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STATE NON-COMMERCIAL ENTERPRISE
STATE UNIVERSITY “KYIV AVIATION INSTITUTE”
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____________ Tamara Dudar
«_____» ____________ 2025

BACHELOR THESIS

(EXPLANATORY NOTE)

Theme: «Environmental aspects of integrating the decommisioned airport into the urban space»

Done by: seeker of the FESET – 401 group, Anastasiia S. Rud
(student, group, surname, name, patronymic)

Supervisor: Ph. D. in Biol. Sc., Associate Professor of the Ecology Department, Tetiana I. Bilyk
(academic degree, academic rank, surname, name, patronymic)

Standards Inspector: _______________ Andrian IAVNIUK
(signature) (S.N.P.)

KYIV 2025

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ДЕРЖАВНЕ НЕКОМЕРЦІЙНЕ ПІДПРИЕМСТВО
«ДЕРЖАВНИЙ УНІВЕРСИТЕТ «КИЇВСЬКИЙ
АВІАЦІЙНИЙ ІНСТИТУТ»
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
_____________ Тамара Дудар
«_____» ____________ 2025 р.

КВАЛІФІКАЦІЙНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «БАКАЛАВР»

Тема: «Екологічні аспекти інтеграції території виведеного з експлуатації аеропорту в міський простір»

Виконавець: здобувачка групи ФЕБІТ 401 Рудь Анастасія Сергіївна
(студент, група, прізвище, ім’я, по батькові)

Керівник: к.б.н., доцент кафедри екології, Білик Тетяна Іванівна
(науковий ступінь, вчене звання, прізвище, ім’я, по батькові)

Нормоконтролер: _______________ (підпис) Андріан ЯВНЮК (П.І.Б.)

КИЇВ 2025

STATE NON-COMMERCIAL ENTERPRISE
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Faculty of Environmental Safety, Engineering and Technologies
Department of Environmental Science
Specialty, Educational and Professional Program: specialty 101 “Environmental Science”, Educational
and Professional Program: “Ecology and Environment Protection”
(code, name)

APPROVED
Head of the Department
___________ Tamara DUDAR
«____» _________ 2025

BACHELOR THESIS ASSIGNMENT
Anastasiia S. Rud

1. Theme: «Environmental aspects of integrating the decomissioned airport into the urban space» approved by the Acting President on April, 28, 2025, №634/ст.

2. Duration of work: from 28.04.2025 to 17.06.2025

3. Output data of work: scientific literature on the environmental assessment of former airport territories; studies on the impact of aviation infrastructure on soil, water, and biodiversity; international and national sources on land reclamation; methods of phytoremediation and bioremediation.

4. Contents of explanatory note: introduction, analysis of environmental issues related to the long-term operation of the airport, a description of the Tempelhof area and the applied research methods, justification of ecological reintegration strategies into the urban space, examples of successful restoration, as well as conclusions and recommendations.

5. The list of mandatory graphic (illustrated) materials: maps, photographs, tables, diagrams, and models.

6. Schedule of thesis performance

№ з/п	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	28.04.2025	
2	Preparing the main part (Chapter I)	05.05-12.05.2025	
3	Preparing the main part (Chapter II)	13.05-26.05.2025	
4	Preparing the main part (Chapter III)	27.05-05.06.2025	
5	Formulating conclusions and recommendations of the thesis	06.06.2025	
6	Making and explanatory note to the previous presentation of the department, consultation with the norms controller	07.06-08.06.2025	
7	Presentation of the work at the department	09.06.2025	
8	Taking into account the comments and recommendations and training to protect	10.06-13.06.2025	
9	Thessis defence at the department	17.06.2025	

7. Date of task issue: «28» April 2025

Diploma (project) advisor: ________________ Anastasiia RUD
(advisor's signature) (S.N.P.)

Task is taken to perform: ________________ Tetiana BILYK
(graduate's signature) (S.N.P.)

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
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Факультет екологічної безпеки, інженерії та технологій
Кафедра екології
Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»
(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
___________Тамара ДУДАР
«____» _________ 2025 р.

ЗАВДАННЯ
на виконання дипломної роботи

Рудь Анастасія Сергіївна

1. Тема кваліфікаційної роботи «Екологічні аспекти інтеграції території виведеного з експлуатації аеропорту в міський простір», затверджена наказом в.о. президента від «28» квітня 2025 р. №634/ст.

2. Термін виконання роботи: з 28.04.2025 по 17.06.2025р.

3. Вихідні дані роботи: наукова література щодо екологічної оцінки територій колишніх аеропортів, дослідження щодо впливу авіаційної інфраструктури на ґрунти, воду та біорізноманіття, міжнародні та вітчизняні джерела з питань рекультивації, методи фітопоглинання та біоочищення.

4. Зміст пояснювальної записки: вступ, аналіз екологічних проблем, пов’язаних із тривалим функціонуванням аеропорту, характеристику території Темпельхоф та методів дослідження, обґрунтування шляхів екологічної реінтеграції території у міський простір, приклади відновлення, а також висновки та рекомендації.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: картосхеми, фотографії, таблиці, схеми, моделі.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	28.04.2025	
2	Підготовка основної частини (Розділ I)	05.05-12.05.2025	
3	Підготовка основної частини (Розділ II)	13.05-26.05.2025	
4	Підготовка основної частини (Розділ III)	27.05-05.06.2025	
5	Формулювання висновків та рекомендацій дипломної роботи	06.06.2025	
6	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтрлером	07.06-08.06.2025	
7	Презставлення роботи на кафедрі	09.06.2025	
8	Урахування зауважень, рекомендацій та підготовка до захисту	10.06-13.06.2025	
9	Захист дипломної роботи на кафедрі	17.06.2025	

7. Дата видачі завдання: «28» квітня 2025 р.

Керівник дипломної роботи (проекту): ________________ Тетяна БІЛИК
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: ________________ Анастасія РУДЬ
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Environmental aspects of integrating the former airport territory into the urban space»: 52 pages, 10 figures, 2 tables, 30 references.

Object of research – the process of environmental restoration of the former airport area after the cessation of technogenic pressure

Subject – measures and methods for restoring environmental quality to return the airport area to urban space.

Methods of research: analytical, cartographic, comparative, environmental assessment methods.

The thesis examines the environmental impact of former airport operations, including soil and water pollution and biodiversity loss. It outlines remediation methods such as phytoremediation and constructed wetlands, and proposes strategies for ecological restoration and urban reuse. The findings show that such areas can be transformed into green, resilient, and publicly valuable spaces through interdisciplinary and participatory approaches.

POST-INDUSTRIAL LANDSCAPE, AIRPORT TRANSFORMATION, ECOLOGICAL RESTORATION, SUSTAINABLE URBAN DEVELOPMENT, SOIL REMEDIATION, PFAS, GIS ANALYSIS, BIODIVERSITY, TEMPELHOF, NATURE-BASED SOLU

CONTENT

LIST OF SYMBOLIC NOTATIONS AND ABBREVIATIONS

PM_{10} / $PM_{2.5}$ – particulate matter with a diameter of 10 micrometers / 2.5 micrometers;

mg/kg – milligrams per kilogram (used for measuring soil contamination);

mg/L – milligrams per liter (used for measuring water pollution);

ha – hectare (unit of area);

$\mu g/m^3$ – micrograms per cubic m eter (air pollutant concentration);

GIS – Geographic Information System;

WWTP – Wastewater Treatment Plant;

SDG 15 – Sustainable Development Goal 15: Life on Land;

EPA – Environmental Protection Agency;

NGO – Non-Governmental Organization;

PFAS – Per- and polyfluoroalkyl substances;

BAT – Best Available Techniques;

AAS – Atomic Absorption Spectroscopy;

GC-MS – Gas Chromatography-Mass Spectrometry;

eDNA – Environmental DNA;

AOPs – Advanced Oxidation Processes;

GBIF – Global Biodiversity Information Facility;

LPI – Living Planet Index;

IUCN Red List – International Union for Conservation of Nature Red List;

RTE species – Rare, Threatened, or Endangered species

INTRODUCTION

Relevance of the work. Nowadays, environmental sustainability and the rehabilitation of industrial urban areas are gaining increasing relevance in the context of climate change and urban population growth. Germany stands out as a leader in ecological policy and sustainable urban development, and one of the most illustrative examples of this is the transformation of Berlin's former Tempelhof Airport into a public ecological space. This project exemplifies how environmentally degraded and historically industrial zones can be repurposed to promote biodiversity, urban greenery, and public well-being.

Aim and tasks of the diploma work

Aim of the work – to analyze the environmental consequences of long-term airport operations and explore the strategies applied in the ecological rehabilitation of the Berlin-Tempelhof airport area.

Objectives of the work:

1. To assess the environmental impact caused by the prolonged operation of Tempelhof Airport.
2. To investigate the methods and technologies used in the environmental remediation of the site.
3. To evaluate the success of biodiversity restoration and ecological integration in the Tempelhof Feld project.
4. To explore the role of public participation and urban planning in the transformation process.

Object of research is the process of environmental transformation of post-industrial urban territories.

Subject of research is the case of the ecological rehabilitation of the Berlin-Tempelhof airport area.

Methods of research – analysis of scientific literature, case study methodology, field data review, and comparative evaluation of remediation practices.

Personal contribution of the graduate: independent analysis of environmental data, synthesis of best practices in land rehabilitation, and critical evaluation of biodiversity restoration outcomes in Tempelhof Feld.

Approbation of results. The findings of the research were presented at the Tenth World Congress “AVIATION IN THE XXI-st CENTURY” Safety in Aviation And Space Technologies, held in Kyiv: National Aviation University on September 28-30, 2022

Publications: The results of the study have been published in 1 scientific articles in peer-reviewed journals and in the proceedings of national and international conferences.

CHAPTER 1
ENVIRONMENTAL IMPACT OF AIRPORT OPERATIONS AFTER LONG PERIOD OF USE

1.1 Soil contamination in the airport area

Long-term operation of airports results in significant environmental burdens, especially in relation to soil quality. The processes of fuel combustion, aircraft maintenance, de-icing procedures, and constant movement of vehicles and aircraft lead to the accumulation of various toxic substances in the soil, including petroleum hydrocarbons, heavy metals, and persistent organic pollutants. These substances are gradually absorbed into the upper soil layers and accumulate in dangerous concentrations [1].

The proximity of runways and maintenance zones to natural or urban soil exposes large areas to contamination from polycyclic aromatic hydrocarbons (PAHs), oils, lubricants, and combustion residues. Over time, these compounds lead to the degradation of soil structure and reduction of its biological activity. Among the most concerning elements found in airport zones are cadmium, lead, arsenic, and zinc—elements with high mobility and long-lasting toxicological effects on microorganisms and plants [2].

Soil in the vicinity of airports often displays low enzymatic activity, reduced porosity, and poor water retention capacity. These changes stem not only from chemical pollution but also from mechanical compaction due to heavy machinery and aircraft movements. Studies confirm that the topsoil layer within airport territories contains elevated concentrations of metals and complex chemical residues that often exceed permissible environmental thresholds [3].

One of the most dangerous pollutants found in airport soil is the group of per- and polyfluoroalkyl substances (PFAS), used in fire-fighting foams. These compounds are known for their extreme persistence and toxicity. Once released into the environment, PFAS can migrate through soil and contaminate groundwater sources, posing a long-term threat to ecosystems and human health [4].

Monitoring data from European and North American airports show that de-icing agents, especially those based on glycols and formates, contribute to significant seasonal contamination of soil, especially during winter months. Inadequate drainage and unsealed infrastructure elements allow pollutants to infiltrate directly into the subsurface [5]. In addition, technical areas such as hangars, refueling zones, and maintenance platforms often lack protective coverage and allow direct runoff of contaminants into the ground.

In urban airports, contamination is often aggravated by mixed land-use pressures. Adjacent zones may include residential or recreational areas, which increases the risk of human exposure to soil pollutants. Some contaminated sites are repurposed without prior remediation, further exacerbating the risk. Analytical studies using contamination indices (e.g., the geoaccumulation index or ecological risk index) show that airport soils typically fall into moderate to high pollution categories [6].

One of the modern trends in assessing the impact of airport-related soil contamination is the use of bioindicators. Plants such as *Miscanthus giganteus* have demonstrated both tolerance and phytoremediation potential in soils contaminated by hydrocarbons and metals. These methods help assess not only chemical residues but also biological stress responses in soil microbiota [7].

In the context of reclamation, the role of microbial communities is of utmost importance. Soil samples from former airport zones often show suppressed microbial diversity and reduced activity of key enzymatic processes responsible for organic matter turnover. Restoration efforts must therefore include not only physical or chemical remediation but also biostimulation of natural processes.

Another relevant approach involves the evaluation of health risks associated with exposure to contaminated urban soils. Studies in Central European cities demonstrate that even recreational land converted from former industrial or airport areas may pose a threat due to residual contamination. Soil health indicators, including enzymatic activity and contaminant leaching potential, must be evaluated prior to any repurposing for public use [8].

In the case of Berlin-Tempelhof, preliminary soil analyses revealed elevated levels of lead and hydrocarbons, primarily in zones that had historically been used for aircraft refueling and mechanical servicing. The rehabilitation strategy included partial removal of the topsoil layer, soil washing procedures, and the application of natural absorption materials such as zeolites and biochar. These measures helped reduce pollutant concentrations and improve the physical structure of the soil for future ecological use.

Despite the technical complexity and economic costs of remediation, the successful transformation of such sites demonstrates that former airport territories can be converted into healthy and multifunctional urban environments. These transformations not only restore environmental balance but also unlock new socio-economic potentials, including public recreation areas, ecological corridors, and green infrastructure nodes. The key to this success lies in systematic preliminary investigation that includes comprehensive soil diagnostics, pollution mapping, and risk assessment. Targeted remediation strategies—ranging from soil excavation and chemical neutralization to phytoremediation and in-situ stabilization—must be adapted to the specific contaminants and local environmental conditions. Equally important is the implementation of long-term monitoring systems that can track post-remediation recovery and detect any resurgence of harmful substances.

A comprehensive understanding of pollution sources, chemical behavior of contaminants in the soil matrix, and the interaction between soil, groundwater, and biological systems is crucial for developing effective and sustainable integration strategies. Urban redevelopment projects must embed these scientific findings into the planning and design phases to prevent secondary contamination and ensure compatibility with future land uses, whether ecological, recreational, or residential.

Thus, soil contamination in airport zones remains a pressing issue of environmental safety and urban sustainability. Addressing this challenge requires genuine interdisciplinary collaboration between urban planners, ecologists, chemists, geotechnical engineers, landscape architects, and policy makers. Their coordinated input is essential to align environmental remediation with city-scale development goals, regulatory frameworks, and community expectations. Only through such integrated efforts can former infrastructure-heavy territories be prevented from becoming ecological time bombs and instead be reimagined as resilient, sustainable, and health-promoting components of the modern urban fabric.

1.2. Pollution of water bodies in the airport area

Airports represent major hubs of anthropogenic activity that exert significant pressure on surrounding water ecosystems. The continuous use of de-icing agents, hydraulic fluids, fuel residues, detergents, and other chemical compounds often leads to surface runoff carrying toxic substances directly into nearby rivers, streams, and groundwater systems. These pollutants can accumulate over time, altering the chemical composition and biological integrity of the water bodies [9].

Hydrological modeling confirms that most airport platforms, including aprons and runways, are impervious, resulting in high surface runoff coefficients. This facilitates the rapid transport of contaminants into local drainage systems, particularly during precipitation events. In areas where airports are situated near coastal regions or estuaries, the influence extends to saltwater habitats, compromising marine biodiversity and fisheries productivity [10].

Among the most persistent and harmful water contaminants are per- and polyfluoroalkyl substances (PFAS), which are widely used in fire-fighting foams and have been detected in alarming concentrations in the vicinity of many airports. Their chemical stability and bioaccumulative properties make them particularly hazardous. Even low concentrations of PFAS in drinking water sources pose risks to human health, including hormonal disruption and carcinogenic effects [11].

Advanced machine learning analyses applied to large-scale water datasets reveal the extensive distribution of PFAS contamination across various geographic zones affected by airport activity. These technologies help identify contamination clusters, predict future migration pathways, and determine likely points of origin [12]. Monitoring programs in urban zones like Melbourne have demonstrated the widespread presence of PFAS not only in surface waters but also in sediments, which serve as long-term pollutant reservoirs [13].

Efficient removal of PFAS from water treatment systems remains a technical challenge, with ongoing research focused on industrial process optimization. Techniques such as ion exchange, activated carbon adsorption, and advanced oxidation processes have shown varying degrees of success, depending on PFAS chain length and concentration [14]. Without proper removal systems, PFAS can easily enter municipal water supplies, posing a systemic risk.

A holistic approach to mitigating water pollution at airports involves both infrastructural and management strategies. Life-cycle analyses of terminal operations highlight the necessity of spatial-temporal planning in handling pollutants that impact not only water but also climate and public health. Strategies must include green infrastructure, stormwater buffering systems, and regulatory frameworks to limit emissions at the source [15].

An increasingly adopted strategy in environmental risk management is the "presumptive contamination" approach. This involves assuming the presence of PFAS and related pollutants in water bodies around specific high-risk facilities, such as airports, and implementing protective measures even in the absence of complete analytical confirmation. This principle allows quicker response to pollution without waiting for full-scale scientific validation [16].

Airport authorities are gradually integrating more robust water management protocols. For instance, Frankfurt Airport has implemented several innovative systems for the retention, treatment, and reuse of stormwater. These systems not only reduce the volume of discharged polluted water but also help meet sustainability goals and improve cost-efficiency in water use [17].

In the case of Berlin-Brandenburg Airport, mobile atmospheric measurements have identified localized pollution plumes affecting surrounding areas. These plumes contain volatile compounds and particulate matter that eventually deposit into soil and water bodies, particularly during rainfall events. The closure of older airports like Berlin-Tegel has led to a measurable reduction in ultrafine particle emissions, indirectly improving water quality due to lower deposition rates [18,19].

Despite advances in airport infrastructure and water treatment technology, contamination of water bodies remains a critical environmental challenge. The legacy of PFAS usage, the ongoing input of de-icing and maintenance chemicals, and the limited permeability of airport surfaces contribute to continuous water pollution risks. Moreover, urbanization surrounding airport zones often limits the availability of natural buffering systems such as wetlands or green zones that could mitigate pollutant flow.

Effective solutions require not only a combination of regulatory enforcement, real-time monitoring, and public transparency, but also a commitment to long-term environmental stewardship. Modern environmental policy should mandate that airports perform regular assessments of their hydrological footprint, evaluating not only direct pollutant emissions but also cumulative ecological risks. These assessments must be integrated into broader urban planning frameworks to ensure that airport development aligns with local water protection objectives. Furthermore, the application of best available technologies (BAT) for the control and treatment of surface runoff—such as biofiltration systems, permeable pavements, and closed drainage circuits—should become a standardized requirement.

Public access to pollution data and environmental performance metrics of airports must be ensured through open databases and community engagement programs, fostering a culture of accountability and civic participation. Importantly, the ecological restoration of degraded watercourses must go beyond technical rehabilitation; it should involve the reestablishment of native aquatic vegetation, the reintroduction of indicator species, and the reconstruction of natural hydrological connectivity. Constructed wetlands, buffer strips, and sedimentation ponds not only serve as effective water purification systems but also create valuable habitats for flora and fauna, contributing to the overall ecological resilience of urban environments.

In conclusion, the pollution of water bodies in airport-adjacent areas is emblematic of the broader tensions between rapid infrastructural expansion and the imperatives of environmental sustainability. If left unchecked, the chronic discharge of pollutants from airport activities into surrounding hydrological systems threatens the long-term viability of freshwater and marine ecosystems. However, by embracing science-driven environmental management, investing in cutting-edge technologies, and enforcing transparent and adaptive governance models, it is both feasible and necessary to secure the ecological integrity of water resources that are vital for both human and environmental health in the urban age.

1.3. Impact on biodiversity of the area adjacent to the airport

The operation of airports significantly alters the ecological character of adjacent areas, causing habitat fragmentation, introducing noise and light pollution, and contributing to the decline of native flora and fauna. Airport environments are dominated by artificial surfaces and mechanical disturbances, which reduce the continuity of natural ecosystems and disrupt trophic interactions in surrounding habitats [20]. The physical transformation of landscapes near airports leads to the displacement of wildlife, altering species distribution and reducing biodiversity levels, particularly among sensitive indicator species.

Airports typically act as barriers to wildlife movement, severing migration corridors and isolating populations. The continuous operation of aircraft and support vehicles generates high levels of acoustic disturbance, which can modify animal behavior, especially among birds and amphibians. Certain species show an avoidance response, abandoning previously suitable habitats due to chronic stress and disrupted breeding cycles. Environmental monitoring of such areas has identified notable shifts in species richness and community structure in comparison to adjacent non-urbanized zones [21].

Beyond the immediate effects of noise and pollution, airport-adjacent ecosystems suffer from secondary impacts such as altered hydrological cycles, reduced pollinator populations, and the introduction of invasive species. Inadequate stormwater management contributes to the degradation of nearby wetlands and aquatic systems, leading to loss of aquatic biodiversity and impaired ecosystem services. Furthermore, the artificial illumination associated with runways and terminal buildings interferes with circadian rhythms in both plants and animals, disrupting nocturnal pollination and migration behaviors [22].

In addition, airport zones often become ecological peripheries—spaces where native biodiversity is replaced by opportunistic and generalist species better adapted to urban conditions. This results in biotic homogenization, with a loss of ecological uniqueness and a weakening of ecological networks. Biodiversity assessments in such environments reveal declines in key taxonomic groups and altered ecological functions in soil, water, and air interfaces [23].

The spatial influence of airports extends beyond their physical boundaries. Adjacent urban and suburban developments amplify anthropogenic pressures and often restrict ecological restoration efforts. These infrastructural margins can become chronically underutilized, ecologically degraded areas unless purposefully reclaimed for green infrastructure and biodiversity enhancement [24]. In this context, the integration of biodiversity protection into urban regeneration initiatives becomes a strategic necessity, not an optional gesture.

Sustainable airport redevelopment initiatives increasingly emphasize biodiversity as a core principle, moving beyond technical remediation to include ecological rebalancing. Urban regeneration projects that incorporate green corridors, native vegetation belts, and wildlife-friendly design can transform former airport zones into vibrant ecological systems. These actions promote habitat continuity, restore ecological functions, and improve human-nature interaction within the urban environment [25].

Recent studies highlight the potential of repurposed airports to become multifunctional ecological and innovation zones, contributing not only to city resilience but also to community well-being and urban sustainability. Such areas offer opportunities for creating experimental landscapes, nature education programs, and decentralized green infrastructure. In the case of Berlin, transformation initiatives at the former Tempelhof airfield demonstrate how post-industrial landscapes can evolve into socially inclusive and biodiverse urban environments [26].

Examples of successful rewilding include projects that enable multispecies cohabitation, encourage spontaneous vegetation growth, and reinterpret urban nature through participatory ecological design. These approaches redefine urban biodiversity not as a remnant of wilderness but as a dynamic and co-produced ecological reality. In doing so, they challenge traditional dichotomies between urban and natural, infrastructure and habitat [27].

Moreover, airport closures offer unique research opportunities to assess long-term ecological responses. Natural experiments tracking avian vocalization patterns before and after airport shutdowns have provided direct evidence of behavioral restoration among bird populations in previously disturbed zones. Reduced noise levels lead to the re-establishment of complex acoustic behaviors and increased reproductive success among sensitive species [28].

Initiatives that promote experiential engagement with urban nature—such as biodiversity trails, environmental art installations, or participatory science—foster deeper public understanding of ecological processes and encourage stewardship of restored airport spaces. Such programs transform formerly restricted and industrialized zones into accessible arenas for biodiversity education and recreation [29].

However, ecological enhancement must also be harmonized with competing urban demands, including renewable energy development, housing, and transportation infrastructure. Scenario planning tools that model the energy–biodiversity–land nexus are critical to finding balanced solutions that support biodiversity while meeting other sustainability goals [30].

In sum, the biodiversity of areas surrounding airports is heavily influenced by a complex interplay of infrastructural expansion, operational activity, and environmental neglect. The constant disturbance from noise, light, and chemical pollutants, combined with the physical fragmentation of habitats, leads to a measurable decline in species richness, ecological resilience, and the overall health of adjacent ecosystems. However, these degraded environments are not beyond recovery. With intentional and ecologically informed design strategies, science-based restoration efforts, and inclusive participatory planning, it is entirely possible to reverse biodiversity loss and cultivate dynamic, adaptive systems within the very spaces once dominated by aviation infrastructure.

Former airport landscapes hold the latent potential to become ecological sanctuaries embedded in the urban matrix—serving as migratory stopovers, pollinator habitats, or even biodiversity hubs within densely populated regions. Integrating such spaces into the broader green infrastructure network can reconnect isolated ecological corridors, enhance urban climate resilience, and provide restorative environments for both people and wildlife. Through rewilding, habitat engineering, and community engagement, these territories can evolve into models of how post-industrial land use can actively contribute to the regeneration of urban nature and the redefinition of what constitutes a thriving city.

1.4. Conclusions to chapter

This chapter examined the long-term environmental impacts of airport operations, focusing on soil contamination, water pollution, and biodiversity loss. Key findings revealed persistent pollutants (PFAS, heavy metals) in soil and water systems, alongside habitat fragmentation and species decline in adjacent ecosystems. The analysis highlighted the need for integrated remediation strategies, combining technical solutions (e.g., soil washing, biofiltration) with ecological restoration (rewilding, green corridors). Case studies like Berlin-Tempelhof demonstrate that post-airport landscapes can transition into multifunctional spaces balancing ecological recovery and urban needs. These insights underscore the importance of interdisciplinary approaches to mitigate aviation’s environmental legacy and foster sustainable land reuse.

CHAPTER 2.

MATERIALS AND METHODS OF INVESTIGATION

2.1. Characteristics of the studied airport territory

The territory selected for this study is the former Berlin Tempelhof Airport (Flughafen Berlin-Tempelhof), located in the central-southern part of the German capital. Once one of Europe’s oldest operational airports, Tempelhof was decommissioned in 2008 and has since undergone gradual transformation into a multifunctional public and ecological space known as Tempelhofer Feld. The total area of the former airport encompasses approximately 386 hectares, of which a substantial portion remains unbuilt and covered by open grasslands, scattered vegetation, sealed surfaces (runways and aprons), and legacy technical infrastructure. (Fig 2.1)

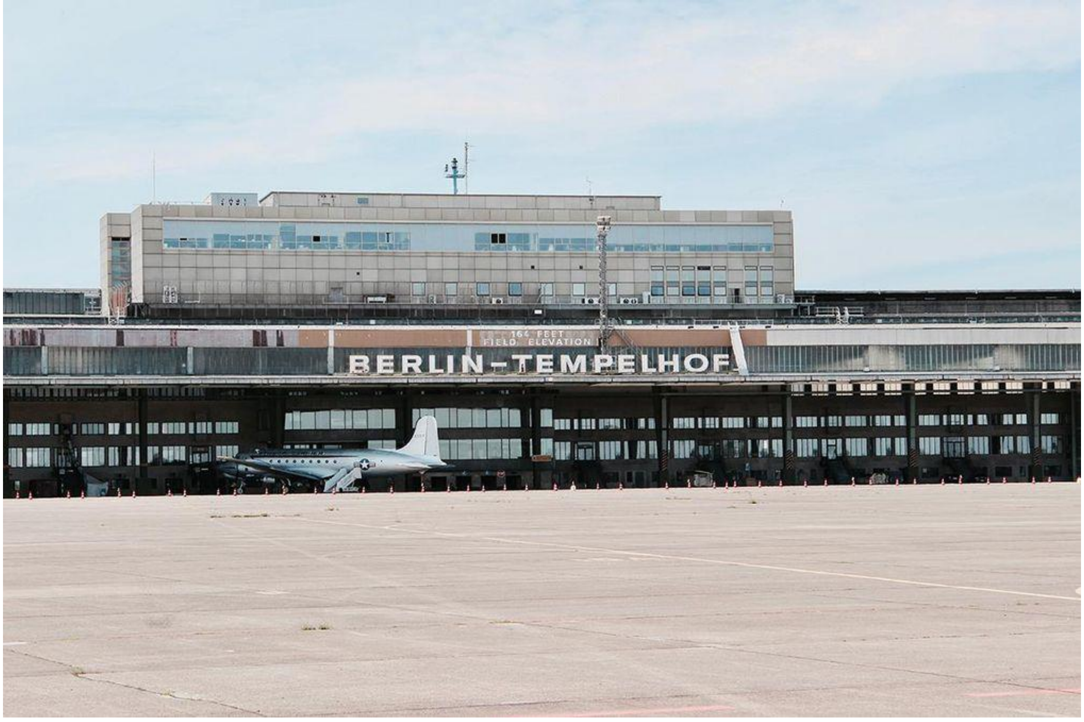

Fig 2.1 View of the operational terminal at Berlin-Tempelhof Airport.

Historically, the airport operated for over eight decades, serving both civilian and military purposes. Its long-standing use resulted in complex layers of anthropogenic disturbance and contamination, particularly in soil and water systems. The spatial composition of the site includes concrete airstrips, old maintenance hangars, fuel storage facilities, de-icing zones, and adjacent green belts that were previously under restricted access. These spatial zones exhibit varying degrees of ecological degradation and recovery potential. (Fig 2.2)

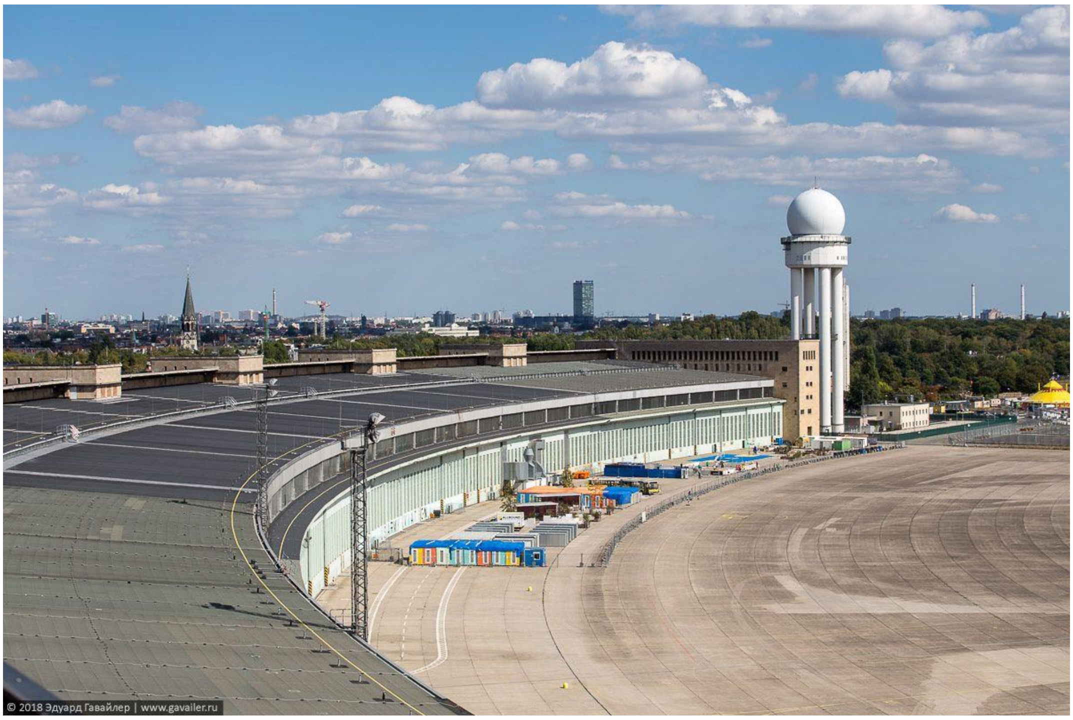

Fig 2.2 View of the airport territory after its completion

From a biogeographical standpoint, Tempelhof is located within the temperate climate zone, with moderate precipitation and clearly marked seasonal fluctuations. Its landscape prior to airport construction consisted of typical lowland meadows and wetland systems, which were largely disrupted by the introduction of hardened surfaces and intensive operational activity. Despite this, spontaneous ecological succession over the past decade has led to partial recolonization by grassland species, insects, and ground-nesting birds, particularly in less disturbed sectors of the site. (Fig 2.3)

Fig 2.3 Aerial photograph of the runway

The current topography is predominantly flat, with isolated depressions where water tends to accumulate after rainfall. These low-lying zones exhibit the highest potential for soil and water contamination, particularly with hydrocarbons and de-icing residues. A network of underground drainage channels, once designed for runoff management during airport operations, still influences the hydrology of the site. Some of these channels now act as unintended conduits for contaminant dispersion into adjacent groundwater systems.

The combination of built and unsealed land, presence of residual infrastructure, and proximity to urban districts makes Tempelhofer Feld a unique case for assessing the environmental legacy of decommissioned airport zones. It offers a rare opportunity to study interactions between infrastructure and nature in a post-industrial context, especially in regard to soil rehabilitation, water system restoration, and biodiversity recovery. Furthermore, its current status as a public space with minimal building redevelopment allows for open access and continuous ecological monitoring without major urban construction interference. (Fig 2.4)

Fig 2.4 The area adjacent to the airport

Thus, the Tempelhof site represents an exemplary model for investigating long-term environmental impacts of airport operations and the feasibility of urban ecological integration. As a former aviation hub embedded within a dense urban fabric, it encapsulates the full spectrum of environmental legacies associated with prolonged industrial and infrastructural use—ranging from hydrocarbon-saturated soils and altered hydrology to disruptions in biodiversity and ecological continuity. Its heterogeneous surface composition, which includes sealed runways, semi-natural meadows, compacted technical zones, and gradually rewilded areas, offers a spatially diverse and scientifically rich platform for comparative analysis.

Legacy pollution zones—particularly those associated with refueling sites, de-icing areas, and technical service points—present complex contamination profiles that require the application of interdisciplinary remediation techniques. At the same time, the spontaneous return of vegetation and fauna in less disturbed sectors provides real-world evidence of ecological resilience and natural recovery potential. This coexistence of degradation and regeneration creates a dynamic testing ground for developing, applying, and evaluating innovative soil remediation, hydrological rehabilitation, and biodiversity restoration strategies within a real and evolving urban landscape.

Moreover, the site’s public accessibility, political visibility, and minimal redevelopment pressure enable continuous environmental observation and stakeholder engagement without the constraints often present in more commercially-driven urban projects. This makes Tempelhof not only a subject of scientific inquiry but also a participatory model for urban environmental governance, where ecological knowledge, public use, and policy experimentation can intersect. Ultimately, it serves as a critical reference point for reimagining how post-industrial urban territories can be transformed into multifunctional ecological assets for the cities of the future.

2.2. Research methods used

To investigate the environmental legacy of the former Berlin Tempelhof Airport and assess the potential for its ecological reintegration, a combination of qualitative and quantitative research methods was employed. The applied methodology draws from the fields of environmental science, soil chemistry, hydrology, landscape ecology, and urban planning to ensure a comprehensive and multilayered evaluation of the site.

The first stage of research involved spatial analysis using Geographic Information Systems (GIS). Satellite imagery, historical maps, and aerial photographs were georeferenced and overlaid to identify spatial patterns of land use change, soil sealing, vegetation cover, and hydrological infrastructure. This helped delineate zones of potential contamination and areas undergoing natural regeneration. (Fig 2.5)

Fig 2.5 Aerial airport map

This aerial map provides a comprehensive visualization of the spatial structure and current land use within Tempelhofer Feld, the repurposed area of the former Berlin-Tempelhof Airport. The image combines satellite photography with clearly marked overlays and a detailed legend, illustrating how the post-airport landscape has been transformed into a multifunctional urban park that integrates ecological, recreational, and infrastructural elements. (Fig 2.6)

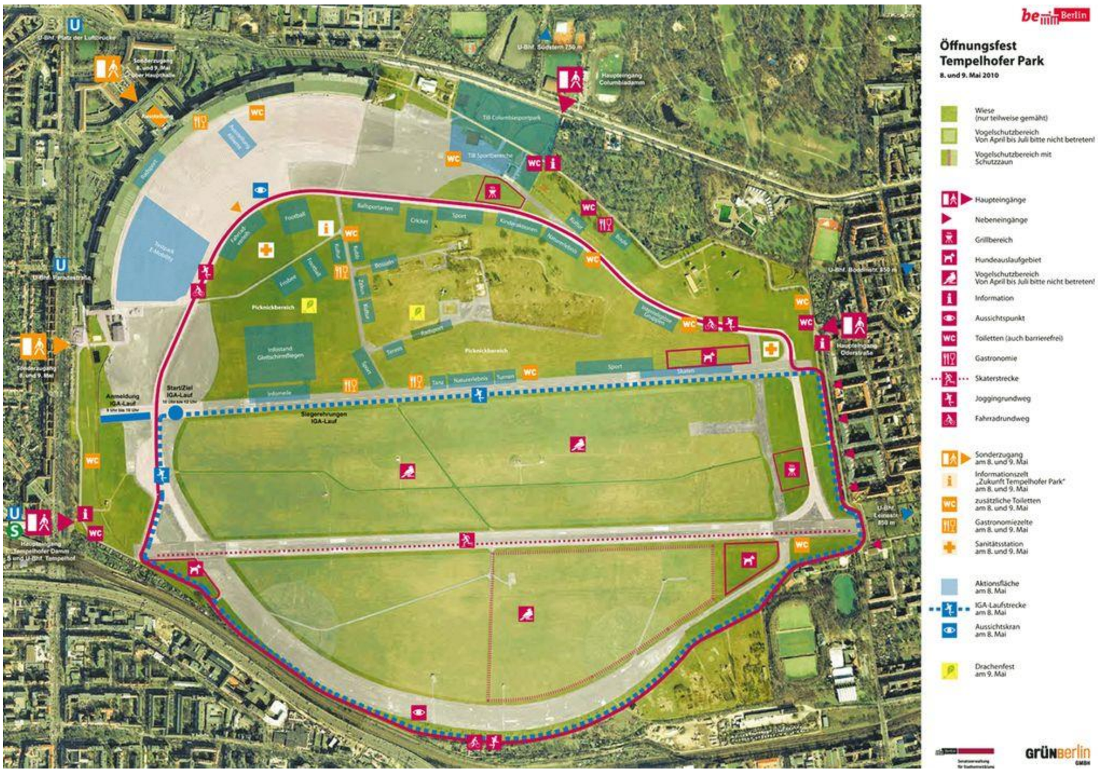

Fig 2.6 Scheme of division of territory for human use

For soil assessment, field sampling was conducted in pre-defined transects covering active contamination zones (former technical areas, aprons) and control zones (unsealed, rewilded spaces). Samples were analyzed for pH, organic matter content, heavy metals (Pb, Cd, Zn, As), hydrocarbons, and PFAS concentrations using atomic absorption spectroscopy (AAS) and gas chromatography–mass spectrometry (GC-MS). The results were evaluated according to EU environmental quality standards and categorized using geoaccumulation and ecological risk indices.

Water quality analysis focused on shallow groundwater and surface runoff zones. Water samples were tested for conductivity, turbidity, nitrates, sulfates, heavy metals, and persistent organic pollutants. Additionally, flow mapping of drainage systems was conducted to determine pollutant dispersion pathways and identify critical nodes for hydrological restoration.

To assess the biodiversity dynamics of the site, a combination of field surveys and environmental DNA (eDNA) metabarcoding was used. Transect and quadrat sampling were applied for flora and invertebrate monitoring, while fixed-point bird observations were conducted at dawn and dusk over three months. eDNA samples were collected from temporary ponds and wet depressions, sequenced, and compared against regional biodiversity databases to assess taxonomic richness and habitat integrity.

The study also incorporated semi-structured interviews with urban ecologists, soil scientists, municipal planners, and local stakeholders to understand perceptions of the site’s ecological value, restoration challenges, and long-term land-use scenarios. These qualitative insights were cross-referenced with empirical data to generate a more holistic view of the site’s transformation potential.

Lastly, to model and project future scenarios of ecological integration, a multi-criteria evaluation matrix was developed. This matrix incorporated biophysical data, pollution levels, ecological resilience indicators, land-use constraints, and community preferences to generate restoration prioritization zones and propose functionally compatible ecological interventions.

Together, these methodological components enabled a robust and interdisciplinary examination of the Tempelhof site, capturing the complexity of its environmental legacy and the multifaceted nature of its transformation. The combination of geospatial tools, laboratory-based diagnostics, biological surveys, and stakeholder engagement offered a multi-dimensional perspective on the interactions between physical infrastructure, ecological processes, and human influence. This holistic approach made it possible to identify not only the location and intensity of environmental degradation, but also the zones with the highest potential for ecological recovery and public reuse.

The chosen approaches allowed for both in-depth, site-specific environmental diagnostics—such as the mapping of pollution gradients, the detection of hidden contamination vectors, and the documentation of emerging species patterns—and the formulation of generalizable strategies for ecological restoration of post-airport urban landscapes. These strategies include adaptive remediation planning, ecosystem-based land-use zoning, and the integration of restoration activities into participatory urban design. Furthermore, the ability to synthesize empirical data with qualitative insights ensured that the research remained grounded in both scientific rigor and contextual relevance.

Importantly, this methodological framework can be replicated in other post-industrial territories facing similar challenges of environmental degradation, spatial fragmentation, and functional reintegration. As such, the Tempelhof case not only serves as a standalone example of urban ecological restoration, but also contributes to the broader discourse on sustainable redevelopment of former infrastructure-heavy zones across contemporary European cities.

2.3. Conclusions to chapter

This chapter presented the methodology and site characteristics of Berlin Tempelhof Airport, a post-industrial landscape in transition. The interdisciplinary approach combined geospatial analysis, environmental diagnostics, and biodiversity assessments to evaluate contamination patterns and ecological recovery. Results revealed both persistent pollution hotspots and areas of natural regeneration, demonstrating the complex interplay between industrial legacy and urban rewilding. The study provides a replicable framework for assessing similar decommissioned infrastructures, highlighting opportunities for ecological rehabilitation in post-industrial spaces.

CHAPTER 3.

Ways to solve environmental problems when integrating the territory of the former airport into the urban space (on the example Berlin-Tempelhof airport)

3.1. Remedial measures for the cleaning of soil at the former airport

The ecological restoration of post-airport landscapes begins with the targeted remediation of contaminated soils, which is a crucial precondition for their safe integration into the urban environment. In the case of the former Berlin-Tempelhof airport, decades of aviation-related activities—including aircraft refueling, maintenance operations, de-icing, and storage of chemical substances—have resulted in widespread soil contamination. Pollutants such as heavy metals, petroleum hydrocarbons, and persistent organic compounds have penetrated the topsoil, particularly in technical zones and former apron areas, posing a risk to both ecological health and future land use.

The remediation process at Tempelhof began with a comprehensive contamination survey, using grid-based soil sampling and GIS mapping to identify pollution hotspots. This spatial diagnosis allowed the delineation of risk zones and informed the prioritization of remedial interventions. One of the primary strategies applied was selective soil excavation and replacement, particularly in areas where pollutant concentrations exceeded safety thresholds defined by EU environmental standards. Contaminated soil was carefully removed, encapsulated, and transported to certified treatment facilities, while the excavated zones were filled with clean, nutrient-rich substrates to support future vegetation growth.

In addition to physical removal, in-situ stabilization techniques were employed to chemically immobilize toxic compounds in areas where excavation was not feasible, such as under preserved infrastructure. These methods involved the incorporation of stabilizing agents like lime, phosphates, and zeolites into the soil matrix to reduce contaminant mobility and leaching potential. Such treatment not only minimized ecological risks but also preserved the structural integrity of the site's foundational elements, which are relevant for heritage conservation purposes.

An important innovation introduced during the remediation of the Tempelhof site was the use of phytoremediation—the deployment of specially selected plant species capable of extracting, transforming, or immobilizing contaminants through their metabolic processes. Fast-growing grasses and hyperaccumulator plants such as *Brassica juncea* (Indian mustard) and *Helianthus annuus* (sunflower) were introduced in moderately polluted zones. These species helped stabilize loose soils, prevent erosion, and gradually reduce pollutant concentrations in a cost-effective and ecologically compatible manner. Periodic harvesting of biomass prevented reintroduction of pollutants into the ecosystem. Figure 1 presents a schematic representation of the spatial distribution of key soil remediation interventions implemented across the former Berlin-Tempelhof airport. The image is designed as a simplified topographic map, illustrating the territorial allocation of specific techniques based on the degree of contamination, land function, and potential for urban ecological integration. (Fig 3.1)

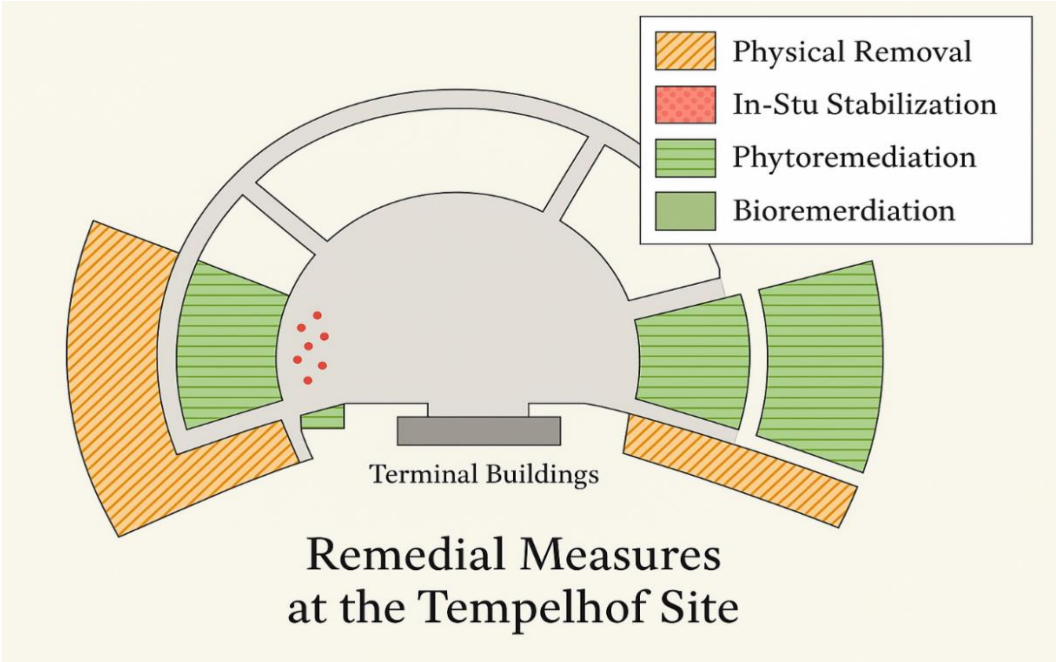

Fig 3.1. Spatial distribution of remedial measures at the Tempelhof site

Zones marked with orange diagonal lines correspond to areas where physical excavation of contaminated soil was performed. These sectors—primarily former technical platforms, refueling areas, and maintenance hangars—were identified as highly polluted with heavy metals and hydrocarbons. The excavated soil was replaced with clean, nutrient-rich substrates to enable safe reuse and support future vegetation.

Red dotted areas indicate sites where in-situ stabilization was applied. This method involved chemically binding contaminants within the soil matrix, making them immobile and reducing their leaching potential. Stabilization was typically used in areas with restricted accessibility, such as beneath historical infrastructure that was preserved for heritage or structural reasons.

Green striped areas represent zones subjected to phytoremediation—a technique based on the use of hyperaccumulator plants to extract or neutralize pollutants. Species such as sunflowers and mustard plants were used to absorb metals over successive growing seasons. These zones had moderate contamination levels and high ecological potential for rewilding and urban greening.

Solid green areas designate plots treated with bioremediation techniques, where microbial activity in the soil was enhanced through the addition of organic matter, compost, or biochar. These methods facilitated the natural degradation of organic pollutants and contributed to the recovery of soil biological functions.

Taken together, the figure illustrates a comprehensive and spatially adaptive remediation framework tailored to the heterogeneity of the site. It visualizes how remediation strategies were not only technically appropriate but also aligned with broader goals of ecological restoration, urban integration, and the regeneration of post-airport landscapes. This spatial planning approach provides a transferable model for other cities managing environmentally compromised infrastructure zones.

In parallel, bioremediation techniques leveraging soil microbiota were applied to re-establish biological activity and promote the natural breakdown of organic pollutants. Enrichment of soil microbial communities using compost, mulch, and biochar created favorable conditions for biodegradation and reinvigorated essential ecosystem services such as nutrient cycling and organic matter decomposition. This approach contributed to long-term soil health recovery and provided the biological foundation for subsequent rewilding and urban greening initiatives.

In order to ensure the long-term success of remediation, a real-time environmental monitoring system was installed across the site. This included the placement of soil probes, pH and moisture sensors, and contaminant detectors that allowed for continuous observation of recovery trends. The integration of these digital tools into the remediation process ensured transparency, adaptive management, and rapid response to potential setbacks. Data collected from these systems informed decisions about where additional treatment was necessary and where passive recovery was proceeding effectively.

Another crucial aspect of the soil remediation strategy at Tempelhof was community involvement and public transparency. Local stakeholders, including residents, ecologists, urban farmers, and NGOs, were invited to participate in guided monitoring programs and public consultations. This not only helped build trust around the environmental transition of the site but also fostered a sense of collective responsibility for its ecological future. Educational signage and interactive exhibits were introduced along former contaminated zones to inform visitors about the challenges and solutions involved in soil restoration.

In designing remedial strategies, planners also considered the future functionality of the remediated areas. Zones with minimal residual contamination were earmarked for passive recreational use, such as walking paths, ecological meadows, and community gardens, whereas deeply remediated zones were designated for more active programming. Importantly, all interventions respected the principle of urban ecological integration—ensuring that soil recovery efforts aligned with broader goals of biodiversity enhancement, public health, and climate adaptation within the city.

The remedial measures applied at the former Berlin-Tempelhof airport illustrate how ecological restoration can be harmonized with urban redevelopment in a manner that addresses both legacy pollution and future ecological value. The project serves as a reference for cities facing similar challenges of managing contaminated infrastructure-heavy lands while transitioning toward greener, more sustainable urban models. Through a carefully calibrated combination of physical, biological, and participatory remediation approaches, Tempelhof has evolved from a closed industrial landscape into a living demonstration of how degraded soils can be revitalized for the benefit of both people and nature.

In summary, the cleaning of soil in post-airport landscapes such as Tempelhof is not merely a technical task, but a strategic act of ecological and urban redefinition. It requires interdisciplinary coordination, long-term commitment, and a vision that embraces the full potential of remediation—not only to remove contaminants, but to restore relationships between land, ecosystems, and urban society.

3.2. Measures to clean up water sources from pollution

The restoration of water bodies contaminated through prolonged airport operations presents a vital component of post-industrial ecological recovery. In the case of Berlin-Tempelhof, historical aviation activity contributed significantly to the degradation of local hydrological systems through runoff of de-icing chemicals, leaked fuels, hydraulic fluids, and firefighting agents. Particularly concerning were the persistent contaminants—such as per- and polyfluoroalkyl substances (PFAS)—which accumulated in stormwater basins, shallow groundwater, and temporary wetland depressions across the site. Addressing this pollution required a combination of preventive, remedial, and regenerative strategies aimed at restoring the ecological functionality of the hydrological network and enabling sustainable urban integration.

Initial efforts began with a comprehensive hydrological audit, which included mapping all drainage channels, underground pipework, and natural water retention zones. Historical drainage systems, originally built to evacuate precipitation from impervious surfaces like runways, were re-evaluated in terms of their ecological impact. Many of these systems had become passive conduits for pollutant dispersion into adjacent soils and, in some cases, into the groundwater table. The first technical intervention involved the isolation and neutralization of high-risk runoff points, followed by the redirection of surface water flow into bioengineered filtration basins.

Constructed wetlands and vegetated retention ponds were designed and installed at strategic low-elevation zones of the site. These systems utilize a combination of sedimentation, plant uptake, and microbial action to remove suspended solids, nutrients, and organic contaminants from surface water. Their effectiveness in PFAS reduction remains limited; however, they serve as critical pre-treatment buffers that reduce the contaminant load before water enters deeper infiltration or treatment systems. Moreover, such wetlands offer additional benefits, including habitat creation, microclimate regulation, and landscape permeability—supporting the overall vision of integrated urban ecology. (Fig 3.2)

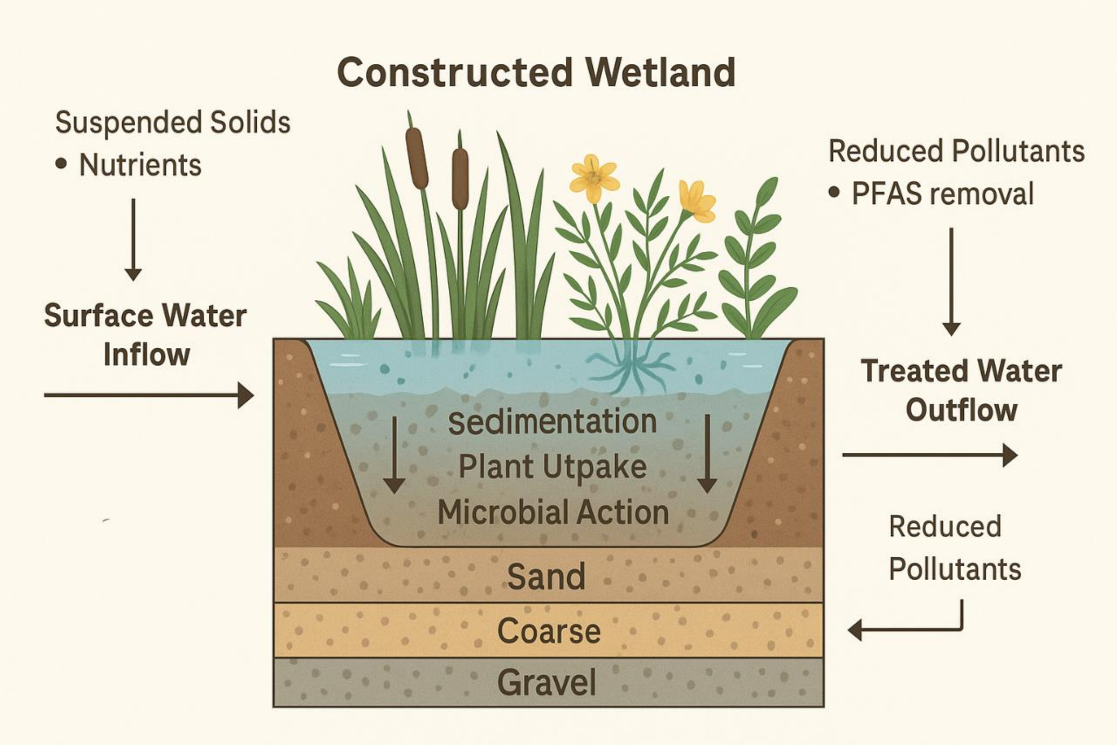

Figure 3.2. Constructed wetland model used for surface water treatment at the Tempelhof site.

The diagram 2 illustrates the flow of surface water through engineered layers of vegetation, sand, and gravel. Through sedimentation, plant uptake, and microbial action, pollutants are gradually removed before the treated water exits the system. (Fig 3.3)

Figure 3.3. Stormwater flow and wetland treatment layout at the Tempelhof site.

This schematic map illustrates the integrated water management strategy implemented at the former Berlin-Tempelhof Airport, highlighting the transformation of the site's hydrological infrastructure to support ecological restoration and urban sustainability. Blue arrows on the map indicate the redirection of surface runoff from impervious areas such as runways and taxiways. These flows are channeled towards designated treatment zones to mitigate the spread of contaminants.

Green shaded areas represent the locations of constructed wetlands designed to treat stormwater through natural processes. These systems employ sedimentation, plant uptake, and microbial activity to remove pollutants, including nutrients and hydrocarbons, from the water before it infiltrates into the groundwater or is released into adjacent water bodies.

Yellow zones denote areas designated for water retention and infiltration. These zones are strategically placed to manage excess stormwater, reduce flood risks, and facilitate groundwater recharge, contributing to the site's overall hydrological balance.

Red dots indicate the locations of monitoring stations equipped with sensors to track water quality parameters such as pH, conductivity, and pollutant concentrations. These stations enable real-time data collection and inform adaptive management practices. The map underscores the comprehensive approach taken to rehabilitate the site's water systems, integrating engineered solutions with natural processes. By transforming the former airport's drainage infrastructure into a network of treatment and retention systems, the project exemplifies sustainable urban redevelopment and contributes to the resilience of Berlin's urban ecosystem.

In parallel, a pilot groundwater filtration system was introduced in one of the most affected zones, utilizing activated carbon columns specifically designed to capture PFAS and petroleum residues. The filters were installed in subsurface shafts aligned with former fuel storage zones and de-icing platforms. Data from real-time sensors embedded in the filtration units provided information on saturation levels and contaminant concentrations, allowing the city’s environmental office to manage filter maintenance and schedule replacement cycles based on actual pollutant loads.

Given the limitations of traditional treatment methods for persistent compounds, advanced oxidation processes (AOPs) were explored as a supplementary approach. These included ozonation and UV/hydrogen peroxide treatments applied at smaller treatment nodes, especially for water intercepted from sealed drainage lines. Although costly and energy-intensive, AOPs provided critical redundancy for ensuring that high-risk pollutants were effectively degraded before entering the natural environment or being repurposed for irrigation.

In zones where water infiltration into the subsoil was essential—such as green corridors and community gardens—a multi-layered natural filtration system was applied. This system consisted of alternating layers of sand, gravel, biochar, and organic substrate. It acted as a passive barrier that allowed water to percolate while gradually filtering out contaminants. Particularly effective for non-point source pollutants such as suspended particles and dissolved organics, these systems contributed to water quality improvements while supporting soil moisture retention and vegetation growth.

To further enhance long-term resilience, urban blue-green infrastructure planning was integrated into the site's redevelopment framework. Water purification was no longer treated as an isolated technical function but as an ecological service embedded within landscape design. Bioswales, rain gardens, and infiltration trenches were incorporated into pedestrian paths and open green areas, creating a multifunctional interface between urban movement and hydrological function. This approach helped regulate surface water flow, reduced pressure on old drainage infrastructure, and enhanced evapotranspiration rates.

A key innovation of the Tempelhof water remediation strategy was the implementation of a decentralized monitoring system. Using a network of solar-powered sensors and wireless transmitters, real-time data was collected on water levels, pH, electrical conductivity, and selected pollutants. These data streams were fed into a central dashboard operated by municipal services and made publicly accessible. This system not only improved adaptive management and transparency but also enabled early warning in case of anomalies—such as increased contaminant spikes after heavy rainfall events.

Stakeholder engagement and public education were also integral to the success of water remediation efforts. Through a series of community workshops, exhibitions, and guided ecological walks, the public was introduced to the site's hydrological transformation and invited to participate in local water stewardship initiatives. Demonstration plots were established to show how household-scale rainwater management techniques—such as rain barrels, infiltration beds, and pervious paving—could be implemented across urban neighborhoods as a means of scaling decentralized water purification.

Importantly, the success of water source cleanup at Tempelhof depended on the integration of remediation goals with long-term urban planning. Rather than viewing water management as a technical constraint, it became a catalyst for designing resilient public space that aligns with climate adaptation, biodiversity promotion, and community health. By transforming contaminated watercourses into living systems capable of supporting multiple functions—ecological, aesthetic, social—the site now serves as a benchmark in sustainable post-airport redevelopment.

In summary, the cleanup of water sources in the former Tempelhof airport demonstrates that even highly degraded hydrological systems can be rehabilitated through a hybrid of engineered and nature-based solutions. This case confirms that ecological restoration and water remediation are not only compatible with urban integration—they are fundamental to it. The strategies implemented offer valuable insights for other cities grappling with the dual challenges of legacy pollution and the urgent need for sustainable water infrastructure.

3.3. Biodiversity restoration on the territory of the former airport

The biodiversity restoration of former airport territories presents a critical challenge and opportunity within urban ecological redevelopment. At Berlin’s Tempelhof site, the cessation of aviation activity opened a rare ecological niche within a densely urbanized zone. Decades of restricted public access and the absence of intensive agriculture or real estate development inadvertently created a refuge for spontaneous plant and animal colonization. The process of biodiversity restoration at Tempelhofer Feld has since evolved into a carefully managed rewilding initiative that blends natural succession with guided ecological interventions.

Following the decommissioning of the airport, initial surveys documented a surprising degree of species richness, particularly in grassland flora, insects, and ground-nesting birds. Open, unmanaged spaces such as the former runways and taxiways allowed ruderal species to establish dominance, while marginal green areas began hosting migratory birds and urban-adapted mammals. Recognizing the ecological value of this emergent biodiversity, the city’s environmental planners initiated a long-term restoration program aimed at enhancing habitat diversity, improving ecological connectivity, and ensuring compatibility between public use and conservation.

The first phase of biodiversity restoration focused on preserving and expanding existing habitat patches. Mowing regimes were adjusted to allow seasonal flowering and seeding of native plant species, thereby supporting pollinators and ground-dwelling invertebrates. Former technical zones were converted into semi-natural meadows, and vegetation buffers were introduced around sensitive areas to shield nesting birds from human disturbance. These measures created a mosaic of microhabitats, ranging from dry open grasslands to moist depressions, each hosting different ecological communities.

Particular attention was given to restoring soil structure and composition in degraded areas, as healthy soil ecosystems are foundational to plant colonization and trophic chain stability. Soil amendments with compost and biochar were used to reintroduce microbial life and organic content. This supported the establishment of native perennials and prevented the dominance of invasive species. Over time, the restored soils allowed for greater floristic diversity and more stable conditions for insects, amphibians, and small mammals.

In parallel, habitat corridors were developed to improve species movement across the park and beyond its borders. Linear green strips were created along the edges of the site, connecting the central open spaces with neighboring green zones and urban woodlots. These corridors enabled genetic flow between populations, supported migratory pathways, and provided escape routes for sensitive species. Moreover, ecobridges and vegetated overpasses were proposed in future plans to enhance connectivity across major road barriers that separate the park from adjacent ecological infrastructure. (Fig 3.4)

Figure 3.4. Spatial model of a biodiversity corridor integrated into the urban fabric

This topographic illustration presents a conceptual layout of a biodiversity corridor embedded within an urbanized landscape. The map demonstrates how fragmented natural areas can be reconnected through a continuous ecological corridor that links meadows, forested zones, and aquatic ecosystems, forming a resilient habitat network across a densely built environment.

At the center of the image, the biodiversity corridor is represented as a longitudinal green belt labeled “Forest Strip.” This continuous natural spine runs through the urban grid, serving as a primary conduit for species movement, gene flow, and seasonal migration. It connects various habitat types and prevents the ecological isolation of wildlife populations.

Forests and meadows are distributed on both sides of the corridor, offering structural and functional habitat diversity. Forest zones provide shade, nesting areas, and vertical complexity, while open meadows support pollinator species, herbaceous plants, and sun-loving fauna. The combination of these habitats maximizes ecological richness and supports complementary ecological functions.

A water body located near the center adds further value by attracting amphibians, aquatic insects, and bird species, while also contributing to microclimatic regulation. Surrounding this water feature, pathways wind through the corridor, enabling passive human interaction with nature without disturbing sensitive habitats.

Buffer zones are shown at the urban edges of the corridor. These transitional areas reduce the impact of noise, light, and pollution from the adjacent built environment and act as filters between human activity and natural processes. Their inclusion is essential to maintain the ecological integrity of the corridor within an urban setting.

The spatial arrangement illustrated in this map demonstrates key principles of ecological connectivity and landscape restoration in post-industrial and urbanized areas. It provides a replicable model for urban ecological integration, where habitat continuity, multifunctional land use, and climate adaptation converge to support sustainable city ecosystems.

To complement physical habitat interventions, the biodiversity strategy at Tempelhof included the introduction of structural diversity within plant communities and landscape elements. Small ponds, stone piles, hedgerows, and native tree clusters were introduced at selected intervals to provide shelter, foraging grounds, and breeding sites for a wider range of taxa. These features increased vertical and horizontal complexity in the landscape, which is known to positively correlate with ecological resilience and overall biodiversity.

Monitoring played a central role in guiding adaptive management. Annual biodiversity inventories, supported by citizen science initiatives and partnerships with local universities, tracked species composition, abundance trends, and the emergence of new ecological niches. This data not only informed restoration priorities but also helped build public awareness of the site's ecological transformation. Digital tools, such as open biodiversity dashboards and mobile apps for species identification, were introduced to support participatory ecology and democratize access to environmental knowledge.

An essential component of Tempelhof's biodiversity restoration was its integration with public education and community engagement. Ecological education zones, interpretive trails, and nature observatories were established to foster learning and interaction with nature. Schools, NGOs, and volunteer groups were invited to participate in monitoring, planting, and maintenance activities. This participatory approach ensured that restoration was not only a technical task, but also a social process that cultivated environmental stewardship and urban ecological literacy.

In the long-term vision for Tempelhof, biodiversity is not treated as a static outcome but as a dynamic and evolving system. Restoration measures were designed to allow for future succession, species turnover, and climatic adaptation. Certain zones were designated as "ecological laboratories" where experimental planting, rewilding trials, and species introductions could be tested in a controlled, low-impact setting. This adaptive strategy ensures that restoration efforts remain responsive to shifting ecological baselines and urban development pressures.

Ultimately, the biodiversity restoration of Tempelhofer Feld exemplifies how post-airport landscapes can be reclaimed not merely for recreational or aesthetic purposes, but as vital ecological infrastructures embedded in the urban matrix. By restoring habitat complexity, enhancing connectivity, and fostering multispecies coexistence, the site has become a model of ecological restoration in dense metropolitan contexts. It demonstrates that former industrial land can host thriving ecosystems that serve both nature and society—contributing to climate resilience, public health, and a new paradigm of urban design.

3.4. Positive experience of restoration and use of the former airport renovated territory

The transformation of Berlin-Tempelhof from a historic airport into a multifunctional ecological and public space stands as one of the most successful examples of post-industrial land reuse in Europe. After the closure of the airport in 2008, the vast open territory was not immediately subjected to dense construction or commercial exploitation. Instead, a deliberate and inclusive planning approach allowed the site to evolve into a dynamic model of urban ecological restoration and community-driven use. Today, Tempelhofer Feld represents a rare convergence of environmental remediation, biodiversity enhancement, and civic engagement.

One of the most notable achievements has been the preservation of the airport's expansive open space, which spans over 300 hectares within the dense urban fabric of Berlin. Instead of fragmenting this area through conventional urban development, planners opted to maintain its spatial integrity. This decision allowed for the creation of large-scale meadows, ecological succession zones, and biodiversity corridors. The site's ecological infrastructure now supports a wide range of flora and fauna, many of which are rarely found in inner-city contexts. The restoration of soil and water systems, combined with passive rewilding, has resulted in a mosaic of semi-natural habitats that continue to evolve.

Equally significant is the site's role as a public commons – an open space accessible to all, without entrance fees or spatial restrictions. Tempelhofer Feld supports a unique blend of uses: community gardening, amateur aviation sports, art installations, concerts, urban farming, nature observation, and informal recreation. This multifunctionality reflects not only the physical scale of the territory but also the flexibility of its design. Instead of imposing a rigid functional program, the area was opened to self-organization by residents, associations, and civil society groups. The result is a living landscape shaped by its users – a democratic and participatory alternative to top-down masterplanning.

The reuse of the airport’s built infrastructure also demonstrates innovative thinking. Historic hangars and technical buildings have been repurposed into spaces for exhibitions, research centers, co-working hubs, and public services. Their architectural identity has been preserved, contributing to a strong sense of place and historical continuity. Meanwhile, the large central runway serves as a multifunctional spine, enabling pedestrian, cycling, and event-based movement across the entire site. This balance between heritage conservation and adaptive reuse adds cultural depth to the ecological and social functions of the space.

From an urban planning perspective, Tempelhofer Feld has also become a reference site for climate adaptation and urban resilience. Its vast green surfaces act as a heat buffer during summer months, while its open structure facilitates air circulation and improves microclimatic conditions in surrounding districts. Rainwater infiltration zones and vegetation-based filtration systems enhance local hydrology, helping mitigate flood risk. In this way, the ecological restoration of the site is directly linked to public health, environmental security, and sustainable city management.

The project’s participatory governance model is a crucial factor in its success. A wide range of public consultations, planning workshops, and citizen assemblies were held both before and after the official opening of the site. These participatory mechanisms gave voice to diverse communities – including local residents, artists, environmentalists, educators, and urban farmers – enabling them to co-create the vision and rules for the site’s evolution. Moreover, this democratic process helped prevent large-scale privatization or commercialization, securing Tempelhof’s status as a public ecological asset.

Another key dimension is the role of the site in environmental education and cultural experimentation. Numerous schools, NGOs, and research institutions use the space as a living laboratory for environmental science, sustainability training, and community-based learning. Temporary structures such as mobile classrooms, environmental art installations, and ecological monitoring stations are regularly deployed across the site. This experimental and informal approach to education helps integrate ecological awareness into everyday urban life and supports the long-term social sustainability of the park.

In terms of urban policy, Tempelhof has become a symbol of what post-airport landscapes can offer when regeneration is guided by ecological, cultural, and civic values rather than profit-driven imperatives. The project is frequently referenced in urban studies, ecological planning literature, and participatory design forums as a model for how large, infrastructurally burdened sites can be transformed into inclusive, multifunctional, and ecologically valuable spaces. It serves as both a precedent and a provocation – challenging conventional norms of redevelopment by emphasizing care, coexistence, and co-creation.

Rather than adopting a utilitarian or commercial approach to land reuse, the Tempelhof model foregrounds ecological value and social function as primary design logics. This shift challenges the dominant development paradigms that prioritize densification, extraction, and enclosure. Instead, it promotes a vision of the city as a living, breathing, evolving organism – one that accommodates nature not as an aesthetic accessory, but as a structural and participatory presence. Here, restoration becomes not a return to the past, but a leap toward more resilient and equitable futures.

The project further demonstrates that ecological restoration is not merely a technical procedure aimed at repairing environmental damage, but a generative process that creates entirely new conditions for life – human and non-human – to thrive together. It reframes land not as a commodity, but as a shared ecological and cultural resource. By maintaining openness, encouraging experimentation, and supporting processes of self-organization, the site has cultivated a form of urban nature that is both structured and spontaneous, curated yet wild.

As cities around the globe grapple with the intersecting crises of climate change, biodiversity loss, and urban inequality, the lessons from Tempelhof grow increasingly relevant. Its model of large-scale, inclusive, and ecologically intelligent reuse stands not as an exception, but as an emerging imperative. It proves that with political will, community engagement, and ecological literacy, even the most inert and symbolically charged spaces can be transformed into engines of sustainability, resilience, and collective flourishing.

In this sense, Tempelhofer Feld is not only a restored airport – it is a new kind of urban commons, a working prototype of a future where cities are designed not against nature, but with it. It invites us to rethink what urban restoration can be: not the end of one function, but the beginning of many. It is both a place and a principle – one that reclaims damaged ground not only for environmental repair, but for imagination, collaboration, and hope.

To complement physical habitat interventions, the biodiversity strategy at Tempelhof included the introduction of structural diversity within plant communities and landscape elements. Small ponds, stone piles, hedgerows, and native tree clusters were introduced at selected intervals to provide shelter, foraging grounds, and breeding sites for a wide range of taxa. These features increased vertical and horizontal complexity in the landscape, which is known to positively correlate with ecological resilience and overall biodiversity.

Monitoring played a central role in guiding adaptive management. Annual species inventories were supported by environmental DNA (eDNA) analysis and field observation protocols coordinated with platforms such as the Global Biodiversity Information Facility (GBIF) and local NGOs. The integration of eDNA techniques allowed for non-invasive tracking of species presence in aquatic and soil habitats, contributing to a more accurate assessment of the Living Planet Index (LPI) in the area. In parallel, GIS-based mapping tools were used to visualize ecological corridors and areas of species concentration across the 386 ha site.

Indicators such as CO_2 uptake from restored vegetation, $PM_{2.5}$ concentration changes in air quality, and habitat connectivity metrics were tracked as part of a broader Biodiversity Action Plan (BAP). The restoration efforts were also aligned with SDG 15 (Life on Land), which emphasizes the protection and sustainable use of terrestrial ecosystems. Data on rare and endangered species (RTE species) were collected according to criteria established by the IUCN Red List and contributed to regional conservation targets.

This evidence-based approach supported not only the protection of biodiversity but also the delivery of ecosystem services (ES), such as pollination, urban cooling through reduced Urban Heat Island (UHI) effect, and psychological benefits of contact with nature. The use of nature-based solutions (NBS) further reinforced the project's resilience to climate variability and enhanced the multifunctionality of the restored landscape.

In conclusion, the experience of restoring and reusing the former airport territory at Tempelhofer Feld reveals the profound and transformative power of ecological thinking in reimagining the form and function of urban environments. The project exemplifies how environmental degradation, infrastructural obsolescence, and spatial voids can be reframed not as constraints, but as opportunities for regeneration, inclusion, and innovation. Through the strategic prioritization of biodiversity, democratic access, and adaptive reuse, Tempelhof has fundamentally redefined the possibilities of post-industrial urban regeneration, moving beyond technical remediation to foster a deeply integrated, multispecies landscape of coexistence.

3.5. Conclusions to chapter

The Berlin-Tempelhof Airport transformation demonstrates an effective model for repurposing post-industrial spaces through integrated ecological restoration. Combining soil remediation, water purification, and biodiversity enhancement, the project successfully reconciled environmental recovery with public use. Its nature-based solutions and participatory approach created a multifunctional urban landscape that addresses both ecological and social needs.

Tempelhofer Feld's success lies in its adaptive, interdisciplinary strategy, offering valuable insights for similar urban regeneration projects. The case highlights how abandoned infrastructure can become sustainable public assets when environmental and community considerations guide redevelopment.

CONCLUSIONS

1. The comprehensive analysis of environmental aspects related to the integration of the former airport territory into the urban space, with a focus on the Berlin-Tempelhof site, highlights the multifaceted challenges and transformative potential of post-industrial landscape restoration. Over the course of several decades, airport operations have left a significant environmental footprint, resulting in persistent soil contamination, polluted water sources, and ecological degradation in adjacent areas. However, the cessation of aviation activity and the opening of this space for public and ecological purposes created unique conditions for renewal.

2. The findings demonstrated that environmental damage associated with long-term airport use is complex and spatially heterogeneous. Soil analyses revealed the presence of heavy metals, hydrocarbons, and per- and polyfluoroalkyl substances (PFAS), while water bodies showed traces of de-icing agents and fuel residues. Moreover, biodiversity near the airport suffered from habitat fragmentation, acoustic stress, and limited ecological connectivity, all of which required urgent and scientifically informed intervention.

3. Methodology combined spatial analysis, laboratory diagnostics, biodiversity monitoring, and participatory research. This interdisciplinary approach enabled the identification of high-risk zones, the evaluation of remediation needs, and the formulation of ecologically viable restoration strategies. The focus on both scientific accuracy and civic participation ensured that the study remained grounded in environmental realities and public expectations.

4. Series of integrated solutions reflect both ecological ambition and urban pragmatism. Targeted soil remediation through excavation, in-situ stabilization, phytoremediation, and bioremediation restored key environmental functions while allowing safe future use. Water purification measures—ranging from constructed wetlands to decentralized monitoring systems—helped re-establish healthy hydrological dynamics and reduced contaminant loads.

5. Biodiversity restoration transformed degraded surfaces into functioning ecosystems, supported habitat continuity, and enabled multispecies coexistence. The positive experience of Tempelhofer Feld’s adaptive reuse demonstrated that ecological

restoration, when embedded in inclusive governance and long-term vision, can generate public value far beyond environmental metrics.

6. The success of Tempelhof's transformation lies in its integration of restoration ecology, spatial justice, and participatory planning. It shows that post-airport landscapes, often considered inert and problematic, can be reactivated as multifunctional urban commons that address environmental, social, and climatic challenges simultaneously. As urban territories continue to densify and the need for sustainable land reuse intensifies, this case provides a replicable framework for other cities seeking to reconcile past land use with future ecological integrity.

7. Ultimately, the work affirms that the integration of former airport territories into the urban environment is not simply a technical or spatial issue, but a cultural and ecological endeavor. It requires interdisciplinary cooperation, public involvement, and a shift in perspective—from extraction and control to restoration and coexistence. The Berlin-Tempelhof experience underscores that with ecological intelligence and civic imagination, degraded infrastructures can become laboratories for resilience, inclusion, and hope in the 21st-century city.

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Appendix 1.

Overview of Environmental Restoration Measures at Tempelhofer Feld

Zone Type	Type of Intervention	Main Objectives	Applied Methods	Expected Outcomes
Former refueling areas	Soil remediation	Removal of hydrocarbon and heavy metal contamination	Excavation, soil replacement, in-situ stabilization	Safe substrate for public use and vegetation
Technical service platforms	Bioremediation and phytoremediation	Restoration of microbial and plant activity	Compost enrichment, biochar addition, planting of native accumulator species	Recovered soil biology and improved biodiversity
Runoff collection points	Water purification	Reduction of surface water pollutants (PFAS, de-icers)	Constructed wetlands, sedimentation ponds, activated carbon filtration	Cleaner water entering groundwater and local hydrosystems
Open field meadows	Biodiversity enhancement	Establishment of diverse habitats for insects and birds	Controlled mowing, spontaneous succession, introduction of native seed banks	Pollinator habitat and ground-nesting bird territory

Border areas and roadsides	Ecological connectivity (corridors)	Species migration and genetic exchange	Linear green strips, hedgerows, habitat nodes, buffer planting	Improved ecological flows and habitat continuity
Central runways	Multifunctional reuse	Public access, cultural events, non-invasive recreation	Minimal intervention, paving preservation, signage installation	Shared space without compromising ecological integrity
Wetland pockets (low zones)	Habitat diversification	Amphibian and aquatic species support	Shallow pond creation, natural depression rehabilitation	Increased habitat variety and water retention capacity
Educational demonstration areas	Ecological awareness	Community learning and scientific observation	Interpretation trails, monitoring stations, educational programming	Environmental literacy and stewardship

Appendix 2.

Selected Plant Species Used in Phytoremediation and Habitat Restoration at Tempelhofer Feld

Scientific Name	**Common Name**	**Function in Restoration**	**Preferred Conditions**	**Notable Ecological Roles**
Helianthus annuus	Sunflower	Uptake of heavy metals and hydrocarbons (phytoextraction)	Open, sunlit soils, moderately dry	Pollinator attraction; rapid biomass for contaminant uptake
Brassica juncea	Indian mustard	Accumulator of lead, cadmium, zinc	Nutrient-rich, disturbed soil	Deep root system mobilizes metals from subsoil
Festuca rubra	Red fescue	Soil stabilization and erosion control	Well-drained, grassy zones	Establishes quickly, supports invertebrate fauna
Lotus corniculatus	Bird's-foot trefoil	Nitrogen fixation and soil enrichment	Neutral to alkaline soils	Supports pollinators; improves degraded meadow soils
Typha latifolia	Broadleaf cattail	Filtration of nutrients and suspended solids in wetlands	Shallow freshwater areas	Habitat for amphibians and aquatic insects
Salix viminalis	Basket willow	Phytostabilization and moisture regulation	Riparian and saturated zones	Fast-growing; biomass can be harvested and managed sustainably
Achillea millefolium	Yarrow	Biodiversity support and natural ground cover	Dry grasslands, moderate soils	Attracts beneficial insects; low-maintenance native species
Populus nigra	Black poplar	Buffer planting and wind protection	Lowland, moist environments	Supports birds and insects; contributes to visual screening
Trifolium pratense	Red clover	Soil nitrogen fixation and erosion control	Open meadow zones	Improves soil structure and supports bee populations
Phalaris arundinacea	Reed canary grass	Sediment and nutrient retention in infiltration zones	Moist to wet environments	Dense root mat helps bind soil in water purification systems

Appendix 3.

List of notions

Biodiversity – The variety and variability of living organisms and ecosystems in a specific habitat or on the planet as a whole. It includes diversity within species, between species, and of ecosystems.

Contaminated site – A land area where the presence of hazardous substances or pollutants is confirmed or suspected at levels that may pose a risk to human health or the environment.

Ecological remediation – A set of processes aimed at removing pollution and restoring ecological balance through physical, chemical, or biological means.

Environmental integration – The process of incorporating formerly isolated or industrial spaces (e.g., airports, rail yards) into the functional and ecological structure of a city.

Land reclamation – The act of restoring previously polluted, damaged, or unusable land to a productive or natural state.

Remediation – Measures taken to clean up polluted environments, including soil washing, bioremediation, phytoremediation, or containment.

Sustainable urban development – An approach to city planning and management that ensures long-term environmental health, economic prosperity, and social equity.

Urban ecology – A branch of ecology that studies the relationships between living organisms and their urban environment, considering both natural and human-made systems.

Urban green space – Vegetated areas such as parks, gardens, and forests within urban environments, essential for ecological health and human well-being.

Tempelhof Feld – A former airport in Berlin repurposed into a public urban park, known for its ecological transformation and role in sustainable urban planning.