WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945
DOI: 10.24425/ace.2025.156169
ARCHIVES OF CIVIL ENGINEERING
Vol. LXXI ISSUE 4 2025

pp. 267 –281

Review paper

Transformation of degraded and unused post-railway areas for the Arkadia Shopping Center in Warsaw

Fabiana Raco[1], Aleksander Nicał[2]

Abstract: Degraded post-railway areas are a significant spatial and environmental problem in the centers of large cities, limiting their development and aesthetics. These areas often contain historical pollutants that can pose a threat to human health and the natural environment. Revitalization of such areas contributes to the rational management of urban space and limits the sprawl of development into suburban areas. Transforming unused areas into modern service spaces, such as the Arkadia Shopping Center, promotes the socio-economic activation of a given district. The Arkadia project shows that properly conducted reclamation allows for the safe and effective use of degraded land. Additionally, such investments increase the value of nearby properties and improve the quality of life of residents thanks to new service, commercial and recreational functions. The transformation of post-railway areas responds to the contemporary challenges of sustainable urban development and environmental protection. Good revitalization practices, as in the case of Arkadia, can serve as a model for other cities struggling with similar spatial problems. The project is an example of an effective combination of engineering, planning and environmental activities. Analyzing the transformation process of this area allows for a deeper understanding of the benefits, challenges and conditions necessary for the success of similar revitalization projects.

Keywords: Arkadia Shopping Center, degraded area, reclamation, remediation, research, soil pollution

[1]Architect, PhD., Department of Architecture of the University of Ferrara, Via Ludovico Ariosto, 35 – 44121 Ferrara, Italy, e-mail: fabiana.raco@unife.it, ORCID: 0000-0002-6647-0422
[2]PhD., Eng., Warsaw University of Technology, Faculty of Civil Engineering, Al. Armii Ludowej 16, 00-637 Warsaw, Poland, e-mail: aleksander.nical@pw.edu.pl, ORCID: 0000-0001-7124-4481

1. Introduction

The revitalisation of degraded areas in cities has a very significant impact on their development [1]. The subject of revitalisation of post-railway areas has been addressed in many studies in Poland and abroad. The process of revitalisation of post-industrial areas in Skierniewice, with an emphasis on environmentally friendly elements, was discussed already in 2018 [2]. The authors proposed actions aimed at transforming degraded areas into public spaces that will support social integration and improve the quality of life of residents. The process of revitalisation of post-railway areas in Kraków, with particular emphasis on the Bagry-Bieżanów area, was an issue described in 2019 [3]. A spatial development concept was proposed at that time, taking into account functional, aesthetic and social aspects. The aim of the study was to transform the degraded area into a public space that would serve residents and tourists. In Germany, the subject of revitalisation of post-railway areas was discussed in 2017 and concerned the city of Leipzig [4]. The author analysed the spatial and functional changes that aimed to transform the degraded areas around the railway station into a modern urban space. The aspect of revitalization for improving the quality of life of residents and the attractiveness of the city was additionally emphasized. The process of transforming abandoned railway lines into green corridors in Zhangjiakou, China [5]. The authors studied the ecological and social benefits resulting from such revitalization, indicating the improvement of the quality of the urban environment and the increase in the attractiveness of public spaces. In the USA, the issue of transforming degraded railway areas was addressed, among others, in projects in Boston, Gainesville, Minneapolis, New York and Washington, identifying six typologies of such projects [6]. Legal and policy issues related to the preservation and reuse of abandoned rail corridors in Texas and the challenges associated with land acquisition, environmental protection, and conversion to recreational or transportation routes are areas of research in this area [7]. Moreover, sites such as post-industrial, post-military, post-oil, and post-harbour areas are particularly significant in terms of current urban needs [8]. This subject is gaining increasing attention in the context of ongoing urbanization and the growing demand for new urban spaces. Post-harbour zones, in particular, stand out due to their aesthetic appeal, environmental potential, recreational opportunities, and strategic locations. As a result, various development strategies have been proposed for these areas – ranging from residential developments, waterfront parks, public spaces, and service zones that generate employment, to land reserves intended for use during emergencies like pandemics [9] or refugee crises [10]. The complexity and importance of effectively managing these port and post-port territories have even led to the emergence of a dedicated scientific discipline: port geography [11]. It should be noted that the selection of redevelopment technologies, including the transformation of degraded areas, along with the optimization of construction schedules is carried out using artificial intelligence [12, 13].

2. Definitions of terms

2.1. General notice

The term "reclamation", as used in the Arkadia project documentation, corresponds to the term "remediation" introduced in the Environmental Protection Law Act of 27 April 2001 (Journal of Laws 2024, item 54). Additionally, the term "reclamation" has been used in regulations issued by the Ministry of Agriculture concerning soil quality. The definitions of these terms are provided below.

2.2. Reclamation

During the implementation period of the project (2002–2004), the term "reclamation" appeared in legal acts pertaining to the restoration of environmentally degraded areas. It was defined as the process of rehabilitating land adversely affected by human activity, aiming to restore its original function, utility, and natural value to a condition as close as possible to its original, undisturbed state [14].

2.3. Remediation [15]

The Act of 27 April 2001 – Environmental Protection Law (Journal of Laws 2024, item 54) introduced the concept of remediation defined as follows.

31b The concept of remediation – means the subjection of soil, earth and groundwater to activities aimed at removing or reducing the amount of substances causing risk, controlling them and limiting their spread, so that the contaminated area ceases to pose a threat to human health or the state of the environment, taking into account the current and, if possible, planned future use of the area; remediation may consist in self-cleaning if it brings the greatest benefits to the environment.

The concept of remediation appears in the following legal acts:

- Environmental Protection Act of 27 April 2001,
- Act on the prevention of environmental damage and its remediation of 13 April 2007 (the so-called "damage" act),
- Amendment to the Environmental Protection Act, adopted in August 2014,
- Regulation of the Minister of the Environment of 1 September 2016 on the method of conducting the assessment of ground surface contamination (Journal of Laws 2016, item 1395).

2.4. Water permeability (filtration) coefficient of soils

The tables defining the permissible level of contamination provide it depending on the water permeability/filtration index, which is determined in the laboratory based on the water permeation time test. The index depends mainly on the physical properties of the soil – the soil's ability to let water through the system of interconnected pores. The filtration coefficient (k) (Darcy's constant) for specific soils are as follows (Table 1) [16].

Table 1. Filtration coefficients for selected soil categories

No.	Type of soil	Filtration coefficient
1	Medium: fine-grained sands, loess	10^{-5}–10^{-4}
2	Poor: silty sands, clayey silts, sandstones, massive rocks with a sparse network of small cracks	10^{-6}–10^{-5}
3	Semi-permeable rocks: clays, siltstones, silts, sandy loams	10^{-8}–10^{-6}

For the area under the Arkadia Shopping Center, the indicator was 1×10^7 (permeable soils) [17].

3. General characteristics of the investment Arkadia shopping center

Arkadia Shopping Center (hereinafter: C.H. Arkadia or Center) was built in the years 2002–2004 at the Zgrupowania A.K. “Radosław” roundabout, at the intersection of Jana Pawła II, Słonimskiego and railway tracks on an area of over 15 ha. The designers of the facility – built in the concept of combining American shopping centers with the European tradition of urban passages with cultural and recreational functions – were companies from Western Europe, including:

- Jamie PETT, Gordon GODAT – RTKL, main concept of exterior and interior design,
- Guillaume SADOUX – BEG INGENIERIE, adaptation and implementation.

The contractors were Polish companies including:

- Korporacja Radex S.A. Consortium – Warbud SA – skeleton (steel and reinforced concrete structures), – GW,
- Rossi – Teramtex (Kielce) – roof, insulation – as a subcontractor of the consortium,
- Defor (Poznań) – skylights, curtains – as a subcontractor of the consortium,
- POL-Aqua – roads and Plaza,
- Hadart – fountain and green areas, Plaza,
- Ineo (Polish-French company), Elektromontaż (Kraków) – electrical installations,
- Korporacja Radex S.A. – project coordinator,
- Karmar S.A.

The construction of the Arkadia Shopping Center at the turn of the 20th and 21st centuries – offering a broad spectrum of commercial and cultural services – on the border of the Śródmieście and Żoliborz districts, along the route connecting Praga via the Gdański Bridge (Zygmunta Słonimskiego Street) with Jana Pawła II Avenue, Okopowa Street, and Powązkowska Street, represented a significant milestone in the post-transformation urban development of Warsaw. Today, it serves as the primary service facility in the northern part of the city.

The development plan capitalized on the existing transportation infrastructure, with the main entrance situated at the A.K. “Radosław” Roundabout. The layout of the facility follows a triangular plan, adapted to the site’s spatial constraints, with shopping arcades forming the triangle’s sides and a central open plaza – resembling a traditional marketplace – occupying its core.

A noteworthy feature of the facility is Arkadia's extensive "green roof", covering an area of 47,000 m^2 . This roof is layered with soil, enabling rainwater retention, reducing dust and atmospheric pollution, and providing additional thermal and acoustic insulation. It is equipped with an automated irrigation system, including moisture sensors. The soil layer supports plant growth and creates a habitat conducive to insect life.

The service values of Arkadia Shopping Center after the facility was opened in 2004 were characterized by the following parameters:

– A shopping and service gallery with an area of 130,000 m^2, including approximately 230 shops and 25 restaurants,
– A multifunctional entertainment complex with an area of: 30,000 m^2, including Multiplex Cinema City with 15 screens,
– A hotel and office complex with an area of 70,000 m^2,
– An administrative and office complex with an area of 40,000 m^2.

A complex of underground car parks with an area of 180,000 m^2 (6,000 parking spaces).

Usable area of the facilities: – buildings: 270,000 m^2.

Total area of the facilities: – buildings: 310,000 m^2.

During the operation of C.H. Arkadia is being gradually expanded. In 2014–2017, additional space was built in the "western wing", an additional floor was built on part of the building, and additional entrances to the parking lots were made from Słonimskiego Street. The front of C.H. Arkadia is shown in the Fig. 1 [18].

Fig. 1. Entrance to C.H. ARKADIA from the roundabout of the A.K. "Radosław" grouping [18]

4. Soil pollution study

4.1. General description

Given that the Arkadia Shopping Center investment was located on land previously used for over a century as a railway siding – where bulk materials, including fuels, were transshipped – the investor was required to conduct investigations as part of the geotechnical documentation. These investigations were carried out by the French firm Solen, following approval of the research scope by the Environmental Protection Department of the Warsaw City Office. Based on the findings, an application was submitted to the Mayor of Warsaw for approval of the reclamation project titled "Reclamation of the Land Surface within the Planned Multifunctional Development Complex in the Area of the Babka Roundabout and Gdański Railway Station." The conducted research, along with the Reclamation Project and accompanying drawings, form the foundation of this study.

4.2. Research procedure

The research procedure is following:

I. Soil classification

During the tests, the level of contamination was compared with the draft regulation of the Minister of the Environment on soil and earth quality standards of 11 February 2002, prepared on the basis of the Act of 27 April 2001 – Environmental Protection Law, in which standards were given for the following groups of land:

1. Group A – including land subject to protection under the provisions on water protection and nature protection.
2. Group B – including (among others) agricultural land, forest land, areas designated for housing development, cultural facilities, leisure facilities and recreational and leisure areas.
3. Group C – including (among others) industrial and communication areas, areas for development other than those listed in point 2, mining areas.

In accordance with the issued decision on the conditions of development and land management, the area subject to the test was classified to Group C. For further qualification, a water permeability test was performed on the soil and it was determined that it is permeable soil with a permeability index 1×10^7 [19].

II. Test procedure

Stage I – due to the historical use of the area for the reloading of bulk and petroleum products, the occurrence of contamination with petroleum substances and heavy metals was assumed.

Stage II – assessment of the soil contamination status was performed based on two stages of reconnaissance work. In the first stage, a regular drilling grid of 60×60 m was made, with a total of 37 holes with a depth of 3.0 to 5.0 meters. The soils did not show contamination with heavy metals. Macroscopic observations were carried out in the drill cores and samples were taken for laboratory tests.

In 20 samples, the content of heavy metals was determined: arsenic, cadmium, chromium, nickel, lead, zinc, mercury, and:

– testing of 16 aromatic hydrocarbon compounds,
– volatile organic chlorophyll compounds,
– PCBs compounds (a group of halogenated organic chemical compounds derived from biphenyl).

4.3. Research results from stage II

Anthropogenic soils (embankments) composed of demolition materials were identified at depths of 2 to 3 meters, in which no contamination by heavy metals or hydrocarbons was detected. Comparable results were observed in soil tests conducted down to 5 meters below ground level, except for a section of the plot measuring approximately 10,000 m^2. In this area, at depths between 2 and 4 meters below ground level, elevated concentrations of aromatic hydrocarbons, including naphthalene and BTEX compounds, were detected, ranging from 2,000 to 3,000 mg/kg – significantly exceeding the permissible contamination threshold of 10 mg/kg dry soil mass. Contamination levels varied across the affected zone, with higher contamination observed over 6,000 m^2 (zone I) and lower contamination across 4,000 m^2 (zone II). The total estimated volume of contaminated soil amounted to 10,000 m^3. The location of the contamination is depicted in a segment of the map covering the tested area (Fig. 2).

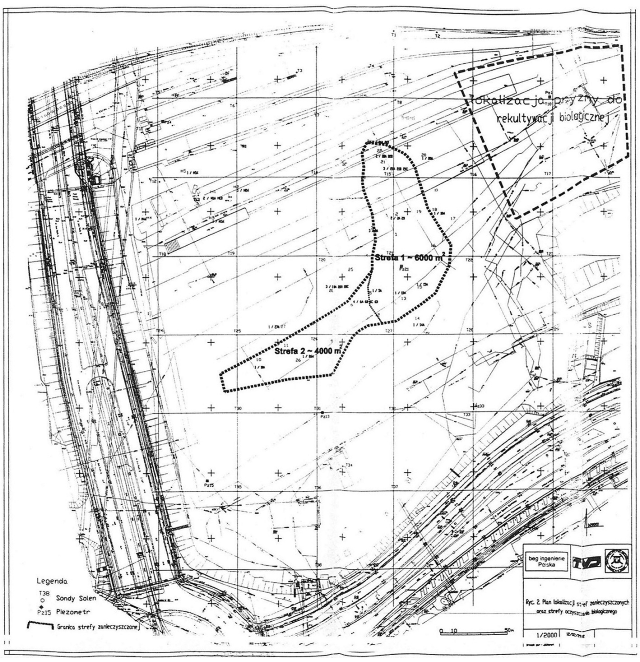

Fig. 2. Fragment of the map showing the location of contaminated soil [20]

The above-standard contaminations concerned aromatic compounds: Toluene, Ethylbenzene and Xylene, which are referred to as BETEX in the soil layer below 2.0 m above ground level.

The criterion for contaminated soil was the level of aromatic compounds: Betex >10 mg/kg dry mass. The density of the tests carried out is shown on the attached map in Fig. 3.

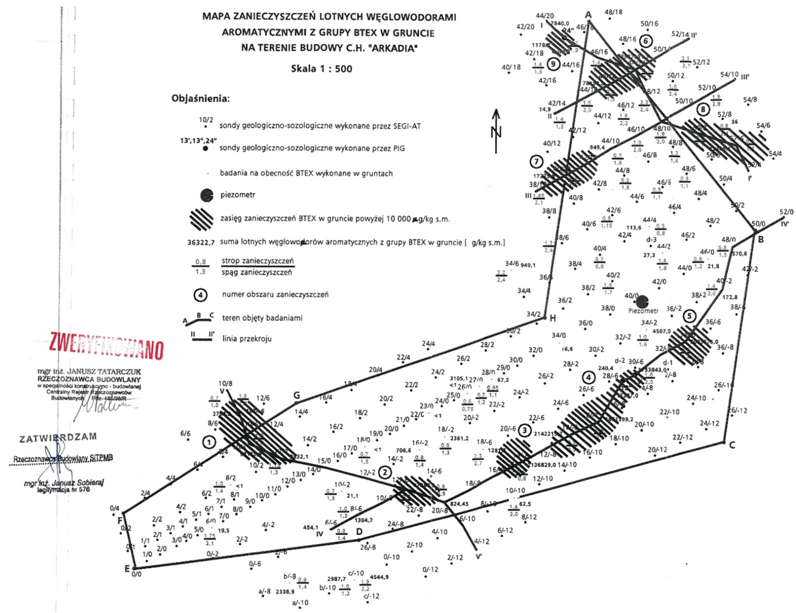

Fig. 3. Location of samples taken for testing [20]

The study results are presented in Table 2 below.

Table 2. Detailed research results

No.	Type	Level found in the study (mg/kg)	Permissible standard according to the draft regulation of the Ministry of National Health (mg/kg)	Notes
1	Arsenic	5.1	25	Below the standard
2	Cadmium	3.0	8	as above
3	Chrome	12.6	100	as above
4	Cooper	One attempt133; 2 attempts 54–57. In the rest < 20	60	as above

Continued on next page

Table 2 – *Continued from previous page*

No.	**Type**	**Level found in the study (mg/kg)**	**Permissible standard according to the draft regulation of the Ministry of National Health (mg/kg)**	**Notes**
5	Nickel	< 113	70	as above
6	Lead	1 attempt 125; 4 attempts > 50; others – 4 ÷ 25	200	as above
7	Zinc	1 attempt > 200; others > 100	200	as above
8	Mercury	0.1–0.6	4	as above
9	Aromatic hydrocarbons (PAH)	In most trials – 5; In one trial 100.	10	
10	Aromatic compounds BETEX* Including: Benzene Toulene Ethylbenzene Xylene m+p	 2000–3000 0.1 2700 110 300	200	Above standard Accepted criterion: Contaminated soil Betex > 10 mg/kg dry matter.

* BETEX – Sum of volatile aliphatic, naphthalene and aromatic hydrocarbons (benzene, toluene, ethylbenzene, xylene).

4.4. Comment

The tests included all pollutants specified in the 2002 draft regulation, which are also listed in the current Regulation of the Minister of the Environment of 1 September 2016 on the assessment of pollution of the earth's surface (Journal of Laws 2016, item 1395). The concentration of aromatic compounds was found to be 300 times higher than the permissible limit. Reducing the level of contamination was a necessary condition for allowing the development of service facilities in the area. Notably, within this group, benzene levels were low – important given that benzene is particularly hazardous due to its well-documented carcinogenic effects on humans, confirmed through epidemiological studies. It is included in the list of hazardous substances maintained by the Chief Sanitary Inspector [21]. Other hydrocarbon compounds present were less harmful. For instance, toluene, an aromatic hydrocarbon that can be harmful at high concentrations, is nonetheless commonly used as an organic solvent in the cosmetics industry [22]. According to the Environmental Protection Act (Journal of Laws 2014, item 1101), the contamination was classified as historical, indicating that it occurred prior to 30 April 2007.

5. Design and implementation of remediation

The remediation approach was based on established knowledge of the structure and degradation mechanisms of aromatic hydrocarbons. These compounds – moderately volatile and water-soluble – undergo decomposition into less toxic substances (such as catechols [23] and diol oxides [24]) through the activity of aerobic bacteria [25]. The remediation was carried out on-site (in situ), directly at the investment location. Based on detailed research, the extent of contamination was accurately delineated, and the affected areas were isolated. In zones with excessive contamination, the topsoil layer (0–2.0 meters) was excavated and temporarily stored in a designated heap. During excavation, additional field testing was performed using a PID OVM 580 photoionization detector to measure vapors of organic compounds. Soil from deeper layers (2–5 meters) was also removed and placed into prepared heaps. Samples from the base of the excavation were collected and submitted for laboratory analysis. The remediation area was prepared for soil heaps up to 15 meters wide, sealed with 2.0 mm HDPE foil. A system of perforated PCF pipes for leachate drainage, along with aeration pipelines, was installed on the lining. These aeration lines were connected to a suction-pressure pump equipped with a carbon filter. Soil was stacked in heaps up to 1.5 meters thick and 15 meters wide. During this process, active bacterial strains capable of breaking down hydrocarbons – such as *Pseudomonas*, *Bacillus*, *Rhodococcus*, and *Paracoccus denitrificans* – were introduced. To minimize leachate generation, the heaps were covered with HDPE foil following mechanical processing. Collected leachate was drained into a container-based pre-treatment unit employing stripping tower technology, where hydrocarbons were removed from the contaminated leachate using a stream of compressed air. Throughout the remediation, comprehensive documentation was maintained, recording the substances introduced and the duration of aeration for each heap. Regular testing was also conducted to monitor contamination levels. After six months, pollutant concentrations had decreased to acceptable levels. The successful completion of the remediation was confirmed by laboratory tests, which were submitted to the President of the Capital City of Warsaw. The remediated soil was subsequently used to level areas designated for green space. The remediation process, conducted through "remedial measures", also complied with the requirements of the Act of 13 April 2007 on the Prevention and Remediation of Environmental Damage (Journal of Laws 2020, item 2187).

6. Soil remediation legal provisions in force in 2024

6.1. List of legal acts

Information on the applicable principles of remediation is included in the following legal acts:

- Act of 27 April 2001 – Environmental Protection Law (Journal of Laws 2024.54) [15],
- Act of 13 April 2007 on the prevention and repair of environmental damage (Journal of Laws 2020.2187) [26],
- Act of 14 December 2012 on waste (Journal of Laws 2023.1587) [27],
- Regulation of the Minister of the Environment of 1 September 2016 on the method of conducting the assessment of ground surface contamination (Journal of Laws 2016 item 1395) [28],
- Act of 17 May 1989 – Geodetic and Cartographic Law (Journal of Laws 2015 item 520, as amended) [29].

6.2. Administrative proceedings

The remediation undertaken in 2001 – being the first of such scale in Warsaw – must be considered in the context of the current regulatory framework. While the permissible pollution levels have remained unchanged, the procedures and stages for pollution assessment by administrative authorities responsible for issuing relevant decisions have evolved. At present, the remediation process is overseen by the Regional Director for Environmental Protection, who is responsible for approving the scope of research, endorsing the remediation project, and confirming the completion of the remediation process. The initiation and implementation of remediation require the following administrative decisions:

Option I: in situ remediation (on site) presented in Figure 4.

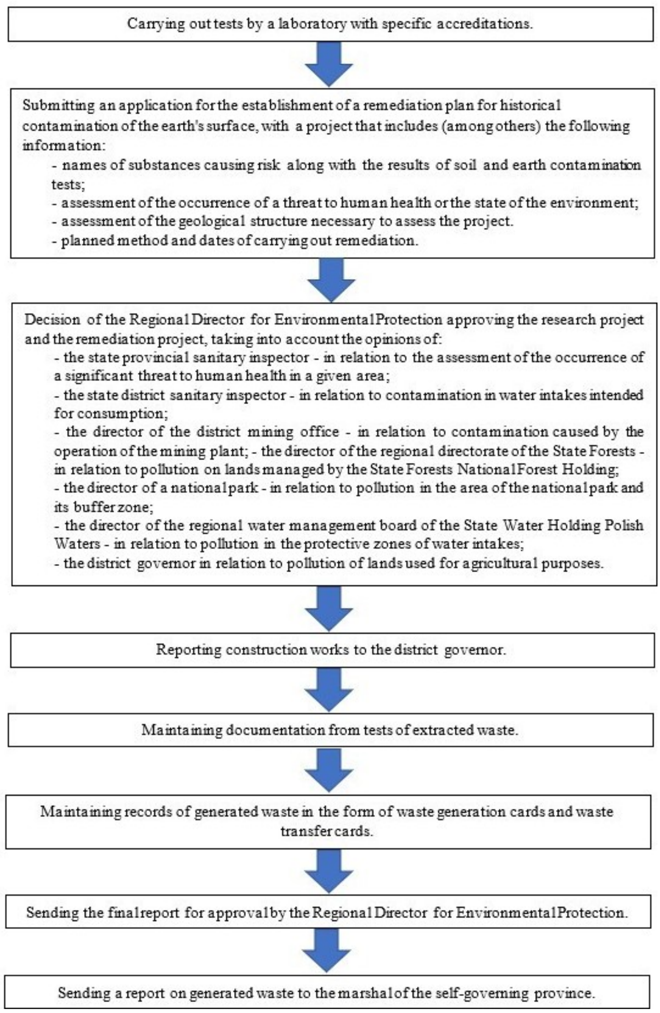

Fig. 4. Administrative decisions in the initiation and implementation of remediation [20]

Option II ex situ – waste removal to a hazardous waste treatment plant.

In the case of ex situ remediation – waste removal to a disposal plant – the investor or direct contractor is obliged to complete all steps, except the last one, i.e. “Sending a report on generated waste generation to the marshal of the self-governing province”.

The direct contractor performing remediation is the waste producer and is obliged to submit an appropriate report to the Marshal’s Office

Note: The entity performing remediation is the waste producer and is obliged to have the required decision of the marshal of the self-government voivodeship for the production and transport of waste.

7. Conclusions

The transformation of the degraded post-railway area into the Arkadia Shopping Center demonstrates a successful integration of environmental remediation, urban planning, and construction logistics within a complex urban redevelopment project. Through a comprehensive site investigation, high levels of historical contamination with aromatic hydrocarbons (BETEX) were identified, far exceeding regulatory limits. The in situ bioremediation method implemented – including the use of aerobic bacterial strains and advanced leachate management systems – proved effective in restoring the soil to environmentally safe conditions within reasonable period of time, enabling further urban development in accordance with Polish environmental regulations. This project also reflects the growing importance of sustainable urban land reuse, particularly in dense metropolitan areas like Warsaw. The Arkadia development not only reclaimed environmentally degraded land but also introduced extensive green infrastructure, such as a 47,000 m^2 vegetated roof that provides environmental, acoustic, and thermal benefits. The average price per square meter after the completed remediation increased by approximately 50%, taking into account the general increase lower than 50% in the value of residential space at that time in Warsaw.

An essential aspect of the Arkadia redevelopment was addressing the interests and concerns of local stakeholders, particularly surrounding communities. From the early stages, public consultations helped shape key planning decisions – especially those related to accessibility, noise reduction, and the integration of publicly accessible green areas. Despite the technical complexity of remediation, efforts were made to communicate risks and timelines transparently to nearby residents and business owners.

Overall, the Arkadia project serves as a model for urban regeneration initiatives, showing that environmentally and economically sustainable redevelopment is achievable when remediation, planning, and construction are effectively integrated. Future work should explore probabilistic and simulation-based approaches to further enhance planning precision in dynamic market conditions.

References

[1] Ł. Kuzak, C. Gabryel, A. Maciejewska, and J. Sobieraj, “Potentials and opportunities for revitalisation of post-harbour areas based on the Port of Zeran in Warsaw case study”, *Archives of Civil Engineering*, vol. 70, no. 2, pp. 195-214, 2024, doi: 10.24425/ace.2024.149859.

[2] M.J. Małuszyński, et al., "Rewitalizacja wybranych terenów poprzemysłowych w przestrzeni miejskiej Skierniewic", *Space – Society – Economy*, vol. 23, pp. 75–93, 2018, doi: 10.18778/1733-3180.23.05.

[3] M. Gurdak, "Rewitalizacja terenów pokolejowych Bagry-Bieżanów", in *Architektura w przestrzeni sztuk 2019: wystawa dyplomów magisterskich absolwentów Wydziału Architektury Politechniki Krakowskiej w Pałacu Sztuki w Krakowie*. Politechnika Krakowska, 2019, pp. 94-99.

[4] P. Kosmowski, "Rewitalizacja miejskich terenów pokolejowych. Przykład Lipska", *Studia Miejskie*, vol. 28, pp. 87-98, 2017, doi: 10.25167/sm2017.028.06.

[5] C. Zhang, S. Dai, and H. Xia, "Reuse of Abandoned Railways Leads to Urban Regeneration: A Tale from a Rust Track to a Green Corridor in Zhangjiakou", *Urban Rail Transit*, vol. 6, pp. 104–115, 2020, doi: 10.1007/s40864-020-00127-2.

[6] E.E. Feldman, "From Linear Spaces to Linear Places: Recycling Rail Corridors in Urban Areas", M.A. thesis, Massachusetts Institute of Technology, Dept. of Urban Studies and Planning, 2002.

[7] C.A. Morgan, L. Loftus-Otway, N.M. Hutson, and J.E. Warner, "Preservation and Reuse of Abandoned Rail Corridors: Legal and Policy Issues", in *Conference Proceedings ASME/IEEE 2012 Joint Rail Conference*. ASME, 2013, pp. 523-532, doi: 10.1115/JRC2012-74091.

[8] A. Maciejewska and A. Turek, *Rewitalizacja terenów poprzemysłowych*. Warsaw, Poland: Wydawnictwo PWN, 2019.

[9] H. Guliyev, "Determining the spatial effects of COVID-19 using the spatial panel data model", *Spatial Statistics,* vol. 38, pp. 1–10, 2020, doi: 10.1016/j.spasta.2020.100443.

[10] A. Maciejewska, Ł. Kuzak, M. Ulanicka-Raczyńska, and K. Moreau, "Land Management Using Land Reserves to Alleviate Emergencies on the Example of Warsaw", *Sustainability*, vol. 14, no. 18, art. no. 11625, 2022, doi: 10.3390/su141811625.

[11] A.K.Y. Ng, C. Ducruet, W. Jacobs, J. Monios, T. Notteboom, J.-P. Rodrigue, B. Slack, K. Tam and G. Wilmsmeier, "Port geography at the crossroads with human geography: between flows and spaces", *Journal of Transport Geography*, vol. 41, pp. 84–96, 2014, doi: 10.1016/j.jtrangeo.2014.08.012.

[12] J. Rosłon, "Materials and technology selection for construction projects supported with the use of artificial intelligence", *Materials*, vol. 15, no. 4, 2022, doi: 10.3390/ma15041282.

[13] J. Kulejewski and J. Rosłon, "Optimization of ecological and economic aspects of the construction schedule with the use of metaheuristic algorithms and artificial intelligence", *Sustainability*, vol. 15, no. 1, 2023, doi: 10.3390/su15010890.

[14] "Definicja pojęcia – rekultywacja", ekologia.pl. [Online]. Available: https://www.ekologia.pl/slownik/rekultywacja/. [Accessed: 17.06.2025].

[15] Ustawa z 27 kwietnia 2001 r. Prawo Ochrony Środowiska (Dz. U.2024 poz. 54).

[16] https://inzynieriasrodowiska.com.pl/encyklopedia/wspolczynnik-filtracji-i-wodoprzepuszczalnosc. [Accessed: 17.06.2025].

[17] https://www.ekologia.pl/slownik/prawo-darcyego/. [Accessed: 17.06.2025].

[18] J. Sobieraj, *Centrum handlowe Arkadia w Warszawie. Vol. 4 Uwarunkowania środowiskowe przy realizacji przedsięwzięcia*. Warszawa, 2024 r.

[19] https://inzynieriasrodowiska.com.pl/encyklopedia/wodoprzepuszczalnosc. [Accessed: 17.06.2025].

[20] Technological project of the Shopping Center "Arkadia".

[21] https://www.bing.com/search?pglt$=$41{&}q$=$szkodliwo{%}C5{%}9B{%}C4{%}87$+ $benzenu{&}cvid$=$f. [Accessed: 17.06.2025].

[22] https://uxxu.pl/toluen-wlasciwosci-i-zastosowan. [Accessed: 17.06.2025].

[23] https://pl.wikipedia.org/wiki/Pirokatechina. [Accessed: 17.06.2025].

[24] https://pl.wikipedia.org/wiki/Diole. [Accessed: 17.06.2025].

[25] T. Bogacka , Z. Makowski , R. Ceglarski, "Rozkład węglowodorów aromatycznych w środowisku wodnym", *Roczniki Państwowego Zakładu Higieny*, vol. 48, no. 2, pp. 149-161, 1997.

[26] Ustawa z dnia 13 kwietnia 2007 r o zapobieganiu szkodom w środowisku i ich naprawie (Dz.U.2020.2187).

[27] Ustawa z dnia 14 grudnia 2012 r. o odpadach (Dz. U.2023.1587).

[28] Rozporządzenie Ministra Środowiska z dnia 1 września 2016 r. w sprawie sposobu prowadzenia oceny zanieczyszczenia powierzchni ziemi (Dz. U. 2016 poz. 1395).

[29] Ustawa z dnia 17 maja 1989 r. Prawo geodezyjne i kartograficzne (Dz. U. 2015 poz. 520, z późn. zm.).

Przekształcenie zdegradowanych i nieużywanych terenów pokolejowych pod centrum handlowe Arkadia w Warszawie

Słowa kluczowe: Centrum Handlowe Arkadia, obszar zdegradowany, rekultywacja, remediacja, badania, skażenie gruntu

Streszczenie:

Transformacja terenów zdegradowanych i nieużytkowanych, w tym dawnych obszarów kolejowych w centrach dużych miast, stanowi jeden z najważniejszych i jednocześnie najtrudniejszych elementów nowoczesnego planowania przestrzennego. W kontekście szybko postępującej urbanizacji i rosnących potrzeb mieszkańców w zakresie nowych przestrzeni usługowych, rekreacyjnych i handlowych, umiejętne przywracanie takich obszarów do użytku staje się priorytetem władz miejskich, inwestorów oraz specjalistów z zakresu inżynierii środowiska i budownictwa. Przykład Centrum Handlowego Arkadia w Warszawie jest wyjątkowym dowodem na to, jak skutecznie można połączyć wymagania techniczne, przepisy ochrony środowiska i nowoczesne podejście do zagospodarowania przestrzeni miejskiej. Dawna bocznica kolejowa, funkcjonująca przez ponad sto lat, była obszarem mocno zdegradowanym, zawierającym w gruncie liczne zanieczyszczenia ropopochodne i aromatyczne, których obecność stanowiła realne zagrożenie zarówno dla ludzi, jak i dla ekosystemu miejskiego. Proces remediacji poprzedzono szczegółowymi badaniami laboratoryjnymi i terenowymi, które pozwoliły dokładnie zlokalizować obszary o najwyższym stężeniu substancji szkodliwych. Do najważniejszych zidentyfikowanych zanieczyszczeń należały związki z grupy BETEX, czyli benzen, toluen, etylobenzen i ksyleny, których stężenia w niektórych próbkach przekraczały wartości graniczne nawet kilkaset razy. Dla porównania, według obowiązujących wówczas i obecnie przepisów, dopuszczalny poziom tych związków w glebie wynosił10 mg/kg suchej masy, podczas gdy w rejonie przyszłej Arkadii wartości sięgały 2000–3000 mg/kg. Przygotowany i zatwierdzony projekt remediacji zakładałprowadzenie oczyszczania metodą in situ. Oznaczało to, że proces neutralizacji zanieczyszczeń odbywałsię na miejscu, bez konieczności kosztownego i czasochłonnego transportu skażonego gruntu do specjalistycznych składowisk. Kluczowym elementem było tu zastosowanie bakterii tlenowych, takich jak szczepy z rodzaju Pseudomonas czy Bacillus, które posiadają zdolność biodegradacji węglowodorów aromatycznych do związków prostszych i mniej szkodliwych. Dodatkowo gleba była systematycznie napowietrzana, a odcieki zbierano i oczyszczano przy użyciu nowoczesnych technologii fizykochemicznych. Cały proces byłściśle nadzorowany przez wyspecjalizowane laboratoria i dokumentowany w celu zachowania pełnej transparentności oraz zgodności z wymaganiami prawnymi. Wyniki końcowych badań potwierdziły, że poziom zanieczyszczeń zostałobniżony do wartości bezpiecznych dla zdrowia i środowiska, co umożliwiło przystąpienie do właściwych prac budowlanych i aranżacji terenu. Sam projekt architektoniczny Arkadii od samego początku zakładał połączenie funkcji handlowych, usługowych i rozrywkowych z elementami ekologicznymi i przyjaznymi dla mieszkańców. Oprócz rozbudowanej oferty sklepów i punktów gastronomicznych, na terenie obiektu przewidziano liczne udogodnienia, takie jak przestrzenie wypoczynkowe, pasaże o charakterze miejskim, a także imponujący zielony dach, który pełni wiele ważnych funkcji środowiskowych. Dzięki niemu możliwe jest m.in. retencjonowanie wody opadowej, ograniczenie efektu miejskiej wyspy ciepła, poprawa jakości powietrza i redukcja hałasu docierającego do wnętrza budynku. Centrum Handlowe Arkadia jest rów-

nież przykładem efektywnego wykorzystania istniejącej infrastruktury komunikacyjnej. Usytuowanie głównego wejścia przy rondzie Zgrupowania AK „Radosław" oraz łatwy dostęp do linii tramwajowych i autobusowych sprawiają, że obiekt jest dobrze skomunikowany z resztą miasta, co redukuje natężenie ruchu samochodowego i sprzyja ograniczeniu emisji spalin. Dodatkowo rozbudowany parking podziemny minimalizuje konieczność parkowania pojazdów na powierzchni, co pozwala zachować więcej przestrzeni dla pieszych i zieleni. Z urbanistycznego punktu widzenia, Arkadia stała się ważnym impulsem dla rozwoju północnej części miasta, wpływając na poprawę jakości życia mieszkańców i wzrost atrakcyjności okolicy zarówno dla inwestorów, jak i dla nowych mieszkańców. Dziś ten rejon Warszawy to nie tylko miejsce zakupów, ale także przestrzeń spotkań, rekreacji i aktywności kulturalnych. Przykład Arkadii pokazuje, że rewitalizacja terenów pokolejowych i poprzemysłowych wymaga zintegrowanego podejścia, łączącego nowoczesne technologie remediacji, staranne planowanie przestrzenne, odpowiedzialne projektowanie architektoniczne i ścisłą współpracę z organami administracji publicznej. Inwestycja dowodzi, że nawet mocno zdegradowane tereny mogą stać się przestrzenią nowoczesną, funkcjonalną i przyjazną dla ludzi oraz środowiska, jeśli tylko odpowiednio się je przygotuje i zagospodaruje. Podsumowując, Arkadia jest przykładem udanej rewitalizacji, która może służyć jako wzorzec dla innych projektów zarówno w Polsce, jak i poza jej granicami. Udowadnia, że inwestycje na terenach wymagających specjalistycznego podejścia środowiskowego są możliwe i opłacalne, a przy tym przynoszą wymierne korzyści społeczne, gospodarcze i ekologiczne. W dobie wzrastających oczekiwań dotyczących zrównoważonego rozwoju miast oraz dbałości o jakość życia mieszkańców, takie projekty jak Arkadia wyznaczają kierunek, w którym powinny podążać kolejne inwestycje urbanistyczne.

Niniejsze opracowanie w znacznym stopniu powstało w oparciu i przy wykorzystaniu pozycji pt. „18. CENTRUM HANDLOWE ARKADIA W WARSZAWIE, NAJWIĘKSZE CENTRUM HANDLOWE W POLSCE I W UE, MATERIAŁY DYDAKTYCZNE Dla studentów I i II stopnia szkółinżynieryjnych, politechnik, studiów podyplomowych oraz początkujących menedżerów budownictwa. TOM IV „UWARUNKOWANIA ŚRODOWISKOWE PRZY REALIZACJI PRZEDSIĘWZIĘCIA" dr inż. Janusz Sobieraj, Warszawa, kwiecień 2024 r."

Received: 2025-06-17, Revised: 2025-07-29