalik baholovchisi, Toshkent shahri.

Аннотация. В данном исследовании с января 2012 года по декабрь 2022 года были проанализированы долгосрочные средние значения концентрации оксида азота (NO) и диоксида азота (NO_2) в воздухе города Ташкента с использованием программы MS Excel. Динамика изменений была статистически проанализирована на основе критерия тренда Манна-Кендалла. По результатам критерия тренда было установлено, что значительные изменения произошли в октябре (Z=2,26), а также для NO (Z=2,02) и NO_2

(Z=2,26). На основании этих результатов были сделаны необходимые выводы относительно мониторинга атмосферного воздуха в будущем.

Ключевые слова: Атмосферный воздух, загрязняющие вещества в воздухе, оксид азота, диоксид азота, статистический анализ, критерий Манна-Кендалла, оценка наклона Сена, город Ташкент.

INTRODUCTION

Urbanization and industrialization have led to a significant increase in air pollution in cities around the world, with nitrogen dioxide (NO_2) and nitrogen oxides (NO) being the most prevalent pollutants. These nitrogen oxides are mainly emitted into the air from vehicle traffic, industrial activities and fossil fuel combustion, and pose a serious threat to the environment and human health. Identifying trends in NO and NO_2 concentrations in urban environments is essential for developing effective mitigation strategies and ensuring sustainable urban development. Recent studies highlight the importance of long-term monitoring and trend analysis and reveal the dynamic nature of nitrogen oxide pollution in cities. For example, in major cities such as London, NO_2 levels have decreased significantly during COVID-19 lockdowns, indicating the direct impact of human activities on air quality [1]. These findings further support the potential for policy interventions and urban planning to reduce nitrogen emissions [2]. In addition to short-term fluctuations, long-term trends in NO and NO_2 concentrations provide valuable insights into the effectiveness of air quality management and ongoing challenges related to urbanization [3]. Different trends are observed in different regions: in some cities, nitrogen oxides levels have decreased due to stricter emission standards, while in others, concentrations remain high due to urbanization and lack of adequate infrastructure [4]. The spatial distribution of nitrogen oxides within a city is often uneven, with high concentrations usually detected near major roads and industrial zones, leading to disproportionate exposure among urban residents [5]. The chronic health effects of nitrogen oxides, including respiratory and cardiovascular diseases, require monitoring and response to these pollutants in urban settings [6]. Given the important role of nitrogen oxides in urban air pollution, this study aimed to analyze trends in NO and NO_2 concentrations in Tashkent city. The study will examine the factors influencing these trends, their implications for public health and environmental policy. Using the latest data analysis and advanced statistical methods, it will enable the development of future strategies for urban air quality management.

Literature analysis and methods.

Research area. Tashkent is the capital and largest city of Uzbekistan, located in the northeastern part of the country, near the border with Kazakhstan. The city is located at an altitude of 455 m above sea level, in the Tashkent Oasis, in the valley of the Chirchik River, a tributary of the Syrdarya.

Climate. Tashkent has a continental climate, with hot summers and cold winters. The city has a semi-arid climate, with significant seasonal variations in temperature and precipitation. Summers in Tashkent are hot, with temperatures often exceeding 35–37 °C in July and August . Winters are cold, with temperatures often falling below freezing, especially in January. The average annual temperature is about 15–17 ° C.

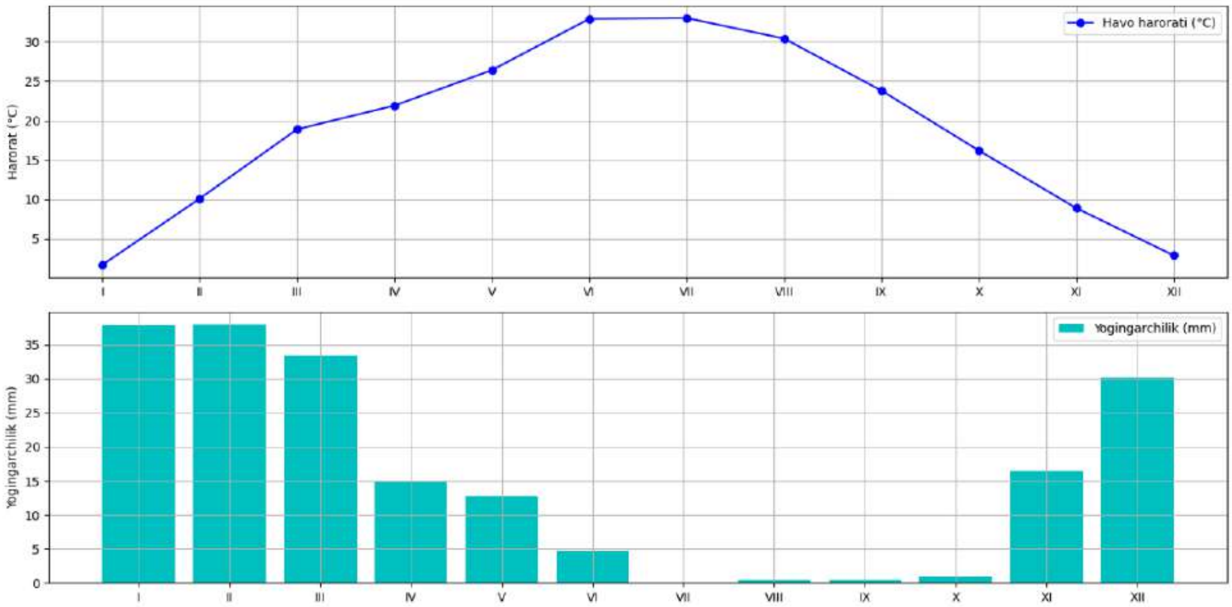

Figure 1. Multi-year average values of air temperature and precipitation

Precipitation in Tashkent is moderate, with most of it falling in spring and autumn. The city receives an average of 450–500 mm of precipitation per year (Figure 2). Snowfall is common in winter.

Data collection and analysis. Multi-year air quality and meteorological parameters data observed in the study area (2012–2022) were provided by the Agency of the Hydrometeorological Service of the Republic of Uzbekistan and underwent initial processing in MS Excel. The prepared data were statistically analyzed using the Mann-Kendall trend test, which allowed us to identify key changes and long-term trends, and to assess the changes in urban air quality and meteorological parameters over time.

Mann-Kendall trend test . This hypothesis test is a nonparametric, rank-based method used to assess the presence of trends in time series data. In it, the data are arranged in time, and then each data point is compared with the other points in the sequence. In this way, each point is compared with all subsequent data points, and trends of increase, decrease, or stability over time are determined. This method is also effective when working with uncertain or uneven data, since it does not depend on the distribution of the data.

$$S \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn = (\chi_j - \chi_i)$$

Here, χ_j and χ_i are the consecutive data values, and n is the number of data used.

$$sgn(\theta) = \begin{cases} +1, & if\ \theta > 0 \\ 0, & if\ \theta = 0 \\ -1, & if\ \theta < 0 \end{cases}$$

The Mann-Kendall test has two important parameters in determining trend:

Significance level – indicates how statistically reliable the test is in detecting the presence of a trend. This parameter is used to assess the strength and significance of the trend. Slope estimate (Sen's slope) – indicates the direction and magnitude of the trend, that is, the rate at which values increase or decrease over time. If there are independent and identically distributed random variables with no associated data values, the expected value for the Mann-Kendall test is $E\ (\ S\ )=0$

E(S)=0. This means that if there is no trend in the data, the test statistic S will have a mean of zero;

$$\text{Var (S)} = \frac{n\ (n-1)(2n+5)}{18}$$

When some data values are linked, an adjustment is made to Var(S):

$$\text{Var}(\ S\ ) = \frac{n\ (n-1)(2n+5) - \sum_{i=1}^{n} t_i\ (i)(i-1(2i+5)}{18}$$

Here ti denotes the number of degree ties. Test statistic for n greater than 10.

$$Z_S = \begin{cases} \frac{S-1}{[Var(S)]^{0.5'}} & if\ S > 0, \\ , & if\ S = 0, \\ \frac{S+1}{[Var(S)]^{0.5'}} & if\ S < 0; \end{cases}$$

Z_s follows the standard normal distribution.

SEN'S slope estimator. Using the Mann-Kendall test, the magnitude of the trend slope can be calculated as follows:

$$\beta = Median\ (\frac{\chi_j - \chi_i}{j-i})$$

Here χ_j and χ_i are the data values at time j and i (j>i), respectively. The median of these N values of β_1 is expressed as the Sen's slope estimator, which is given by

$$Q_i = \begin{cases} & \beta_{N+1)/2} & when\ N\ is\ odd \\ \frac{1}{2} & (\frac{\beta N}{2} + \frac{\beta(N+2)}{2} & \text{when N is even} \end{cases}$$

A positive value of Q indicates an upward trend, while a negative value indicates a downward trend.

RESULTS AND DISCUSSION

The analyzed data show that the average values of nitrogen dioxide (NO_2) concentrations in Tashkent city from January 2012 to December 2022 have changed, reaching from 0.038 mg/m^3 in 2013 to 0.055 mg/m^3 in 2022 (Figure 3). The recommended REM value for nitrogen dioxide for the city is 0.04 mg/m^3. These results indicate that the level of NO_2 in the city atmosphere has been increasing for a long time and is above the current regulatory limit, which poses a threat to air quality and public health.

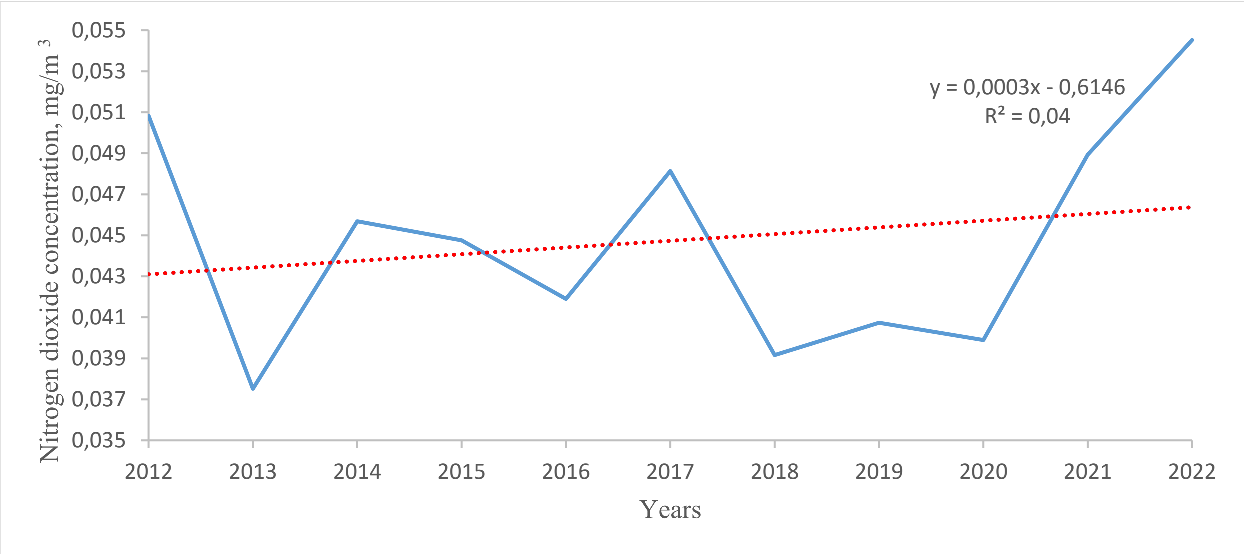

Figure 3. Dynamics of long-term average values of nitrogen dioxide concentration

According to the analysis results, the highest value of nitrogen dioxide (NO_2) concentration was recorded in July 2012 at 0.068 mg/m³, and the lowest value was recorded in October 2013 at 0.015 mg/m³. A multi-year monthly and annual statistical analysis of nitrogen oxide (NO) concentration showed the following data:

The recommended REM value for NO is 0.06 mg/m³.

The average value of NO during the studied period was 0.025 mg/m³.

The multi-year average values varied from 0.014 mg/m³ (2020) to 0.052 mg/m³ (2022). In general, the average values of NO concentrations did not exceed the permissible regulatory limit. These results indicate that, although NO_2 levels in Tashkent city exceeded the recommended norm in some periods, NO concentrations are generally within safe limits (Figure 4).

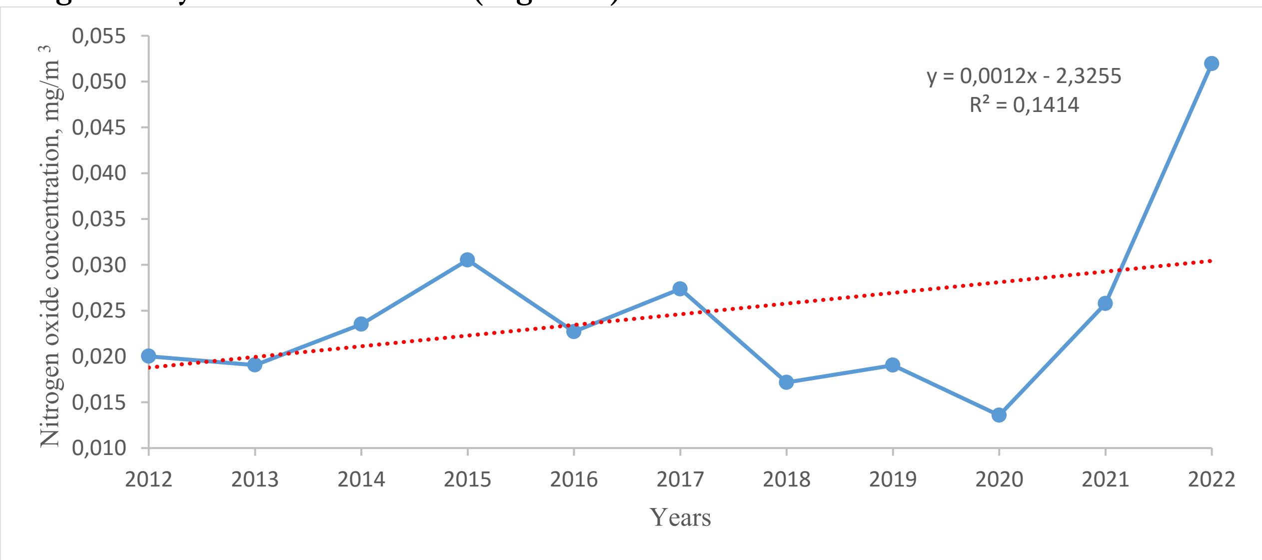

Figure 4. Dynamics of long-term average values of nitrogen oxide concentrations

According to the analysis results, the highest value of nitrogen oxide (NO) concentration was recorded in June 2022 at 0.07 mg/m^3, and the lowest value was recorded in April 2020 at 0.01 mg/m^3. These values indicate seasonal and annual variations in NO levels in Tashkent city: maximum levels are usually observed in the summer months, and minimum levels in the spring months. This confirms that transport activities and meteorological conditions directly affect NO concentrations.

Trend analysis of nitrogen oxide concentrations using the Mann-Kendall trend test. Nitrogen dioxide (NO2) and nitric oxide (NO) concentrations were analyzed by month for the period 2012-2022 using the Mann-Kendall trend test. The NO2 concentration (Z value) showed an increase in September (1.87), October (2.26), November (1.87), and December (2.34) (Table 1).

Table 1

Mann-Kendall trend statistics results of monthly analysis of NO $_2$ and NO concentrations during the study period

Para-meters	Trend test	Side	Feb	March	Apr	May	June	July	Aug	You	Oct	Noe	Dec
Nitrogen dioxide	Z-value	0.93	1.56	0.86	-0.7	-0.6	-1.1	0.00	-0.2	1.87	2.26	1.87	2.34
	Significance									+	*	+	*
	Q value	0.000	0.001	0.001	-0.01	-0.01	-0.01	0.000	-0.01	0.002	0.002	0.001	0.001
Nitric oxide	Z-value	0.00	0.78	-0.2	-0.8	0.31	0.00	0.00	0.23	1.87	2.02	1.40	1.40
	Significance									+	*		
	Q value	0.000	0.001	0.000	-0.01	0.001	0.000	0.000	0.000	0.003	0.001	0.002	0.001

*Note: * trend is significant at α=0.05, + trend is significant at α=0.1.*

According to the results of the analysis, a significant increase in the concentration of nitric oxide (NO) was observed only in September (Z = 1.87) and October (Z = 2.02). If we summarize the analysis of both gases – NO_2 and NO –, it was found that the dynamic increase was especially noticeable in October using the Mann-Kendall trend test. The main reasons for this increase process can be explained as follows:

The arrival of the autumn season and the shedding of leaves from trees, which leads to a decrease in the air filtration capacity. The onset of the cold season, as a result, increases the demand for heating systems and thermal power. A significant increase in fuel consumption by vehicles, especially during periods of high transport activity. Together, these factors contribute to an increase in NO_2 and NO levels in Tashkent during the autumn and winter months.

CONCLUSION

In this study, the Mann-Kendall trend test was used as a reliable statistical approach to identify trends in nitrogen oxide (NO) and nitrogen dioxide (NO_2)

concentrations in Tashkent city. The results of the analysis allowed us to identify significant trends in the data over time, reflecting the impact of anthropogenic activities and environmental policies. If upward trends are observed, this indicates an increase in emission sources associated with urbanization, traffic density, and industrial activities. These results once again confirm the need for continuous monitoring to reduce the negative impact of pollutants on public health and the environment. It would be useful to expand the scope of future studies to include other pollutants and to take into account the effects of seasonal changes and meteorological factors. Overall, the Mann-Kendall trend test is an effective tool for identifying long-term changes in urban air quality, providing valuable insights for environmental management and strategic decision-making.

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