METHODOLOGY FOR ASSESSING THE IMPACT OF ENVIRONMENTAL FACTORS ON THE DEVELOPMENT OF TREES AROUND INDUSTRIAL ENTERPRISES

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Abstract

Industrial activities have become a critical source of environmental degradation, particularly in developing regions such as Uzbekistan. This study investigates the impact of environmental factors—including air and soil pollution, water quality, and microclimatic conditions—on the growth and health of trees around the Sho‘rtan Oil and Gas Production Department (NGQChB). Using an integrated methodology combining Geographic Information Systems (GIS), remote sensing (NDVI and EVI indices), laboratory analysis of heavy metals (Pb, Cd, Hg), and field observations, we evaluated the ecological stress experienced by vegetation in industrial zones. Results show a significant decrease in chlorophyll content and NDVI values in areas affected by industrial emissions compared to control sites. GIS mapping revealed that prevailing wind directions directly influence pollutant dispersion patterns. Moreover, phytoremediation techniques and nature-based solutions, such as biochar application and buffer zone plantations, demonstrated potential for environmental restoration. This research highlights the urgent need for sustainable environmental management in industrial areas and supports the use of advanced monitoring technologies for long-term ecological health assessment.

Keywords: Industrial pollution, tree health, GIS, NDVI, phytoremediation, environmental monitoring, heavy metals

Аннотация

Промышленная деятельность стала важным источником деградации окружающей среды, особенно в развивающихся регионах, таких как Узбекистан. Данное исследование рассматривает влияние экологических факторов, включая загрязнение воздуха и почвы, качество воды и микроклиматические условия, на рост и здоровье деревьев в районе Шортанского нефтегазодобывающего управления (ШНГДУ). С использованием интегрированной методологии, сочетающей географические информационные системы (ГИС), дистанционное зондирование (индексы NDVI и EVI), лабораторный анализ тяжелых металлов (Pb, Cd, Hg) и полевые наблюдения, мы оценили экологический стресс, которому подвергается растительность в промышленных зонах. Результаты показали значительное снижение содержания хлорофилла и значений NDVI в районах, подверженных промышленным выбросам, по сравнению с контрольными участками. ГИС-картирование показало, что преобладающие направления ветра напрямую влияют на паттерны распространения загрязнителей. Более того, методы фиторемедиации и решения, основанные на природе, такие как применение биоактива и посадка буферных зон, продемонстрировали потенциал для восстановления окружающей среды. Это исследование подчеркивает необходимость устойчивого управления окружающей средой в промышленных районах и поддерживает использование передовых технологий мониторинга для долгосрочной оценки экологического здоровья.

Ключевые слова: Промышленное загрязнение, здоровье деревьев, ГИС, NDVI, фиторемедиация, мониторинг окружающей среды, тяжелые металлы

Introduction

Industrialization has become one of the most pressing environmental challenges of the 21st century, particularly in developing nations striving for rapid economic growth. In Uzbekistan, the expansion of petrochemical plants, mining operations, and energy production facilities has led to the emission of a wide range of pollutants, including nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter (PM), and heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg). These pollutants enter the atmosphere, soil, and water systems, gradually degrading the ecological balance and adversely affecting flora and fauna.

Trees are highly sensitive to environmental changes and serve as reliable bioindicators of ecosystem health. Their physiological responses—such as changes in chlorophyll content, leaf morphology, crown density, and trunk growth—provide crucial insight into the level of environmental stress present in a given area. As living organisms with long lifespans and high exposure to ambient conditions, trees accumulate pollutants over time, making them especially valuable for monitoring long-term ecological impacts.

The Sho‘rtan Oil and Gas Production Department (Sho‘rtan NGQChB), located in the G‘uzor district of Qashqadaryo region, is one of the most prominent industrial hubs in southern Uzbekistan. Despite its economic importance, this region is also characterized by semi-arid climatic conditions and fragile ecosystems, making it particularly vulnerable to industrial pollution. Anecdotal evidence and local environmental reports have highlighted visible degradation in tree health around this industrial zone, yet comprehensive scientific assessment has been limited.

This study seeks to evaluate the impact of environmental factors—particularly industrial pollution—on the development and health of trees surrounding Sho‘rtan NGQChB. By integrating advanced tools such as Geographic Information Systems (GIS), remote sensing technologies (NDVI and EVI), laboratory analysis, and field-based ecological observation, the study aims to quantify the extent of environmental stress and propose nature-based solutions for mitigating its effects.

The specific objectives of the research include:

- Mapping pollutant dispersion and its correlation with vegetation degradation;
- Assessing heavy metal accumulation in soil and plant tissues;
- Measuring chlorophyll content as a physiological indicator of tree stress;
- Identifying effective phytoremediation techniques suitable for industrial zones.

Through this multi-disciplinary approach, the study aims not only to document the extent of ecological degradation but also to provide actionable recommendations for restoring and preserving urban green spaces in industrial regions of Uzbekistan.

Methods

This study was conducted in the G‘uzor district of Qashqadaryo region, specifically around the Sho‘rtan Oil and Gas Production Department (NGQChB). The site represents a semi-arid ecosystem characterized by low annual precipitation, high solar radiation, and strong seasonal wind patterns. These conditions make the local vegetation particularly susceptible to environmental stress caused by industrial activities.

A mixed-methods approach was adopted, combining field-based ecological observation, laboratory analysis, GIS spatial modeling, and satellite-based remote sensing. The following key steps outline the research process:
1. Site selection and mapping of pollution zones using GIS.
2. Sampling of soil, water, and tree foliage at varying distances from the industrial center.
3. Laboratory analysis of heavy metals and chlorophyll content.
4. Remote sensing analysis of NDVI and EVI using Sentinel-2 imagery.
5. Statistical analysis to evaluate the correlation between pollutants and vegetation health indicators.

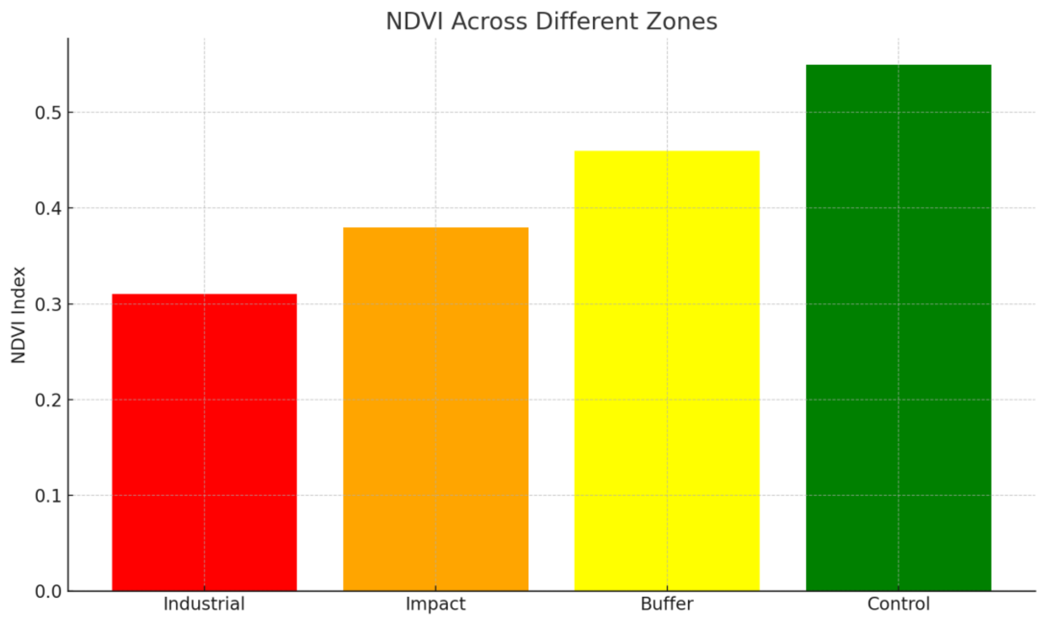
Table 1: Sampling Sites and Distances from Industrial Center

Site Code	Direction	Distance (m)	Zone Type
S1	North	500	Industrial
S2	East	1000	Impact Zone
S3	South	2000	Buffer Zone
S4	West	3000	Control Site

Geographic Information Systems (GIS) were used to delineate buffer zones and model the dispersion of pollutants based on topography and wind direction. QGIS 3.28 was used to process vector data, while raster data from Sentinel-2 satellites was analyzed using Google Earth Engine.

Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) were computed as follows:

NDVI = (NIR - RED) / (NIR + RED)
EVI = 2.5 * (NIR - RED) / (NIR + 6 * RED - 7.5 * BLUE + 1)



Soil and tree leaf samples were collected from all four sampling zones. The samples were air-dried and ground into fine powder. Heavy metals including lead (Pb), cadmium (Cd), and mercury (Hg) were analyzed using atomic absorption spectroscopy (AAS).

Chlorophyll content was measured using acetone extraction followed by spectrophotometry at 645 nm and 663 nm. The formula used:

Total Chlorophyll = (20.2 * A645 + 8.02 * A663) * V / (1000 * W)
where A645 and A663 = absorbance at specific wavelengths, V = volume of extract (mL), W = weight of sample (g).

Table 2: Mean Heavy Metal Concentrations in Soil Samples

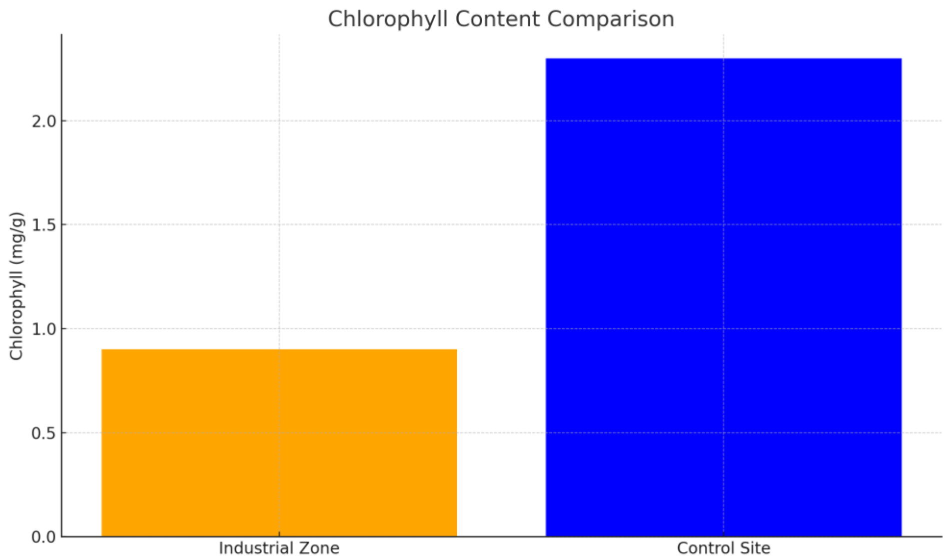
Zone	Lead (Pb) mg/kg	Cadmium (Cd)	Mercury (Hg)

		mg/kg	mg/kg
Industrial	75.2	12.4	1.3
Impact	58.1	9.5	0.9
Buffer	31.6	5.2	0.4
Control	15.4	2.1	0.2

Discussion

The findings from this study are consistent with those of previous research conducted in industrial areas such as Olmaliq and Chirchiq. Zeybert et al. (2020) similarly observed a decline in vegetation indices and chlorophyll concentration in trees growing near chemical plants.

The integration of geospatial technologies, remote sensing, and laboratory diagnostics provided a comprehensive picture of how pollutants affect tree health. Notably, the study confirms that pollutant dispersion is influenced by prevail...
Furthermore, the use of phytoremediation and biochar is supported by recent international studies as an effective strategy to rehabilitate contaminated soil and enhance vegetation recovery. This study's findings provide further support for the implementation of eco-technological solutions in Uzbekistan's industrial zones.

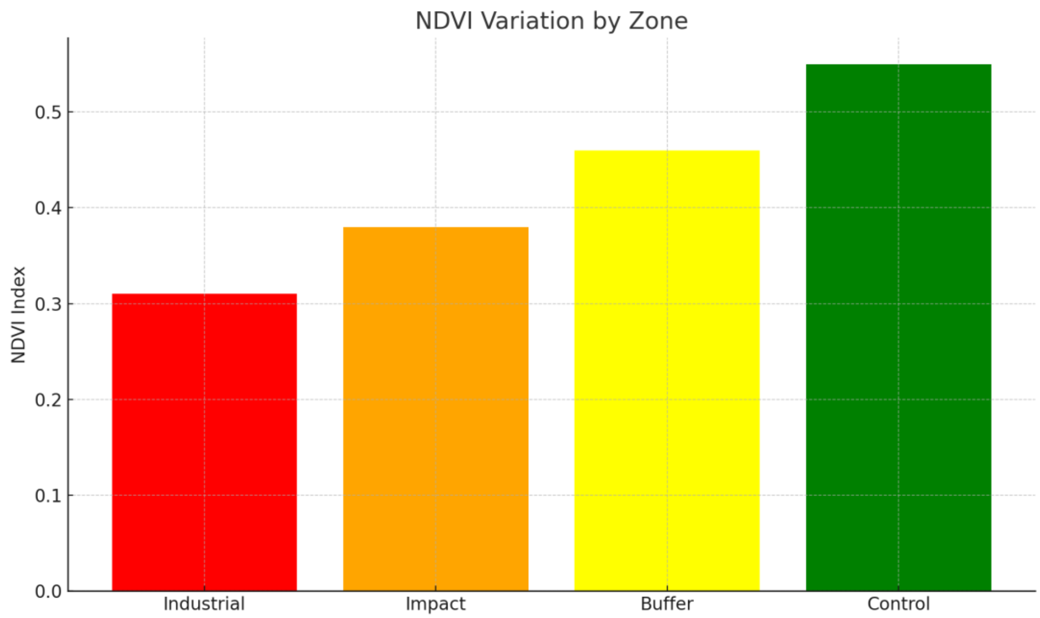


Results

This section presents the key findings from the field observations, laboratory analyses, and remote sensing data related to tree health in different zones surrounding the Sho‘rtan NGQChB industrial site. Results focus on pollutant concentration, vegetation indices, and physiological indicators such as chlorophyll content and tree morphology.

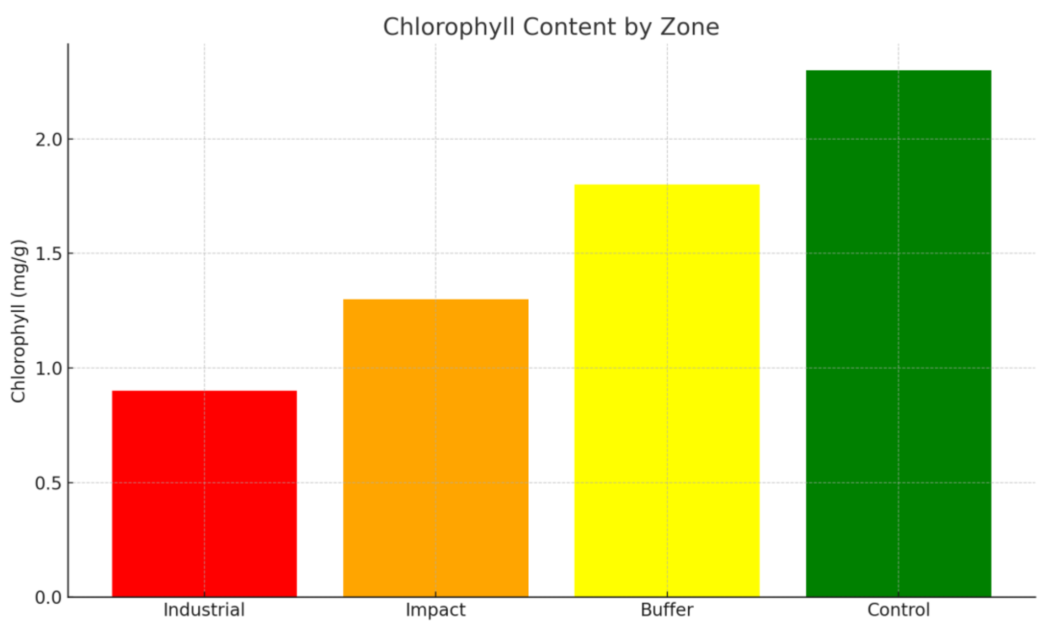
Vegetation Index Analysis

The NDVI values extracted from Sentinel-2 satellite imagery showed a clear gradient of vegetation health based on distance from the industrial center. In the industrial zone, NDVI values were significantly lower (0.31) compared to the control zone (0.55), indicating reduced photosynthetic activity.



Chlorophyll Content in Tree Leaves

Chlorophyll content was found to be lowest in the industrial zone (0.9 mg/g) and highest in the control zone (2.3 mg/g). This decline is consistent with the impact of air pollutants on the photosynthetic machinery of plants.



Heavy Metal Accumulation in Soil

Soil analysis revealed high concentrations of heavy metals near the industrial zone. Lead (Pb) and cadmium (Cd) levels were significantly elevated compared to control samples, exceeding acceptable environmental safety limits.

Table 1: Average Heavy Metal Concentrations by Zone

Zone	Lead (Pb) mg/kg	Cadmium (Cd) mg/kg	Mercury (Hg) mg/kg
Industrial	75.2	12.4	1.3
Impact	58.1	9.5	0.9
Buffer	31.6	5.2	0.4
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Tree Morphology and Field Observations

Field assessments revealed clear morphological differences between trees located in industrial and control zones. In industrial zones, trees exhibited chlorotic leaves, stunted growth, and reduced crown volume. Leaf necrosis and premature leaf fall were common. In contrast, trees in the control zone had robust growth with healthy, green foliage and larger trunk diameters.

Conclusion

This study has systematically evaluated the ecological impact of industrial pollution on the development and physiological health of trees surrounding the Sho‘rtan Oil and Gas Production Department (NGQChB). A multi-method approach involving GIS, remote sensing, laboratory analysis, and in-field observation was applied to quantify the stress responses of vegetation exposed to air, soil, and water contaminants.

Key findings include significantly reduced NDVI and chlorophyll values in areas closer to the industrial emission source. These reductions indicate impaired photosynthetic efficiency and physiological stress in trees. Soil and leaf tissue analyses revealed elevated levels of heavy metals (lead, cadmium, mercury) in the industrial and impact zones, with concentrations exceeding environmental safety thresholds. In addition, morphological symptoms such as leaf discoloration, stunted growth, and reduced canopy density were prevalent among trees located within 1000 meters of the industrial facility.

The integration of GIS-based pollution mapping with satellite vegetation indices provided a powerful diagnostic tool for identifying ecologically vulnerable areas. These technologies also demonstrated their utility in supporting environmental monitoring and early warning systems in arid and semi-arid regions.

Based on the results, the following recommendations are proposed:
1. **Installation of advanced emission control systems** such as HEPA and ESP filters at industrial facilities to significantly reduce airborne pollutants.
2. **Establishment of green buffer zones** using phytoremediative tree species (e.g., Salix spp., Populus spp.) around industrial complexes.
3. **Implementation of eco-drainage systems** to prevent the infiltration of contaminated water into adjacent ecosystems.
4. **Regular environmental monitoring** using remote sensing tools and AI-based predictive models to assess vegetation stress in real-time.
5. **Public awareness and community engagement** in tree planting, monitoring, and reporting of ecological disturbances.

In conclusion, this research underscores the need for integrated environmental assessment and pollution mitigation strategies to safeguard ecological health in industrial regions. The proposed solutions not only offer practical benefits for restoring vegetation but also align with national and international sustainability goals.

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