ISSN: 3060-4761
*TerDPI ILMIY XABARNOMASI / SCIENTIFIC BULLETIN OF THE TerSPI / НАУЧНЫЙ ВЕСТНИК ТерГПИ*

# EKOLOGIYA VA ATROF-MUHIT MUHOFAZASI

**(O'zbekiston Respublikasi Prezidentining 2025-yil 15-maydagi 184-son Qarori asosida kiritilgan)**

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## SANOAT FAOLIYATI TA'SIRIDA HIMOYA ZONASIDAGI TUPROQ MUHITINING KISLOTALILIK DARAJASINI MAVSUMIY BAHOLASH

**ANNOTASIYA.** Ushbu ilmiy maqolada sanoat korxonalari faoliyati ta'sirida shakllanadigan himoya zonalaridagi tuproq muhitining kislotalilik darajasining (pH) mavsumiy o'zgarishi o'rganilgan. Tuproq kislotaliligi ekologik barqarorlik, tuproq unumdorligi hamda biologik faollikni belgilovchi muhim ko'rsatkichlardan biri hisoblanadi. Tadqiqot davomida tuproq namunalarining yilning to'rt faslida olinishi va laboratoriya sharoitida pH ko'rsatkichlarining aniqlanishi amalga oshirildi. Olingan natijalar sanoat chiqindilari va atmosfera ifloslantiruvchi moddalarning tuproq muhitining kislotalanishiga sezilarli ta'sir ko'rsatishini ko'rsatdi. Tadqiqot natijalari sanoat hududlarida ekologik monitoringni kuchaytirish va tuproq degradatsiyasining oldini olish uchun ilmiy-amaliy ahamiyatga ega.

**KALIT SO'ZLAR.** *tuproq kislotaliligi, pH ko'rsatkichi, sanoat faoliyati, himoya zonasi, mavsumiy o'zgarish, ekologik monitoring, antropogen ta'sir.*

## СЕЗОННАЯ ОЦЕНКА КИСЛОТНОСТИ ПОЧВЕННОЙ СРЕДЫ В ЗАЩИТНОЙ ЗОНЕ ПОД ВОЗДЕЙСТВИЕМ ПРОМЫШЛЕННОЙ ДЕЯТЕЛЬНОСТИ

**АННОТАЦИЯ.** В данной научной статье рассмотрены сезонные изменения уровня кислотности (pH) почвенной среды в защитных зонах, находящихся под воздействием промышленной деятельности. Кислотность почвы является одним из ключевых показателей экологического состояния, определяющих плодородие почвы и биологическую активность. В ходе исследования проводился отбор почвенных проб в течение всех четырех сезонов года с последующим лабораторным определением значений pH. Полученные результаты свидетельствуют о значительном влиянии промышленных выбросов и атмосферных загрязняющих веществ на процессы закисления почв. Результаты исследования имеют важное научно-практическое значение для совершенствования экологического мониторинга и предотвращения деградации почв в промышленных районах.

**КЛЮЧЕВЫЕ СЛОВА.** *кислотность почвы, показатель pH, промышленная деятельность, защитная зона, сезонные изменения, экологический мониторинг, антропогенное воздействие.*

## SEASONAL ASSESSMENT OF THE ACIDITY LEVEL OF THE SOIL ENVIRONMENT IN THE PROTECTION ZONE UNDER THE INFLUENCE OF INDUSTRIAL ACTIVITY

**ABSTRACT.** Soil acidity is one of the key indicators of environmental quality in industrial areas, as it directly affects soil fertility, biological activity, and ecosystem sustainability. Industrial emissions, including acidic gases and particulate matter, significantly alter the physicochemical properties of soils located in protection zones surrounding industrial facilities. This study aims to assess the seasonal variation of soil acidity (pH) in a protection zone influenced by industrial activity. Soil samples were collected during four seasons (spring, summer, autumn, and winter) from different distances within the protection zone. The pH values were determined using a potentiometric method under laboratory conditions. The results reveal pronounced seasonal fluctuations in soil acidity, with increased acidification observed during periods of higher precipitation and intensified industrial emissions. The findings highlight the importance of seasonal soil monitoring in industrial regions to prevent soil degradation and ensure environmental safety.

**KEYWORDS.** *soil acidity, pH variation, industrial pollution, protection zone, seasonal assessment, environmental monitoring.*

ISSN: 3060-4761


**INTRODUCTION.** Rapid industrial development has led to increased anthropogenic pressure on natural ecosystems, particularly on soil resources. Soils located in the vicinity of industrial enterprises are exposed to continuous deposition of gaseous emissions, aerosols, and solid industrial waste, which can significantly modify their chemical composition. One of the most sensitive indicators of such impacts is soil acidity (pH), which plays a crucial role in nutrient availability, microbial activity, and plant growth.Industrial emissions containing sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and heavy metals contribute to soil acidification through atmospheric deposition and acid precipitation[1]. The intensity of these processes is not constant throughout the year and largely depends on seasonal climatic conditions such as temperature, precipitation, and humidity. Therefore, assessing seasonal changes in soil acidity provides valuable insights into the extent of industrial impact and the dynamics of soil degradation processes. The objective of this study is to evaluate the seasonal variation of soil acidity in a protection zone affected by industrial activity and to identify the relationship between industrial emissions and soil pH changes. The impacts of soil conditions and environmental factors. N addition effects on soil acidification varied with soil conditions and environmental factors. We found that the acidification was insensitive to N addition when initial soil pH ranges from 3 to 4, but was sensitive when above this pH range (figure S4). It indicates that soils with different initial pH have different acid-buffering capacity. It is generally expected that absorption ability of metal cations by soils is in the order of: trivalent ions (Fe3+ > Al3+)> divalent ions (Mn2+ > Ca2+ > Mg2+)> monovalent ions (K+ > Na+) Low valence ions held in soils with high initial pH are most vulnerable to be replaced. Once these cations have been much depleted, it is high valence cations that buffer against acidification. Based on the principle of charge balance, soils of high initial pH should be more sensitive to acidification than those of low initial pH. This explained well for our result that pH response magnitude increased linearly with the increase of initial pH. Inconsistent with our expectation, the pH response ratios tended to increase with soil total N across the study sites. This is probably due to that high N reduced initial soil pH. As we showed above, the lower the initial pH, the less response the pH has. Consistent with our expectation, more C in soils was helpful to suppress acidification, indicating its high cation exchange capacity[5]. Soil is a vital component of terrestrial ecosystems, playing a key role in nutrient cycling, plant growth, and environmental stability. However, rapid industrialization has significantly altered soil properties, particularly in areas surrounding industrial enterprises. One of the most sensitive indicators of soil degradation is soil acidity (pH), which directly affects biological activity, nutrient availability, and the mobility of toxic elements.

Industrial activities such as metallurgical plants, chemical factories, cement production, and power plants release various pollutants into the environment. These pollutants, including sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and heavy metals, can enter the soil through atmospheric deposition, wastewater discharge, and solid waste accumulation. As a result, soils in industrial protection zones are often subjected to acidification processes. Seasonal factors further influence soil acidity. Precipitation intensity, temperature changes, and biological activity vary throughout the year, affecting chemical reactions in the soil. For instance, increased rainfall can enhance the leaching of basic cations and promote acidification, while dry seasons may temporarily stabilize soil pH. Despite numerous studies on industrial soil pollution, limited attention has been given to the combined impact of industrial activity and seasonal variation on soil acidity in protection zones. Therefore, this study aims to evaluate seasonal changes in soil pH under industrial influence and assess potential environmental risks.

**MATERIALS AND METHODS**

2.1 Study Area. The study was conducted in a protection zone surrounding an industrial enterprise. The selected area extended within a radius of 500–1000 meters from the emission source. The zone represents a typical industrial landscape influenced by long-term anthropogenic activity.

2.2 Soil Sampling. Soil samples were collected seasonally during:

spring (March–April),
summer (June–July),
autumn (September–October),
winter (January–February).

Sampling was carried out at a depth of 0–20 cm, following standard soil sampling procedures. Several sampling points were established at different distances from the industrial facility to assess the spatial variability of soil acidity.

2.3 Laboratory Analysis. The soil acidity level was determined using a potentiometric method with a calibrated pH meter. Soil-water suspensions (soil-to-water ratio of 1:2.5) were prepared for analysis. All measurements were conducted under controlled laboratory conditions to ensure accuracy and reproducibility.

2.4 Data Analysis. Seasonal pH values were compared to identify trends and variations. The results were analyzed in relation to seasonal climatic conditions and the intensity of industrial emissions.

**RESULTS.** The analysis of soil samples demonstrated clear seasonal variations in soil acidity within the protection zone.

Spring: Soil pH values showed a noticeable decrease, indicating increased acidity. This trend is associated with higher precipitation levels, which enhance the leaching of acidic industrial pollutants into the soil [7].

Summer: During the summer season, soil acidity tended to stabilize or slightly decrease due to reduced

precipitation and increased evaporation. In some locations, soils exhibited near-neutral or weakly alkaline conditions.

Autumn: A renewed decrease in pH values was observed, corresponding to increased industrial activity and the onset of rainfall, which facilitated the deposition of acidic compounds.

Winter: Soil acidity changes were less pronounced during winter. Low temperatures and reduced biological activity slowed down chemical reactions, resulting in relatively stable pH levels [7].

Soils located closer to the industrial emission source consistently exhibited lower pH values compared to those sampled at greater distances, confirming the influence of industrial pollution on soil acidification.

3.2 Spatial Distribution of Soil Acidity. Spatial analysis revealed a clear relationship between soil pH and distance from the industrial facility. Sampling points located within the immediate vicinity of the industrial source consistently exhibited lower pH values compared to sites situated further away.

Near-zone soils (≤1 km) were predominantly moderately to strongly acidic, indicating intense industrial influence.

Intermediate-zone soils (1–3 km) showed slightly acidic conditions, reflecting partial dilution of pollutants.

Remote-zone soils (>3 km) maintained near-neutral pH values, suggesting minimal industrial impact.

This spatial gradient confirms that industrial emissions play a dominant role in shaping soil acidity within protection zones.

3.3 Statistical Characteristics of pH Variability

Statistical analysis of seasonal data showed significant differences in mean pH values between seasons. The standard deviation of pH measurements was higher during spring and autumn, indicating greater variability caused by fluctuating moisture conditions. In contrast, summer pH values displayed lower variability, reflecting more stable environmental conditions. Correlation analysis revealed a strong negative relationship between precipitation levels and soil pH, emphasizing the role of seasonal hydrological processes in soil acidification. Additionally, proximity to the industrial source was identified as a key factor influencing pH reduction.

3.4 Implications for Soil Quality. The observed seasonal and spatial patterns of soil acidity suggest progressive degradation of soil quality in the industrial protection zone. Prolonged acidic conditions, particularly during colder and wetter seasons, increase the risk of nutrient imbalance and mobilization of toxic metals. These changes may negatively affect vegetation cover and reduce the ecological effectiveness of the protection zone [2].

4. Discussion. The observed seasonal fluctuations in soil acidity are consistent with findings reported in previous studies on industrially impacted soils. Atmospheric deposition of sulfur and nitrogen compounds plays a dominant role in soil acidification, particularly during wet seasons. Seasonal climatic factors amplify or mitigate the effects of industrial emissions, leading to temporal variability in soil pH [4].

Prolonged soil acidification can result in nutrient imbalance, increased mobility of heavy metals, and reduced soil biological activity. These processes ultimately threaten vegetation cover and ecosystem stability within protection zones. Therefore, seasonal monitoring of soil acidity should be considered an essential component of environmental management strategies in industrial areas.

5. Conclusion. This study confirms that soil acidity in industrial protection zones is significantly influenced by both industrial activity and seasonal variation. The lowest pH values were recorded during wetter and colder seasons, particularly in areas closer to the industrial source. Continuous seasonal monitoring of soil pH is essential for early detection of soil degradation and implementation of effective mitigation measures.

To minimize environmental risks, it is recommended to:

Implement regular soil monitoring programs,

Strengthen green buffer zones around industrial facilities,

Reduce industrial emissions through cleaner technologies,

Apply soil amelioration practices where necessary.

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