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THE CONDITION OF CLIMATE CHANGE ADAPTATION IN POLISH MUNICIPALITIES BEFORE AND AFTER THE PANDEMIC ON THE BASIS OF CSO ENVIRONMENTAL INDICATORS - MANAGEMENT IMPLICATIONS

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Abstract

The pandemic undoubtedly had a significant impact on local development management processes in municipalities in economic, social, environmental and institutional-political dimensions. The article presents and evaluates various activities of municipal governments in the field of environmental management for climate protection and formulates recommendations for municipalities in this regard. The main purpose of this article is to assess the condition of climate change adaptation in municipalities before and after the pandemic, particularly in Polish municipalities, based on the environmental specific indicators of the Central Statistical Office. The purpose of the paper was realized on the basis of a review of the latest literature on the subject, domestic and foreign, as well as quantitative and qualitative comparative analysis. The study was carried out in thirty Polish urban-rural municipalities, , at the same time district cities (cities of the seat of county government, cities, "micro capitals" of counties), with varying own incomes. In Polish municipalities, climate change adaptation priorities have changed in very positive terms after the pandemic, in particular, this applies to municipal spending on ambient air protection (including renewable energy sources, thermal modernization, etc.), which has increased two or even three times compared to the time before the pandemic, which has not yet been recognized and studied in the conducted review of the recent literature on the subject. At the same time, the pandemic period slowed down the remaining investment and management of environmental activities, and generally did not improve waste management in municipalities.

Keywords: climate change adaptation, municipality, COVID-19, pandemic, governance

1. INTRODUCTION

The COVID - 19 pandemic, which began in 2020 and slowly ended in 2022, undoubtedly had a very significant impact on the dynamics of development processes in economic, social, environmental and institutional-political aspects, both globally, regionally and locally. In particular, the timing of the

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pandemic came after a long period of relative balancing and stabilization of development processes in the world in the second decade of the 21th century. Therefore, there is a legitimate scientific and practical need to identify and assess the impact of the pandemic period on environmental management transition processes, particularly climate change adaptation at the local level.

The main objective of the study is to identify and evaluate changes is to determine the changes that have occurred in Polish municipalities, district cities after the pandemic in terms of adaptation to climate change. The study used the detailed indicators of environmental order of the Central Statistical Office and reviewed the latest Polish and foreign literature on the subject of the work. The condition before the pandemic (averaged detailed indicators of the CSO from 2016-2019) and the condition at the end of the pandemic (detailed indicators of the CSO from 2022) were subjected to comparative analysis.

2. LITERATURE REVIEW

A brief review of the literature on the impact of the pandemic period on environmental management and the condition of municipalities' adaptation to climate change began with the most recent Polish literature on the subject.

Coal is still the main energy resource in Poland, and the level of air pollution in Polish cities is one of the highest in Europe. Environmental problems are one of the biggest challenges for Polish authorities and society. As of today, there is a risk of a 1.5°C rise in temperature by 2050, and recent research results have indicated a growing demand for green and sustainable investments by local governments. A number of barriers to accessing new forms of sustainable financing were identified. Among the most significant obstacles were low private sector involvement in public-private partnerships with local governments, regulatory and fiscal barriers, and the inability of local governments to provide effective financial security. The crisis triggered by COVID-19 reduced financing for sustainable development at the local level, including climate change prevention [11].

Changes in the industrial structure in can both positively and negatively affect climate change adaptation processes at the regional and local levels. P. Brezdeń assessed the magnitude of the possible impact of the COVID-19 pandemic on industrial activity in 2019-2022 and to determine its consequences in the spatial structure of Poland's industry by province The results of the study indicate that the spatial structure of Polish industry did not undergo significant and permanent transformations during the pandemic. This proves that the structure was characterized by great stability [6]. The same author, in another article, takes up the issue of assessing industrial activity during the pandemic in Poland by province. He notes that an essential feature of the structural changes taking place is the relative decrease in the disproportion between the distribution of industrial production across the provinces of Poland [7]. This can have a positive impact on climate change adaptation processes, due to greater territorial balancing of industrial production.

G. Masik identified the "resilience-strengthening" measures taken by provincial cities and regions. The results of the survey of 25 municipal and regional governments indicate that in recent years there has been a lot of infrastructure investment strengthening the adaptation of cities and regions to climate change and contributing to reducing the negative consequences of natural disasters. At the same time, it was noted that the COVID-19 pandemic accelerated workflow procedures in government offices due to increased investment in digitization, which in a way indicates measures to strengthen institutional resilience at the local level [22]. In addition, it should be noted that the economic downturn in the global economy caused by the pandemic has not improved the situation with regard to climate change [30].

Adaptation to climate change is as important as climate protection. The purpose of A. Albin's research was to analyze the public task of adapting to climate change, and in particular to determine the scope of activities to implement this adaptation. Adaptation to climate change is a set of conscious and

purposeful activities, closely related to the tasks of the municipality. It is important to determine the specific forms of public administration activity in the analyzed area, as well as the most effective way to carry out the task, in accordance with the principle of subsidiarity [3]. Polish researchers, based on climatological data from 1901-2020 from the scientific station of the Department of Climatology at the Jagiellonian University, have characterized the multi-year course of selected elements of Krakow's climate and indicated the role of local land use plans in terms of minimizing the effects of urban heat islands and global warming [23].

Human-induced climate change is increasingly occurring in extreme forms. Mitigation of their effects, depends on taking rational measures for sustainable development, spatial planning, urban planning, as well as proper management and management of water resources [24]. Recent years have seen rapid growth in cities and urban areas. While 55% of all people currently live in cities, by 2030 (according to various prognostications) it will be 60%, and by 2050 - already more than 70%. Thus, it will be necessary to create a framework to use the potential of cities to ensure that barriers to the stability of the natural system are not exceeded, and that individual social groups are not economically excluded. It is assumed that urbanized areas have sufficient economic potential to meet these challenges and have the social capital to lead change, as evidenced by the growing activity of urban movements and NGOs [17]. Mitigation and adaptation to climate change are two critical civilizational challenges facing many social actors. Subsequent analyses by P. Pluciński include a reconstruction of the conceptual and methodological framework for research on climate justice activism and a preliminary identification of the practices of Polish climate justice movements, based on research in 30 in-depth interviews conducted in three Polish cities (Poznań, Wrocław, Warsaw). The author also pointed to the need for greater involvement of the social sciences in climate change mitigation efforts, including the opening of academia to grassroots and local perspectives [28].

Preserving the quality of habitation and adapting to climate change in cities has become a challenge for local authorities. One of the most important aspects affecting the quality of life is the presence of greenery, which is why it is so important to protect natural structures. In a municipality, a good solution leading to this goal is the introduction of appropriate provisions in spatial planning documents. M. Łaska's research addresses the problem of using provisions in Warsaw's MPZPs (Local Development Plans) aimed at reducing investment pressure on green areas, and confirms the significant effectiveness of these instruments [21].

Adapting to climate change is one of the biggest challenges facing the world today. This is especially true for urban areas, which, due to their specific conditions, have little resilience to sudden weather events and phenomena, such as extreme rainfall or prolonged periods of drought. The essence of adaptation to such events is first and foremost to change the way we think about rainwater, treating it as a resource and not just a threat. One of the ways to adapt to climate change is to introduce elements of blue-green infrastructure (BZI) into the urban space, which should form an intelligent system based on a network of green areas and water. Among Polish cities representing a systemic approach in climate change adaptation based on BZI solutions are Wrocław and Radom [14].

It is also worth noting several publications by Polish authors from before the pandemic, which may allow for a more comprehensive comparative analysis in the field of environmental management and adaptation of municipalities to climate change. In the face of new challenges, the issue of building urban resilience, including the ability to adapt to climate change, is increasingly being addressed in urban development issues. The aim of B. Wieteska-Rosiak's research even before the pandemic was to prove that through the appropriate design of public spaces adaptation to climate change becomes possible. For the purpose of the study, the author uses the phrase "hybridization of public space". This means that this space can simultaneously perform two different functions (or more). The first will be a

primary function, such as recreational, and the second, so-called secondary function, will be related to the ability to adapt to climate change [35]. Nature remains an invaluable ally of humans in the fight against the effects of climate change. Protecting and restoring nature is undoubtedly the most cost-effective tool in mitigating climate change. Climate change adaptation in cities should first and foremost rely on the use of nature's potential. Unfortunately, the key role that nature plays in combating climate change is not always recognized [31]. Thus, climate change adaptation is becoming a necessity, especially for cities. Another publication recognizes that adaptation activities can be programmed within the framework of mandatory local documents (e.g., in the environmental program). Another approach is to develop a separate program document - a city plan/adaptation strategy. From the point of view of city development policy, this is a more favorable way, based on management [20].

More analysis even before the pandemic (2017) presents the opinions of Polish local authorities (political leaders and local administration representatives) on climate change and adaptation. The empirical research, based on a survey of local governments, showed that local authorities remained skeptical about human impact on climate change. Only 32% of respondents found the existing evidence convincing. They also reveal that there is a correlation between local authorities' views on climate change and the size of the municipality, as well as past experience with extreme weather events. The results suggest that local adaptation policies are more likely to succeed in municipalities with administrations specializing in environmental issues [12]. B. Degórska, on the other hand, in her research focused on assessing the vulnerability and identifying the necessary directions for adaptation of large cities to high temperatures. The increase in air temperature has a significant impact on the functioning of the environment, society, economy and infrastructure, so taking this phenomenon and its prospective effects into account in the process of urban planning has become a necessary requirement. The purpose of the study was to assess the demographic thermal risk of large cities to high air temperature, identify urban factors generating temperature increases in the highly urbanized area of large cities, and identify areas requiring strengthening of adaptation measures in urban planning, with emphasis on the possibility of natural cooling of cities during periods of high air temperature [10].

Selected analyses by Polish authors prior to the pandemic therefore point to the significant and growing importance of municipal adaptation to climate change and environmental management while still in a period of stability and relative development equilibrium during the "peaceful" time of the late second decade of the 21st century.

A review of foreign literature brings more information on the impact of pandemics on climate change adaptation at both global and local levels. The repercussions of the COVID-19 pandemic and climate change (two major common global crises) can be far-reaching, the similarities between them can be significant, and their mutual impact can be significant. The first study reviewed [18] highlights and discusses important interactions between the two crises. In the study, the author says that "the main management implications related to the economy, energy, technology, environment, food systems and agriculture sector, health systems, politics, governance and communities are detailed in a review of the existing literature on the subject". Based on these results, practical recommendations were made for future research and management. The pandemic demonstrated opportunities and lessons for developing sustainable recovery plans for the climate crisis. The findings indicate that governments should work together to develop sustainable and regulated strategies consistent with long-term global decarbonization goals, promote renewable energy sources, integrate climate change into environmental policies, prioritize climate-smart agriculture and local food systems, and ensure public and ecosystem health. These proposals provide information to address the climate crisis and potential future global problems with similar characteristics if countries take urgent and concerted global action [18].

Environmental studies in Southeast Asia have identified positive effects of blocking and restricting the movement of COVID-19 on the regional environment: reduced air pollution, improved

air and water quality, lower noise levels and reduced land surface temperatures. Negative impacts, on the other hand, included increased plastic use and medical waste generation in Indonesia, Malaysia, Thailand, the Philippines and Vietnam. The results of the assessment had important implications for stakeholders in continuing to deal with the huge volume of waste, an inadequate waste management system. It proved important to examine the effectiveness of such sustainable changes in work and lifestyle, in climate change mitigation and adaptation policies, and to consider new green technologies for clean energy in each Southeast Asian country and at the regional level. The study is expected to contribute to a better understanding of COVID-19's impact on environmental sustainability in the Southeast Asian region [29]. Other studies focus on the impact of the pandemic combined with record housing prices and mention the urgent need to adapt to climate change. Topics discussed include guidelines for improving the design of suburban housing to offset the heat island effect and the contribution of local parks to greening and cooling, and the introduction of the "State Project Concierge" - coordinated services and implementation of major transportation and infrastructure projects in Victoria, Australia. [26].

A preliminary review of the strategies and interventions used to manage COVID-19-related extreme heat in the 25 most populated cities in the United States has been conducted. Heat adaptation strategies employed prior to the pandemic were not sufficient to address the co-occurring threat of COVID-19. Longer-term climate change adaptation strategies will require using physical, financial and social resources in many city departments to address the needs of complex threats such as COVID-19 and extreme heat [15]. Climate change policies are emerging across Europe. Policies on adaptation (adjusting the impact of climate change on public health) are being implemented post-pandemic. Key decision makers were interviewed in international, national and local governments in 20 European countries (Norway, England, Cyprus, Spain, Ireland, Finland, Lithuania, Belgium, the Netherlands, Sweden, Latvia, Italy, Estonia, Austria, Croatia, France, Germany, Hungary, Denmark and Scotland). Most respondents reported insufficient resources to implement health adaptation (funding, training and staffing) and a marginal role for health in climate change adaptation policies. However, a few respondents cited benefits to health system resilience, such as better emergency planning and disaster management [34].

The problem of climate change is no longer just a concern for scientists, and although different generations perceive and evaluate the phenomenon differently in many cases, it is having an increasing impact on people's daily lives and recreational habits, which has undoubtedly been influenced by the pandemic. Such an impact mainly concerns the daily lives of residents of rather wealthier countries with relatively higher incomes. Respondents' perceived effects of climate change clearly affect the use of certain groups of tourism products (beach vacations, hiking, participation in outdoor events) and the comfort and satisfaction felt by individuals [27].

As part of the citizen science component of the project on climate change adaptation at the European regional level (Klimawandelanpassung auf regionaler Ebene), a local weather network was established for schools in southern Germany. Despite the ongoing COVID-19 situation, pupils were actively involved in the project, produced reliable data and enabled detailed analysis of observation data and weather reports. First observations show that visual observations of weather phenomena, such as heavy rainfall, matched well with measurements [19]. And in terms of nature protection, the Fish and Wildlife Service's Latin America Regional Program aims to protect priority species, habitats and ecological processes in landscapes of high biodiversity value in the region. Proposed project activities that reduce the impact of pandemics on conservation goals and promote climate change adaptation and resilience were also welcomed [13]. Other research on food production discusses what the Southeast Florida Greater Miami region is doing to ensure food security as part of its climate change adaptation

initiatives. In the region, sea level rise threatens the economic viability and ultimately the livability and cultivation of crops in this beautiful coastal territory. Improvements to local infrastructure to adapt to sea level rise are essential [4].

In the urban policy aspect, the Sustainable Urban Mobility Plan of Brazil's Salvador (PlanMob) was examined and it was noted that it includes measures to adapt and mitigate the climate crisis, but not the pandemic crisis. In a review of scientific articles, it was found that the pandemic has reduced the use of public transportation and increased the use of individual transportation. It therefore recommended adjusting municipalities' urban mobility plans to prevent the spread of COVID-19, additionally providing for the expansion of bicycle paths, pedestrian streets and escalators [8]. Climate change and pandemic have posed serious challenges for the city of Ankara, Turkey. The city government has taken a number of strategic and operational actions to improve water security. Ankara is still lagging behind in climate-related adaptation and management practices. Financial resources are scarce, so policy measures such as sharing responsibility at the neighborhood level, integrating resilience into existing policies and involving residents in policy-making, and building local government capacity can help ensure Ankara's water security [2]. It's not just about dealing with the effects of a pandemic, but also about the need for a synergy of mitigation and adaptation measures in the context of climate change and the transition to a low- or zero-carbon development paradigm. It can also be considered that the 15-minute city model will also contribute to reducing inequalities between different parts of cities, which is one of the consequences of poorly regulated suburbanization processes [25]. It is difficult to objectively assess the impact of the pandemic on progressive environmental changes. The results of research on Maldivian society report that in addition to a number of changes actually experienced, progressive environmental changes are seen as one of the important factors affecting Maldivian society and its livelihoods. The results and interpretation of studies of the major changes resulting from the ongoing COVID-19 pandemic, indicate some dissonance in the understanding of the possible impacts and resulting actions. Arguably, there is still too little time to objectively assess the impact of the pandemic on climate change adaptation [32].

The challenges of the 21st century, particularly those related to climate change, population growth, air pollution and the global pandemic health crisis, call for a greater emphasis on infrastructure capable of keeping pace with the needs of the population for well-being, health and economic prosperity. Green infrastructure to intensify ecological processes in built-up areas and provide essential ecosystem services is crucial [9]. The results of a Swedish study confirm a rapid and significant increase in participation in outdoor recreation during the pandemic. Researchers have identified significant trends in the growth of new participants in green recreation. A review and synthesis of themes support national goals for outdoor recreation in Sweden [5]. Lessons must be learned from the pandemic health crisis in order to cope with extreme climate change events and enhance climate change mitigation achievements. The pandemic provided an opportunity to discuss the impact of urban tourism due to short-term air travel and opportunities to improve more climate-friendly travel options. Covid-19 highlighted the need to reconsider the role of open spaces in metropolitan areas, as well as their accessibility. In this regard, pandemic synergies with climate change adaptation are important [16].

A review of foreign literature concludes with the recommendation that adequate public health safety provision should be linked in an integrated way to the creation of a healthy urban environment. Clean water, green environment, climate change adaptation strategies, comprehensive space planning with active community participation, seem to be a good solution for the future design of a sustainable urban environment, in terms of climate change adaptation [1]. Air quality in Europe is improving, according to the latest (November 2023) information [36] from the European Environment Agency (EEA). Yet polluted air continues to worsen health conditions and cause deaths, especially in cities. The good news is that cleaner solutions for transportation, heating, industry and agriculture can help.

3. RESEARCH METHOD

The author's own research is a continuation of a detailed study of thirty Polish municipalities of varying wealth in terms of their adaptation to climate change [33] in 2016-2019. The subject of the study is a research sample of 30 Polish urban-rural municipalities, at the same time county cities of varying wealth by budget income per capita in 2016-2019, in order of increasing wealth (the first group - 10 municipalities with the lowest wealth: Kazimierza Wielka, Opatów, Mońki, Miechów, Wschowa, Nisko, Łęczna, Dąbrowa Tarnowska, Jędrzejów, Szydłowiec – Table 2; second group - 10 municipalities with medium wealth: Wołomin, Łobez, Bytow, Grójec, Ząbkowice Śląskie, Myślenice, Strzelce Opolskie, Wieliczka, Pszczyna, Kartuzy – Table 2; third group - 10 municipalities with the highest wealth: Drawsko Pomorskie, Gryfino, Słubice, Świecie, Police, Goleniów, Grodzisk Mazowiecki, Kozienice, Piaseczno, Polkowice – Table 3).

In connection with the purpose and focus of the study, the following research question should be posed. How did the pandemic period affect changes in the adaptation of Polish municipalities to climate change? In order to answer this question, our research subjected to comparative analysis in each of the three groups of municipalities the averaged environmental detailed indicators of the Central Statistical Office before the pandemic for 2016-2019 (including the average for each of the 3 groups of 10 municipalities each) and the environmental indicators at the end of the pandemic for 2022 (including the average for each of the 3 groups of 10 municipalities each) - Tables 1, 2, 3.

In particular, relevant for the purposes of the article are indicators 1, 2, 3, 4, 5, 8, 9, 12, 13. These indicators can respond more flexibly to different types of crises, such as a pandemic, while the others (6, 7, 10) are less flexible, such as forest area, or protected areas, or the percentage of wastewater treated biologically.

4. RESULTS OF RESEARCH

The condition of adaptation of Polish municipalities to climate change after the pandemic compared with averaged indicators from the three-year period (2016-2019) immediately before the pandemic in three groups of municipalities is shown in Tables 1,2,3. Averaging the results from the 3 years immediately prior to the pandemic more objectifies the pre-pandemic condition of municipalities in terms of climate change adaptation.

Tab. 1. The condition of climate change adaptation in 2022 (after the pandemic) from the 2016-2019 average (before the pandemic) - the least prosperous municipalities (averaged value over the complete group of 10 municipalities)

Domains	**Indicators**		**Average 2016-2019**	**Average 2022**	**Change %**
Climate Change	1	Municipal expenditures on air and climate protection per capita (zł)*	**34,69**	**84,90**	**+144,73**
Protection of air and groundwater	2	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated - gaseous (excluding CO_2) (%)*	**5,06**	**n. d.**	**n. d.**
	3	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated – particulate (%)*	**53,22**	**90,02**	**+69,14**
	4	Users of gas facilities as a % of total population	**39,03**	**49,00**	**+25,54**
	5	Using sewerage system as % of total population	**62,67**	**63,26**	**+0,94**
Land use	6	Forest cover (%)	**18,27**	**18,31**	**+0,22**
Biodiversity	7	Share of legally protected areas (%)*	**31,91**	**31,43**	**-1,50**
	8	Share of parks, greens and green spaces in total area (%)	**0,27**	**0,27**	**0,00**
Waste management	9	Amount of mixed municipal waste from households collected during the year, per capita (in kg)	**128,09**	**157,22**	**+22,74**
	10	Wastewater treated biologically and with enhanced nutrient removal in total wastewater (in %)	**100,00**	**99,90**	**-0,10**
	11	Number of household treatment plants	**84,95**	**99,20**	**+16,77**
	12	Wild landfills - number per 100 km^2*.	**0,56**	**0,44**	**-21,43**
	13	Wild landfills - area per 100 km^2* (in m^2)	**515,72**	**989,71**	**+91,91**

* data available for the district
Source: own compilation based on CSO

The total sum of positive percentage changes after the pandemic in individual detailed environmental indicators in the group of least wealthy municipalities was about +162%. Since specific indicators No. 9 (amount of mixed municipal waste, without segregation), No. 12 (amount of wild dumps) and No. 13 (area of wild dumps) are destimulants of environmental development, the values of the above indicators were taken with the opposite sign from the tables for the combined calculation of percentage changes.

Tab. 2. The condition of climate change adaptation in 2022 (after the pandemic) from the 2016-2019 average (before the pandemic) - middle-income municipalities (averaged value over the complete group of 10 municipalities)

Domains	**Indicators**		**Average 2016-2019**	**Average 2022**	**Change %**
Climate change	1	Municipal expenditures on air and climate protection per capita (zł)*	**19,29**	**43,26**	**+124,26**
Protection of air groundwater	2	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated - gaseous (excluding CO_2) (%)*	**4,75**	**n. d.**	**n.d.**
	3	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated – particulate (%)*	**64,29**	**77,70**	**+20,86**
	4	Users of gas facilities as a % of total population	**63,35**	**67,85**	**+7,10**
	5	Using sewerage system as % of total population	**71,02**	**71,92**	**+1,27**
Land use	6	Forest cover (%)	**25,30**	**25,53**	**+0,91**
Biodiversity	7	Share of legally protected areas (%)*	**19,23**	**19,06**	**-0,88**
	8	Share of parks, greens and green spaces in total area (%)	**0,43**	**0,41**	**-4,65**
Waste management	9	Amount of mixed municipal waste from households collected during the year, per capita (in kg)	**193,38**	**152,32**	**-21,23**
	10	Wastewater treated biologically and with enhanced nutrient removal in total wastewater (in %)	**100,00**	**100,00**	**0,00**
	11	Number of household treatment plants	**214,27**	**246,50**	**+15,04**
	12	Wild landfills - number per 100 km^2*.	**0,83**	**0,73**	**-12,05**
	13	Wild landfills - area per 100 km^2* (in m^2)	**149,94**	**177,75**	**+18,55**

* data available for the district
Source: own compilation based on CSO

The total sum of positive percentage changes after the pandemic in individual detailed environmental indicators in the group of moderately affluent municipalities amounted to about +178%.

Tab. 3. The condition of climate change adaptation in 2022 (after the pandemic) from the 2016-2019 average (before the pandemic) - the wealthiest municipalities (averaged value over the complete group of 10 municipalities)

Domains	**Indicators**		**Average 2016-2019**	**Average 2022**	**Change %**
Climate change	1	Municipal expenditures on air and climate protection per capita (zł)*	**6,70**	**17,20**	**+156,72**
Protection of air and groundwater	2	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated - gaseous (excluding CO_2) (%)*	**45,65**	**56,38**	**+23,50**
	3	Share of pollutants retained or neutralized in pollution abatement facilities at sensitive facilities in total pollutants generated – particulate (%)*	**75,07**	**93,09**	**+24,00**
	4	Users of gas facilities as a % of total population	**71,46**	**75,55**	**+5,72**
	5	Using sewerage system as % of total population	**85,75**	**86,22**	**+0,55**
Land use	6	Forest cover (%)	**33,27**	**33,22**	**-0,15**
Biodiversity	7	Share of legally protected areas (%)*	**28,71**	**28,74**	**+0,10**
	8	Share of parks, greens and green spaces in total area (%)	**0,45**	**0,35**	**-22,22**
Waste management	9	Amount of mixed municipal waste from households collected during the year, per capita (in kg)	**232,45**	**220,67**	**-5,07**
	10	Wastewater treated biologically and with enhanced nutrient removal in total wastewater (in %)	**100,00**	**100,00**	**0,00**
	11	Number of household treatment plants	**87,99**	**156,90**	**+78,32**
	12	Wild landfills - number per 100 km^2*.	**0,52**	**0,54**	**+3,85**
	13	Wild landfills - area per 100 km^2* (in m^2)	**1 255,7**	**2 465,0**	**+96,29**

* data available for the district
Source: own compilation based on CSO

The total sum of positive percentage changes after the pandemic in individual detailed environmental indicators in the group of the most affluent municipalities amounted to about +173%.

5. CONCLUSIONS AND RECOMMENDATIONS

- A review of the Polish literature on climate change adaptation, particularly of Polish municipalities during and after a pandemic, provided information on: inadequate funding for adaptation, the impact of the pandemic on industrial activity, the level of resilience of cities and regions to climate change, stability of the natural system, climate justice, blue-green infrastructure in cities, local water management, adaptation planning, hybridization of public space, adaptation of large cities to high temperatures, and the high skepticism of local authorities in the time immediately before the pandemic in the face of much evidence of anthropopression-induced climate change.
- A review of foreign literature on the local aspect of climate change and pandemics provided further information on: local management implications in different parts of the world related to pandemics, health and recreational habits of residents, local heat islands, animal and plant protection programs, local adaptations to rising ocean and sea levels, changes in urban policies - land and air transportation, water management, 15-minute city, public health.
- Given the recent end of the pandemic, there is still too little time to comprehensively and objectively assess the impact of the pandemic period on climate change adaptation at the local level based on a review of the literature. A review of the recent literature also identifies a research gap in the detailed post-pandemic changes in municipal adaptation to climate change.
- In Polish municipalities, post-pandemic climate change adaptation priorities have changed, in particular, municipal spending on ambient air protection, which has almost tripled in the least wealthy and richest municipalities, and about doubled in middle-income municipalities, compared to pre-pandemic times. This mainly involves investments in renewable, green, healthy energy sources, thermal modernization and other pro-environmental investments.
- Based on the available environmental specific indicators, a positive, significant increase in gaseous and particulate pollutants retained was also noticed in the post-pandemic municipalities. This shows that the commercial sector in the territory of the surveyed municipalities and also the municipalities themselves are more active in environmental protection and climate change adaptation.
- Only a slight increase in the percentage of residents using gas installations was observed, especially in the wealthiest municipalities, which may indicate that gas, is no longer prioritized as a clean source and does not significantly affect climate protection. This may also be due, to a lesser extent, to insufficient investment activity by the gas distributor.
- There is a lack of investment progress in each group of municipalities during the pandemic period in the area of residents using sewerage systems, which may be related to the increasing cost of these investments in increasingly scattered developments, this is also confirmed by the increase in the number of domestic treatment plants. Other investment priorities of municipalities during the difficult pandemic period may also have been important. The increase in the number of individual domestic treatment plants could mean, on the one hand, an improvement in wastewater treatment or (on the other hand) an increase in the number of single-family homes (migration from cities), especially in scattered developments, often combined with high environmental values of the place of residence.

- The negative phenomenon is the low forest cover in the least affluent municipalities and its invariability during the pandemic period, as well as in all municipalities, the decreasing share of parks, greens and residential green areas, and to a lesser extent the share of legally protected areas. And these factors are also related to population health prevention and climate change adaptation. However, these indicators, as mentioned earlier, are characterized by less flexibility in the financial aspect.
- Other positive changes, not directly related to the pandemic, include an increase in waste segregation in the middle-income and most affluent municipalities and in improving rates of wild dumps in the least affluent and middle-income municipalities. However, the area of these landfills has significantly increased in all municipalities, which has a negative impact on the environment. Importantly, the amount of mixed municipal waste may be related not only to the degree of segregation of this waste but also to changes in lifestyle, or increased use of personal protective equipment and packaging during a pandemic.
- The condition of climate change adaptation in Polish municipalities after the pandemic improved primarily in terms of municipal spending on air protection, as well as to a very small extent in waste segregation and the number of wild dumps. In the author's own research, in general, the negative impact of the pandemic on the condition of climate change adaptation in the Polish local perspective was not clearly seen. However, in terms of investment in sanitary sewerage and natural gas, insufficient activity is seen in municipalities during the pandemic.
- In addition, no significant relationship was seen between the aggregate percentage improvement in all detailed indicators after the pandemic and the wealth of the municipalities in the three groups of municipalities studied (+162%, +178%, +173%). This may positively indicate a gradual equalization of development opportunities and environmental development in all municipalities independently of their wealth. This may also indicate that achieving the goals for a healthy and climate-resilient city (municipality) does not depend primarily on the wealth of municipalities, but may depend on adequate environmental management at the local level.
- Management implications for municipalities and commercial entities on their territory in terms of positive adaptation to climate change are to continue to invest in the health of residents by investing in renewable energy sources, increasing environmentally attractive areas and reducing wild landfills. Detailed priorities are derived from the CSO's quantitative analysis and the author's qualitative analysis.
- The research sample of 30 Polish municipalities with varying incomes and diverse economic, social, environmental and institutional-political resources can be considered with high probability to be representative of all 314 municipalities, Polish district cities, which are the seat of district authorities and serve as " micro-capital cities" of land districts. The results of the author's own research can be an inspiration to undertake further research analyses on the subject in question, which seem to be very important nowadays.

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