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Original Research Article

SOIL SEALING ON EXAMPLE OF THE JEDRZYCHOW RESIDENTIAL AREA IN ZIELONA GORA, POLAND

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A b s t r a c t

The progressing urbanization leads to the growth of buildings within the cities and taking up new areas for investments. Uncontrolled urban sprawl entails a number of consequences resulting in the soil sealing of the areas which has been permeable so far. Cutting off deeper soil layers from gas exchange and access to water causes a reduction in biological activity and biodiversity. That is why EU considers soil sealing as one of the main problems of the 21st century.

The paper attempts to analyze the progressing urbanization on the one of the Zielona Góra housing estates - Jędrzychów Residential Area.

Keywords: urban soil, urbanosol, soil sealing, soil degradation

1. INTRODUCTION

As a result of a significant population growth and increased migration in recent decades, uncontrolled and systematically progressing urbanization can be observed. Suburban areas with a low number of inhabitants and relatively small buildings began to develop intensively, while city centers became places for the development of trade, industry and entertainment, and ceased to perform housing functions. This phenomenon is called urban sprawl.

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Adaptation of rural, agricultural and forest areas for housing development, as well as construction of road and communication infrastructure, lead to a reduction of the biologically active area.
According to the Regulation of the Minister of Infrastructure on technical conditions which should be met by buildings and their location, the biologically active area is understood as the native soil covered with vegetation as well as surface water on the building plot [8]. These types of activities is called soil sealing. It consists in covering the soil with non-permable materials, such as asphalt or concrete. EU considers soil sealing as one of the main problems of the 21st century what was pointed in EEA report [9].
This work is devoted to the problem of soil sealing over the years and analysis of one of the Zielona Góra housing estates - Jędrzychów Residential Area.

2. MATERIALS AND METHODOLOGY

2.1. Site characteristic

Zielona Góra is a town on the Polish-German borderland (51°56'23"N, 15°30'18" E), inhabited in 2017 by about 140 thousand residents. Zielona Gora covers the area of 277 km^2; the density of the population is around 498 inhabitants/km^2.
From the geological and geomorphological point of view, Zielona Góra is located on the Middle-Odra-Land. The town and its surrounding areas shows significant variability caused by both natural and anthropogenic factors - mainly related to urbanization. The area of Zielona Góra is covered mainly by post-glacial formations in the form of sands of different granulation, in some places in the city there are also more concise compositions - clays and moraine clays, as well as organic material [12]. The sum of precipitation is around 591 mm/years, with storms in July and an average of 175.1 days with rainfall during the year [13, 14]. The location of the research area is shown in Figure 1.
The Jędrzychów Residential Area is located in the southern part of Zielona Gora. There is mainly single-family and low multi-family housing. Urban spatial development plan [30], establishes for this district low single-family housing up to 2 floors, with the possibility of use an attic. Landowners are obligated to introduce greenery to new plots. The minimum index of biologically active area is set at 30% to 40%, and the maximum indicator of the development area has been set from 40% to 60%, depending on the plot. Two parking spaces have been planned for each single-family house. There is also a possibilities of the building of single-storey utility and public service buildings, not inconvenient for neighbors and harmless to the environment. For commercial premises, one parking space for every 30 m^2 is available.

Due to the city growth, it was necessary to adapt the district to urban conditions, the availability of schools, shops, etc. There is one large supermarket with a shopping mall, 3 grocery discount and a restaurant. In this region, a network of car and bicycle roads and walking paths is developed, there are tennis courts and a playground for children. Residents have access to school and kindergarten. In this district there are two Roman Catholic churches and a churchyard cemetery. Jędrzychów district includes only single-family housing with the population about 7 thousend inhibitants, the density is low (881.4 inhabitants/km^2).

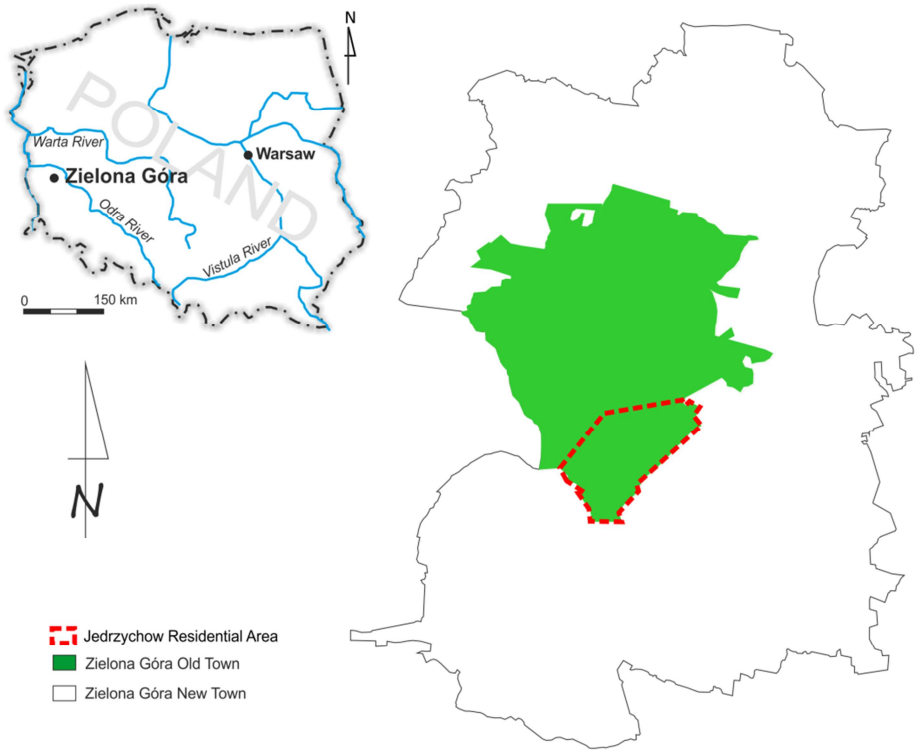

Fig. 1. Site location

2.2. Analytical methods

The study was conducted at a housing estate dominated by single-family housing (Jędrzychów). A cartographic analysis including aerial photographs from 1964 and 2008 was carried out.

In the analysis selected divisions of land use has been separated: residential buildings, industrial buildings, farm buildings, public utility buildings, roads, pavements, parking, sports facilities, allotments, sealed and unsealed surface.

3. RESULTS AND DISCUSSION

Many authors [1, 6] consider soil sealing by in the context of decrease in arable land. It is also a problem for urbanised areas, especialy in biggest cities [10].
In the 1960s (XX century), Jędrzychów was a separate town located within the range of the influence of Zielona Góra, to which it was incorporated in 1961 during the city development [7]. Over the years, the progressive development of arable land, with a relatively low loss (replenishment for non-forest purposes) of forest areas can be observed, which is an undisputed advantage, both for the residents of the housing estate and the entire city. The eastern part of the village was adapted for garden plots.
The Jędrzychów district was intended only for single-family housing (Phot. 1). There is a sealed access road and pavements for every house, parking lots and garages. A minimum of 2 parking spaces with soil sealing materials are assigned to most houses.
The total area of Jędrzychów is 7.74 km^2. In 1964, the sealed area of the given area was 0.22 km^2, which gives 2.89% of the total area (Table 1, Phot. 2). In 2008, the sealed area increased to 1.04 km^2, which is 13.47%. Over the years, the land consolidation of the Jędrzychów district increased by 2.89% to over 13.47%, which means that the soil sealing increased by 465%. The increasing in the built-up area was observed in many European countries, especially in 1950-1980. The end of XX century brought increased in the sealed area in EU15 by 6% [10].

Table 1. Type of land usage of Jedrzychow Residential Area

Type of usage	Area in 1964		Area in 2008		Changes	
	km^2	%	km^2	%	km^2	%
Total	7.739	100	7.739	100	-	-
Residential buildings	0.178	2.30	0.462	5.97	0.284	260
Industrial buildings	-	-	0.004	0.05	0.004	0.05
Farm buildings	-	-	0.022	0.28	0.022	0.28
Public utility buildings	-	-	0.013	0.17	0.013	0.17
Roads	0.046	0.59	0.299	3.86	0.253	650
Pavements	-	-	0.221	2.86	0.221	2.86
Parking	-	-	0.019	0.25	0.019	0.25
Sports facilities	-	-	0.002	0.03	0.002	0.03
Allotments	-	-	1.102	14.21	1.100	14.2
Sealed surface	0.224	2.89	1.042	13.47	0.818	465
Unsealed surface	7.515	97.11	6.697	86.53	0.818	10.9

Phot. 1. Jędrzychów Residential Area

Phot. 2. Jędrzychów Residential Area. A – in 1964, B – present day

3.1. Urban sprawl and its consequences

About 75% of the population lives in urbanized areas in Europe. By the 2020 this percentage will increase to 80%, and in some countries it may exceed even 90%. In Poland these values are slightly lower - it is around 60%, while from predicted data this value, over 30 years, will increase to 75% [29].

Uncontrolled urbanization is the cause of many problems, which include:

- social problems: homelessness, social exclusion, ethnic segregation, areas of poverty,
- economic problems,
- urban problems resulting from an ineffective system of the planning, development and operation of cities.

The development of cities and the sealing of ever larger areas brings with it many problems, not only environmental but also technical. This generate huge

costs. By covering the ground with impermeable materials during precipitation, water is not absorbed by the soil and vegetation, but it flows surface or causes overflow of the sewage system causing the so-called urban floods [11, 17]. One hectare of unsealed soil is able to absorb 3750 tonnes of water. By limiting this absorption, and in some cases, completely eliminating the absorption of water, it interferes in the water management [23, 27, 30].

To avoid overcrowding and technological problems in sewage treatment plants, it is necessary to build a separate sewer system, in which domestic waste water is supplied to the sewage treatment plant, and atmospheric precipitation to the receiver (eg. river). Such a solution increase of investment costs, starting from the design stage, through the amount of material and labour.

In environmental terms, it seems much more advantageous to build housing estates in multifamily housing (higher population density), where service and economic functions are already planned in local development plan. In multi-family buildings, the resolution defines the minimum demand for public areas.

Covering the soil surface with asphalt or concrete, putting stone and concrete blocks on it, involves greater absorption of solar energy. Traffic and heat, which produce devices in buildings and less release of water from soil and plants (evapotranspiration or evaporation), can lead to the formation of so-called urban heat islands (UHI) [21, 25]. These are areas with increased air temperature, less humidity, less air flow and altered absorption of sunlight. When analyzing the temperature in and outside the city, it was noticed that the temperature outside the city is from 2°C to 5°C lower than in the city, and in metropolitan areas, even up to 15°C [30]. A good practice that can stop this phenomenon is the inclusion of parks and green areas at the stage of spatial planning. Leaving empty green air corridors leads to better air flow. It has been noticed that there is no problem wth UHI in the areas of cities with trees and urban greenery [24, 30].

In areas where planting and changing the terrain due to too large buildings is not possible, it is proposed to design green roofs and green walls [18, 26].

This applies to both newly constructed and existing buildings. Trees and shrubs affect the speed of air flow and its turbulence, contributing to better air quality and concentration of pollutants. Green roofs contribute to the improvement of the microclimate, have a positive effect on the thermal insulation properties and reduce the effect of UHI. Green roofs contribute to:

- improvement of water balance,
- reducing the amount of water entering the sewage system,
- reduction of dusts and pollutants contained in the air,
- leveling noise and improving aesthetics [2, 3, 20].

3.2. Soil degradation in urban areas

Soil degradation affects the deterioration of the hygienic condition of the environment, reduces productivity and can lead to the total exclusion of the soil from the production process [22, 25]. The main factors affecting the deterioration of urban soils include, among others: building, sealing, compaction, salinisation and chemical pollution [4, 16, 17]. Urban soils are often characterized by the shortening of the soil profile, the presence of admixture materials of natural and anthropogenic origin, the mixing of the material and the introduction of liquid and gaseous substances [5].

Human activities that affect anthropogenic variability of urban soils include, among others:

- residential development,
- industrialization,
- regulation of water relations,
- reclamation of transformed land,
- storage of waste [16, 17].

As a result of mechanical transformations, the basic physical, biological and chemical properties of urban soils may change [14, 17]. Depending on the degree of degradation, the soil profile may be devastated, as a result of which the soil loses functional qualities. Soil sealing is the most intense and essentially irreversible form of soil degradation, because soil formation is a process so long lasting that the accumulation of just a paracentrum layer of soil lasts for whole generations.

Soil sealing has a huge impact on organisms living both above and below the ground. Covering the surface with a layer of asphalt or concrete, causes permanent separation of the soil and atmospheric environment. Water does not penetrate the ground, there is no gas exchange. Sealed soils are generally desiccated because their water storage capacity is limited. They are also characterized by shortening or complete destruction of the soil profile, artificial formation of the soil layer and soil content of anthropogenic materials, such as concrete, steel, debris, roofing fragments, glass, etc. This may cause impeded water flow through individual soil profile layers and deterioration of properties physical soils and impeded vegetation development [17, 19].

4. CONCLUSIONS

- From the point of view of soil protection, it is less invasive to create large, multi-family housing estates with a high population density. The higher the density of population, the more the housing estate must be adapted for

residents. Jędrzychów has a surface seal of 13.47% with a population of 7 thousend inhibitants.

- Soil sealing for parking lots is much smaller in single-family housing area comparing to multi-family housing area as most parking spaces are located in home garages, and they are often made of openwork plates.
- The area occupied by single-family buildings with accompanying facilities (public facilities buildings) is much larger than in the case of the same buildings in multi-family buildings.
- Uncontrolled development of cities and building settlements with low population density pose a threat to sustainable territorial development. It is therefore a challenge for city hosts and urban planners.

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