REPORT ON ENVIRONMENTAL IMPACT ASSESSMENT (TESTING OF TOOL AT14)

D.T2.1.5	Ver.2.0
Report on testing of tool AT14	12 / 2021

Project Partners

Study provided by: Central Mining Institute (LP)

Authors:

Małgorzata Markowska
Małgorzata Deska
Grzegorz Gzyl
Mariusz Kruczek
Paweł Łabaj
Elżbieta Uszok
Paweł Zawartka

Report elaborated as D.T2.1.5

within the project CE1308 Healing Places - *Enhancing environmental management capacities for sustainable use of the natural heritage of Central European spa towns and regions as the driver for local and regional development*.

co-financed by the European Union from the European Regional Development Fund within the scope of the INTERREG Central Europe Programme.

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1. Introduction

The project HealingPlaces – ***Enhancing environmental management capacities for sustainable use of the natural heritage of Central European SPA towns and regions as the driver for local and regional development*** is funded by the EU Interreg Central Europe program and runs between April 2019 and March 2022. The project is coordinated by the Central Mining Institute (Katowice, Poland) as the lead partner, and implemented together with nine Central European partner institutions from Hungary, Austria, Croatia, Italy, Slovenia, and the Czech Republic.

In Poland, there are two partners responsible for project activities: Central Mining Institute from Katowice and Institute of Territorial Development from Wrocław.

In this document we present the results of tool application to assess the impacts on selected mineral water reservoirs closest to the Lower Silesia region. The report on environmental impact assessment concerning testing of the tool was prepared to be used for further database development. The purpose of the tool is to determine the strength of the impact of SPAs on natural resources in different regions of the Central Europe area with a special focus on the regions that participate in the HealingPlaces project.

The tools developed in the frame of WPT1 have been tested in the framework of WPT2 pilot actions in each of the Central Europe regions that participate in the HealingPlaces project. The logic of testing the tool is presented in the following diagram (Figure 1).

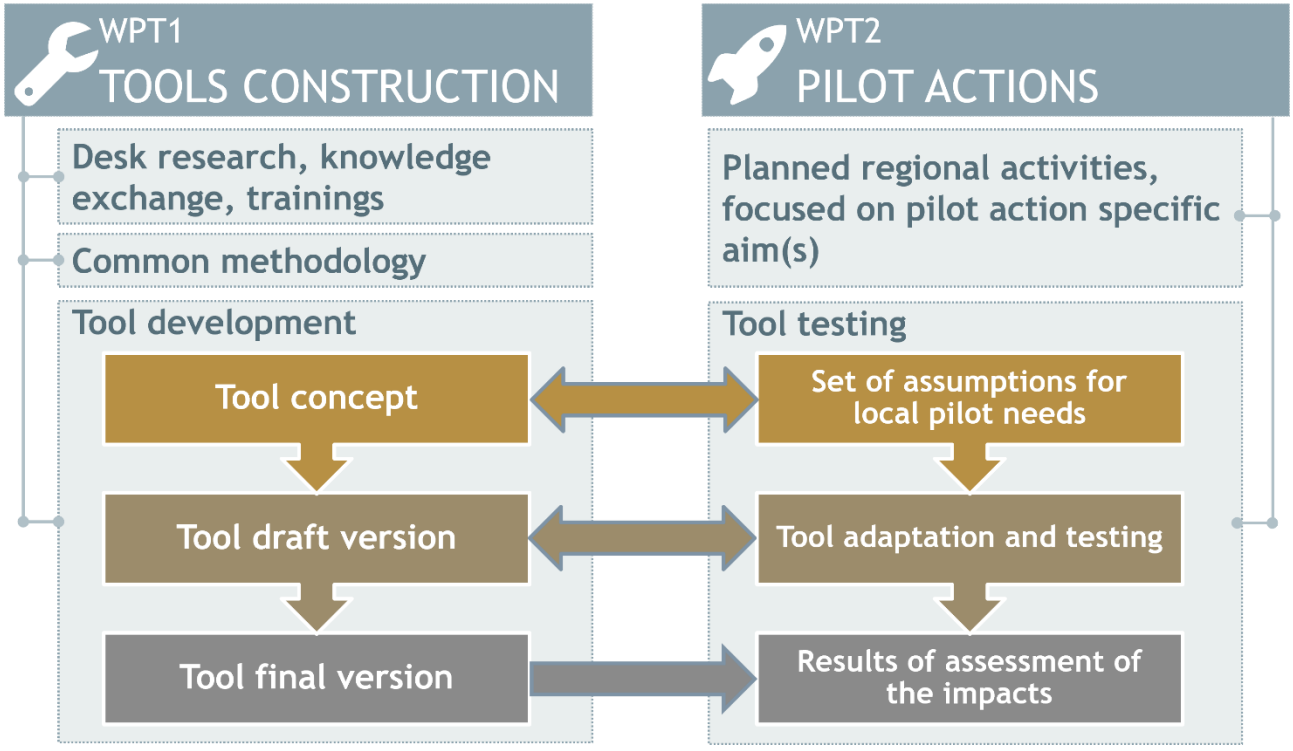


Figure 1 The logic of testing WPT1 tools

Source: GIG own study

Feedback from testing of WPT1 tools in the frame of WPT2 has been an important input to the process of tool development (in the framework of WPT1). The important strategic decision that was done in cooperation with all Project Partners is that the tool for assessment of the environmental pressures of SPAs development should be as simple for the user as possible in order to increase the probability of its wide use after the project ends throughout Central Europe space also outside the partner regions. Furthermore, due to the specificity of each pilot action, the development of assumptions for AT14 tool adaptation to local needs was necessary.

Generally, the main objective of WPT2 is the practical implementation of sustainable thermal water use in SPA. It is understood primarily as ensuring effective & rational use of identified resources & protection of ecosystems while realizing and enhancing its social & economic functions.

In particular, the objective of Pilot action 1 – "Balanced and sustained management of mineral waters in Lower Silesia (PL)" is to be achieved through the integration of regional and local spatial planning policies with the management of curative water resources (including both mineral and thermal water).

One of the works which have been implemented within this pilot action are, among others:

- identification of key stakeholders involved in mineral water management and regional/ local planning,
- tool adaptation to local needs,
- detailed and in depth analysis of threats for mineral waters sensitive areas in pilot area,
- tool application for assessing the impacts on selected mineral water reservoir (testing of the tool AT14),
- description and results of the tool application for assessing the impacts on selected mineral water reservoir within the borders of the Lower Silesia region.

2. Description of Lower Silesia pilot action

The pilot action in Lower Silesia aims at a balanced and sustained management of mineral waters in Lower Silesia through:

- developing a joint Action Plan for the 11 existing spas of the region, containing general and specific recommendations for their development to strengthen the actions beneficial for the protection of the most valuable resources;
- increasing awareness of local administration and society regarding the impact of field investments on the deposits of curative waters;
- better recognition of the regional value of existing spas.

The Lower Silesian Voivodeship pilot action is related to the widest possible implementation of the methodologies, ideas and analytical tools developed in the project to conduct sustainable spa management, not only in the area of the spa municipalities themselves, but also in the areas of municipalities covered by the range of mineral and thermal waters resources on which the spa resorts are based. The key steps of the Polish pilot action are presented in the scheme below (Figure 2).

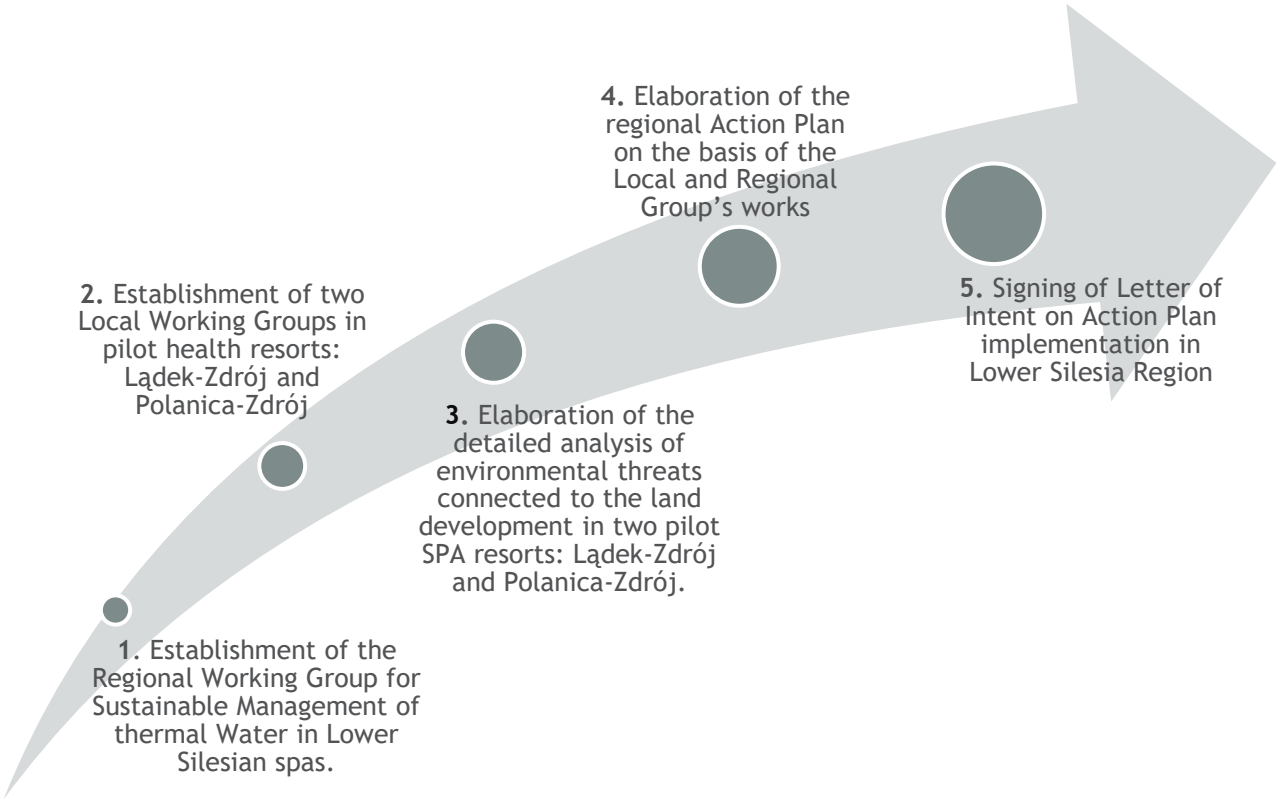


Figure 2 The key steps of Polish pilot action

Source: GIG own study

2.1. List of SPAs

SPA development is a very important sector of general development of the southern part of the Lower Silesia Voivodeship together with tourist activities due to the fact that in the Lower Silesia region there are 11 municipalities that have the official status of „Health Resort" (according to Polish law). In Poland, the granting of the health resort status takes place in accordance with the procedure set out in the *Act of 28 July 2005 on health resort treatment, health resorts and areas of health resort protection and health resort municipalities*. The status of a health resort in Poland can only be granted to an area that simultaneously meets the following requirements:

- has deposits of natural healing resources,
- has a climate with proven medicinal properties,
- the infrastructure of the spa treatment operates within the area,
- meets the environmental requirements set out in environmental regulations,
- has technical infrastructure for water, energy, public transport and waste management.

In the table below the list of Lower Silesian SPAs are presented, together with the information in which commune they are located, as well as the information about the dates of the SPA establishment and the official status of the SPA being granted (Table 1).

Table 1 The Lower Silesian SPAs

Name of the spa	Name of the commune (LAU 2 level)	Date of establishment of the health resort	Date of the official health resort (SPA) status being granted
Cieplice Śląskie-Zdrój	Jelenia Góra	1819	1967
Czerniawa-Zdrój	Świeradów-Zdrój	1860	1967
Długopole-Zdrój	Bystrzyca Kłodzka	1802	1967
Duszniki-Zdrój	Duszniki-Zdrój	XV/XVI w.	1967
Jedlina-Zdrój	Jedlina-Zdrój	1923	1967
Kudowa-Zdrój	Kudowa-Zdrój	1636	1967
Lądek-Zdrój	**Lądek-Zdrój**	**1241**	**1967**
Polanica-Zdrój	**Polanica-Zdrój**	**XVIII w.**	**1967**
Przerzeczyn Zdrój	Niemcza	1802	1997
Szczawno-Zdrój	Szczawno-Zdrój	1815	1967
Świeradów-Zdrój	Świeradów-Zdrój	1899	1967

By the Lower Silesian SPAs listed above, two (Lądek-Zdrój and Polanica-Zdrój) have been selected for a deeper recognition of local circumstances regarding the management and protection of healing waters. The selection has been motivated by several reasons:

a) different hydrogeological and geological circumstances – as Lądek-Zdrój is an example of relict deposits, while Polanica-Zdrój is an example of deposits with renewable characteristics;

b) different ownership structure;

c) different level of popularity;

d) last but not least, the interest and will of cooperation clearly expressed by municipality administration.

Due to these differences, these two SPAs are examples of different problems in the field of management for protection of water resources and preservation of the quality and quantity of the resource and the mitigation of conflicts of interest of the stakeholders involved. Thanks to these differences, the experiences built on the basic of these two pilot actions may be generalized and utilized for broader consideration about Lowers Silesian SPA managements, as most of Lower Silesian SPAs have characteristics more similar to Lądek-Zdrój or to Polanica-Zdrój, respectively, which is described in more details in next chapters.

The protection of healing waters is becoming a very important challenge that European spas are currently facing, including those located in Lower Silesia. In Poland, the deposits of exploited mineral and thermal waters with recognised therapeutic properties are covered by the health resort protection zones (A, B and C) defined in the *Act of 28 July 2005 on health resort treatment,*

health resorts and areas of health resort protection and health resort municipalities. All concessions for the extraction of mineral and thermal waters, including the therapeutic ones, determine the limits of exploitation and the range of possible damages. At the same time, all restrictions related to development activities, including transport infrastructure, buildings and agricultural activity in Poland, do not apply directly to the areas with the mineral and thermal waters deposits, but to the above-mentioned protection zones (A, B, C) within and around health resorts.

Many of the national and regional level strategic documents, take into consideration the existence and potential of health resorts, including *the Strategy for Responsible Development until 2020 (with an outlook until 2030)*[1] (in Polish: *Strategia na rzecz Odpowiedzialnego Rozwoju do roku 2020 z perspektywą do 2030 r.*), in which some measures are focused on *the development of areas with high natural and landscape values, as well as those based on health resorts and cultural values which constitute their high tourist attractiveness.*

The need for development and the increasing influence of human activities put more and more pressure on the valuable healing water resources located in the spa area. Detailed and in-depth analysis of threats for mineral waters sensitive areas in the Polish pilot area was elaborated within Deliverable D.T2.1.3.

2.2. General information about thermal and mineral water resources in Spa resorts and their use and protection aspects

The relevant acts transposing the *Water Framework Directive* and *the Groundwater Directive*[2] into Polish law are the following:

- *The Water Law* - Prawo wodne, Dz.U. 2021 poz. 624[3], with its executive acts
- *The Act on collective water supply and collective sewage disposal* - Ustawa z dnia 7 czerwca 2001 r. o zbiorowym zaopatrzeniu w wodę i zbiorowym odprowadzaniu ścieków, Dz.U. 2020 poz. 2028[4].
- *The Environmental Protection Law* - Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska, Dz.U. 2021 poz. 1070[5]

In general, groundwater in Poland is regulated by the *Water Law*, however, thermal and mineral waters, which are excluded from ordinary groundwater and are regulated by the *Geological and Mining Law*[6]. As a result of this legal framework, most of SPAs are regularly monitored, however,

[1] pol. Strategia na rzecz Odpowiedzialnego Rozwoju do roku 2020 z perspektywą do 2030 r.

[2] Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration

[3] Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 1 marca 2021 r. w sprawie ogłoszenia jednolitego tekstu ustawy - Prawo wodne / Announcement by the Head of the Sejm of the Republic of Poland of 1 March 2021 on the publication of the consolidated text of the Water Law Act

[4] Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 8 października 2020 r. w sprawie ogłoszenia jednolitego tekstu ustawy o zbiorowym zaopatrzeniu w wodę i zbiorowym odprowadzaniu ścieków / Announcement by the Marshall of the Sejm of the Republic of Poland of 8 October 2020 on the announcement of the consolidated text of the Act on collective water supply and collective sewage discharge

[5] Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 18 maja 2021 r. w sprawie ogłoszenia jednolitego tekstu ustawy o Inspekcji Ochrony Środowiska / Announcement of the Marshall of the Sejm of the Republic of Poland of 18 May 2021 on the announcement of the uniform text of the Act on Environmental Protection Inspection

[6] Act of 9 June 2011 on geological and mining law / Ustawa z dnia 9 czerwca 2011r. Prawo geologiczne i górnicze (Dz.U. 2020 poz. 1064)

there are no legally binding regulations or procedures comparable to the State Environmental Monitoring (monitoring of components of the environment in Poland legally established centrally coordinated) from which the thermal and mineral waters are excluded.

Article 5 of the Act of 9 June 2011 the *Geological and Mining Law* classifies brines, curative or thermal waters, as opposed to fresh groundwater, as minerals. The specific requirements and parameters that groundwater must meet to qualify as a mineral regulated by the Geological and Mining Law are the following:

1. To be formally a **curative water**, groundwater cannot be contaminated either in chemical or microbiological terms and must be characterized by natural variability of physical and chemical characteristics, meeting at least one of the following requirements:

a) total dissolved solids- not less than 1000 mg/dm^3, or
b) ferrous ion content- not less than 10 mg/dm^3 (ferruginous waters), or
c) fluoride ion content - not less than 2 mg/dm^3 (fluoride waters), or
d) iodine ion content- not less than 1 mg/dm^3 (iodide waters), or
e) bivalent sulphur ion content - not less than 1 mg/dm^3 (sulphide waters), or
f) meta-silicic acid content - not less than 70 mg/dm^3 (silicic waters), or
g) radon content- not less than 74 Bq/dm^3 (radon waters)[7], or
h) free carbon dioxide content - not less than 250 mg/dm^3 (from 250 to 1000 mg/dm^3 are carbonic acid waters, and above 1000 mg/dm^3 are carbonated waters)[8];

2. To be officially a thermal water, the groundwater must have a temperature at least 20°C at the outlet;

3. To be officially a brine, the groundwater must have at least 35 g/dm^3 total dissolved solids;

4. Mine waters are by definition excluded formally from being curative waters, thermal waters or brines.

The concessions are being issued at first for the research of curative waters, thermal waters or brines and then separately for the exploitation.

Potentially curative waters, that is, for example mineralised (with total solid dissolved minerals over 1,000 mg/dm^3) and specific groundwater, not considered as curative, occur commonly in Poland, including Lower Silesian Voivodeship, at various depths, more often deeper than ordinary waters[9]. Generally, bicarbonate waters with a significant amount of carbon dioxide dominate in the Lower Silesian Voivodeship.

According to the Geological and Mining Law Act (Article 5.2.2), thermal water is groundwater, the temperature of which is at least 20°C in the outflow of the intake. There are thermal waters in the region, mainly within the Sudeten Geothermal Region. The Polish part of the Sudeten geothermal region includes the Sudetes Mountains with the following subregions: Jelenia Góra and

[7] Bq (becquerel) - is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

[8] http://geoportal.pgi.gov.pl/surowce/skalne/solanki_wody/2018

[9] Sokołowski J., Skrzypczyk L., 2018, Brines, curative and thermal water, available at: http://geoportal.pgi.gov.pl/surowce/skalne/solanki_wody/2018, accessed: 22.04.2020

Wałbrzysko-Kłodzki, and the Fore-Sudetic Block, where the following subregions can be distinguished: Legnica and Świebodzice-Niemodlin. Point occurrence of thermal waters has been found so far in the following subregions: Jelenia Góra (Cieplice, Turów), Wałbrzysko-Kłodzkie (Duszniki, Kudowa-Jeleniów, Lądek) and Świebodzicko-Niemodliński (Grabin). The heat flow density in the region is low (45-60 mW/m^2). Only in productive thermal water drillings at Lądek and Cieplice it exceeds 70 mW/m^2 [10]. which is explicable by the important role of the heat flow convectional component. Thermal water temperatures are caused by its deep infiltration due to considerable altitude differences between recharge and discharge areas and the presence of a dense network of fissures accompanying faults. The collectors of thermal waters are strongly involved in tectonically igneous and metamorphic carboniferous formations.

At the same time, it should be noted that geothermal conditions and the method of formation of thermal water deposits in the Sudetes are relatively poorly understood. This condition is related to the complex geological structure of the entire unit and above all, to the few deep boreholes that have been made so far to identify such deposits within the Sudetes.

Table 2 Information about the resources of thermal and mineral waters for the analysed SPAs

SPA name	Water type*	Exploitation reserves [m^3/h]	Water abstraction flow rate [m^3/year]	
			2009	2018
Cieplice Śląskie-Zdrój	LsT	56.54	53 423.00	157 488.00
Czerniawa-Zdrój	Ls	7.88	215.00	-
Długopole-Zdrój	Ls	1.95	12 705.40	2 210.50
Duszniki-Zdrój	LsT	107.48	322 397.80	245 046.99
Jedlina-Zdrój	Lz	5.66	23 370.30	35.00
Kudowa-Zdrój	Lz	29.10	18 890.50	89 446.40
Lądek-Zdrój	LsT	59.82	343 884.00	174 530.50
Polanica-Zdrój	LsLz	51.00	380 903.60	224 874.30
Przerzeczyn Zdrój	Ls	7.67	7 526.00	-
Szczawno-Zdrój	Lz	0.53	4 390.80	3 955.80
Świeradów-Zdrój	LzLs	19.97	10 011.00	9 541.00

** - Water types:*
Lz - mineralized curative waters (mineralization >1 g/dm^3)
Ls- low mineralized curative waters (mineralization >1 g/dm^3)
T- thermal waters
source: http://geoportal.pgi.gov.pl/css/surowce/images/2009/pdf/09_55_solanki_wody_lecznicze_i_termalne.pdf and http://geoportal.pgi.gov.pl/css/surowce/images/2018/pdf/wykaz_solanek_uklad_wojewodzki.pdf

In table below (Table 3) the information concerning types of curative waters in analysed SPAs is presented.

[10] Dowgiałło J., Stan rozpoznania zasobów wód termalnych regionu sudeckiego i perspektywy ich wykorzystania, Technika Poszukiwań Geologicznych, 2007, R. 46, nr 2, s. 29-34

Table 3. Information concerning types of curative waters in analysed SPAs

SPA name	Existing therapeutic agents	Curative waters used in balneotherapy (types)
Cieplice Śląskie-Zdrój	Curative waters, climate	Mineral waters - low mineralised, thermal (up to 90°C), fluoride, silicic, hypotonic.
Czerniawa-Zdrój	Curative waters, climate, radon gas, which saturates air, soil and water	Specific mineral waters of low mineralisation (silicic waters, carbonated waters, ferruginous waters, radon waters)
Długopole-Zdrój	Curative waters, climate	Mineral waters – carbonated waters, bicarbonate-calcium-magnesium-sodium, ferruginous waters, radon waters, silicic waters
Duszniki-Zdrój	Curative waters, climate	Mostly carbonic acid mineral waters; specific mineral waters of low mineralisation (silicic waters, carbonated waters, radon waters)
Jedlina-Zdrój	Curative waters, climate	Specific mineral waters of low mineralisation - carbonated waters, ferruginous waters, fluoride waters, radon waters,
Kudowa-Zdrój	Curative waters, climate	Hydrogen-carbonate-sodium-calcium, arsenic and ferruginous acidic waters from "Śniadecki", "Moniuszko" and "Marchlewski" springs.
Lądek-Zdrój	Curative waters, climate	Natural thermal mineral waters, rich in fluorides, sulphides, hydrogen and radon. The resort operates seven springs of which six are naturally flowing and one that emanates from a borehole. The temperature of the spring water ranges between 17.5°C and 43.9°C[11].
Polanica-Zdrój	Curative waters, climate	Low mineralised carbonated waters
Przerzeczyn Zdrój	Curative waters, peat, climate	Low mineralised radon and sulphide waters
Szczawno-Zdrój	Curative waters, climate	Specific waters of various mineralisation – mostly low and medium carbonated spring water which is high in bicarbonates, sodium, calcium and magnesium, radon waters
Świeradów-Zdrój	Curative waters, climate	Specific waters of low mineralisation - radon-active mineral waters, acidoulus waters, silicic waters, ferruginous waters

Source: GIG own study, based on http://geoportal.pgi.gov.pl and specific SPA resorts websites.

2.3. Lądek-Zdrój

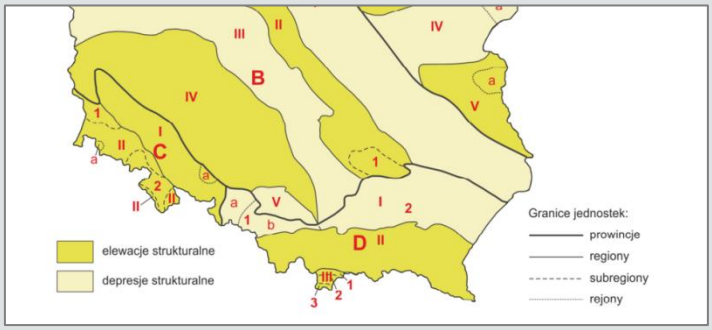
The Lądek-Zdrój municipality is located in the south-western part of the country, in the Dolnośląskie voivodeship, in the Kłodzko County. It borders the following municipalities: Złoty Stok (from the north), Stronie Śląskie (from the south), Bystrzyca Kłodzka (from the south-west) and the rural municipality of Kłodzko (from the north-west). From the east, it borders the Czech Republic. In terms of physicogeographical location, the municipality is located in the Eastern

[11] https://www.poland.travel/en/experience/relax/spa-wellness/ladek-zdroj-radioactive-waters

Sudetes, and its area covers parts of two mesoregions: the Złote Mountains with the Biała Lądecka Valley, the Lądecka Basin and the Śnieżnik Massif (Krowiarki). The highest point of the municipality is the Borówkowa peak located in the Złote Mountains (900 m above sea level), the lowest one is the riverbed of Biała Lądecka with a height of 360 m above sea level. The total area of the Lądek-Zdrój municipality is 117 km^2. Taking into account geothermal energy, the commune belongs to the "Sudeten geothermal region"[12]. Lądek-Zdrój spa is one of the oldest health resorts in Europe. The first mention of the hot springs, discovered by Prince Bolesław Wysoki, dates back to 1175. In 1498, the "Jerzy" Natural Medicine Centre was established, where the first tests to determine the chemical composition of the waters were conducted. The health resort specializes in providing the following therapeutic treatments: baths and swimming pool baths, hydrotherapy, mud treatments, individual and group gymnastics, dry and underwater massages, individual and group inhalations, magnetotherapy and electro and light therapy. For drinking water treatment, water from all springs is used. All therapeutic properties of individual springs have been included in the local Resolution No. XV/87/11 of the Municipal Council in Lądek Zdrój. The Spa Lądek-Zdrój also produces cosmetics containing biosulphur[13].

The table below summarizes the most important information about Lądek-Zdrój (Table 4).

Table 4 The general information about Lądek-Zdrój

	CHARACTERISTICS
Location	Sudeten region - Sudetes province C, Sudeten region II  Figure 3. Regional division of Poland's healing and mineralized waters (based on Dowgiałło & Paczyński, 2002)
Geology	Waters occur mainly in crystalline massifs (granites, metamorphic rocks - gneisses, mica schists). Lądek thermal healing waters are fed from one deep circulation fissure deposit.
Hydrogeology	▪ The flow of water and their accumulation are associated with fractures of various origins; the greater degree of fracuring of the rock massif is mainly related to the zones of deep faults. ▪ Time of underground flow up to approx. 10 thousand years (1 m/year)
The origin of water	infiltration
Recharge zone	The southern part of the Złote Mountains and in the Bialskie Mountains, SE from Lądek-Zdrój

[12] Ciężkowski, W., Michniewicz, M., Przylibski, T. A., 2011. Wody termalne na Dolnym Śląsku. W: Żelaźniewicz, A., Wojewoda, J., Cieżkowski, W., [red.] – Mezozoik i Kenozoik Dolnego Śląska, 107-120, WIND, Wrocław

[13] Felter, A., Skrzypczyk, L., Socha, M., Sokołowski, J., Stożek, J., Gryszkiewicz, I., Gryczko-Gostyńska, A., 2018. Mapa zagospodarowania wód podziemnych zaliczonych do kopalin w Polsce 2017. Tekst objaśniający. Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Drukarnia Braci Grodzkich S. J., Warszawa

	CHARACTERISTICS
Resources	The total amount of water now naturally flowing out of the deposit is almost constant. Currently, the deposit is exploited in stabilized conditions. Total resources of poorly mineralized and thermal waters: ▪ Available resources: 915,00 m^3/h. ▪ Exploitation resources: 59,82 m^3/h. ▪ Consumption in 2020: 95 656,00 m^3/year.
Characteristics of the water	Thermal waters with low mineralization below 0.2 g / dm^3, radium sulphide, fluoride: type HCO_3 – Na, F, Rn, (S) one of the few in the world containing radon up to over 1300 Bq / dm^3 emitting ionizing radiation having one of the highest groundwater temperatures in Poland (Cieplice Śląskie-Zdrój).
Usage	All intakes are used for balneotherapy and are located within the Lądek-Zdrój mining area. The exploited thermal waters are used only for balneological purposes, as much as 43% of the abstraction is not used at all. The heat from the post-treatment waters is also not obtained. Healing water intakes: 6 springs - Jerzy, Wojciech, Chrobry, Skłodowska-Curie, Dąbrówka, Stare; 1 borehole - L-2 - 1973 - 700 m; 1 well - LTZ-1 - 2019 - 2,500 m.
Entity with a water extraction license	Lądek-Długopole S.A. Health Resort
Threats	Conditions may be disturbed in the event of excessive exploitation of the L-2 borehole and / or other deep intake, such as e.g. a planned new thermal water intake.

Source: GIG own study, based on: Struktura hydrogeologiczna wód leczniczych Lądka-Zdroju, prof. dr hab. inż. Wojciech CIĘŻKOWSKI, dr Barbara KIEŁCZAWA, Politechnika Wrocławska, Wydział Geoinżynierii, Górnictwa i Geologii, Lądek Zdrój, HealingPlaces workshop, 23.09.2021; Liber-Makowska E., Kiełczawa B., Charakterystyka wybranych parametrów złożowych termalnych wód leczniczych Lądka-Zdroju, Technika Poszukiwań Geologicznych Geotermia, Zrównoważony Rozwój nr 2/2017; Mapa zagospodarowania wód podziemnych zaliczonych do kopalin w Polsce 2015, PIG PIB, Warszawa, 2017; Bilans zasobów złóż kopalin w Polsce wg stanu na 31.12.2020 r., PIG PIB, Warszawa, 2021

2.4. Polanica-Zdrój

The Polanica-Zdrój municipality is located in the south-western part of the Dolnośląskie Voivodeship (Lower Silesia), in Kłodzko County. It is located in the Bystrzyca Dusznicka valley at an altitude of 370-560 m above sea level. The neighbouring communes are as follows: Szczytna commune (from the west, north and north-west), Kłodzko rural commune (from east) and Bystrzyca Kłodzka commune(from south). From the northwest the municipality is sheltered by the Stołowe Mountains and from the southeast by the Bystrzyckie Mountains. The highest hill is the Wietrznik peak (758 m above sea level). Polanica-Zdrój belongs to the Sudety geothermal region and to the Wałbrzych-Kłodzko subregion, separated within it[14].

[14] Paczyński, B., Sadurski, A., 2007. Hydrogeologia regionalna Polski, tom I, Wody słodkie. Państwowy Instytut Geologiczny, Ministerstwo Środowiska, Warszawa.

The first records of Polanica-Zdrój date back to the 14th century[15]. In 1827 a merchant from Kłodzko, Grolms, bought Polanica and decided to build there a health resort following the example of nearby Duszniki[16]. In 1904 the SPA passed into the hands of a medical company, which started to build a modern and luxurious infrastructure there. At that time, the SPA specialized in the treatment of cardiovascular diseases. After World War II, Dom Zdrojowy was transformed into a cardiological sanatorium and by 1950 the therapeutic profile was developed to include also gastrology[17]. In 1974 Zespół Uzdrowisk Kłodzkich (The Complex of Kłodzko Spas) was established with its seat in Polanica, which managed the sanatorium and spa objects and water bottling plants in Polanica, Duszniki and Kudowa. Currently the group operates as Uzdrowiska Kłodzkie S.A. - PGU Group, which received a permit for exploitation of therapeutic waters from deposits in Polanica-Zdrój under concession no. 165/93 of 16 July 1993 granted by the Minister of Environmental Protection, Natural Resources and Forestry and is valid until 16 July 2043[18].

In the area of the health resort there are health resort facilities, such as: health resort hospitals, health resort sanatoriums, natural medicine institutions and health resort clinics. Spa treatment facilities in Polanica-Zdrój include: mineral water pump room, spa park, salt caves, swimming pools.

Table 5 The general information about Polanica-Zdrój

	CHARACTERISTICS
Location	Sudeten region - Sudetes province C, Sudetes region II, mid-Sudetes subregion
Geology	These waters occur within the Quaternary sediments and the Upper Cretaceous aquifer complex.
Hydrogeologia **Hydrogeology**	▪ Artesian springs where the water flows naturally under hydrostatic pressure. ▪ Underground flow time from approx. 10 thousand. years (1 m/year) up to 25 years: – P-300 - Pre-1952, but not more than 10,000 years old – Pieniawa Józef I and Pieniawa Józef II - 300 and 130 years old – JS - over 25 years
The origin of water	Contemporary - Infiltration
Recharge zone	Located to the west of Polanica-Zdrój and covers the Duszniki Depression, from Szczytna to Złotno (Szczytna and Duszniki Zdrój commune).
Resources	Total mineralized and poorly mineralized water resources: ▪ Available resources: 6 713,00 m3/h. ▪ Exploitation resources: 81,22 m3/h. ▪ Consumption in 2020: 246 707,52 m3/year.
Characteristics of the water	▪ bicarbonate and carbonic acid waters belong to the HCO3 – Ca, (Fe) type with mineralization from 0.9 to 2.7 g/dm3 and free carbon dioxide content from 500 to 2 700 mg/dm3 ,

[15] Marcinek K., Prorok W., 1984. Duszniki Zdrój, Polanica Zdrój i okolice.

[16] Duszniki – Zdrój had been an official health-resort since 1769 r., when "Zimny Zdrój" medicinal spring was included in the official list of medicinal springs of Prussia. Source:

[17] *Brygier W., Dudziak T., 2010. Ziemia Kłodzka. Pruszków: Oficyna Wydawnicza „Rewasz",*

[18] Felter A., Skrzypczyk L., Socha M., Sokołowski J., Stożek J., Gryczko-Gostyńska A., 2019. Mapa zagospodarowania wód podziemnych zaliczonych do kopalin w Polsce 2019. Tekst objaśniający. Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Drukarnia Braci Grodzkich S. J., Warszawa.

	CHARACTERISTICS
	▪ cool waters.
Usage	Within the Polanica-Zdrój mining area, there are five hydrogeological wells adapted to the exploitation of curative waters. The Żelaziste and Józef Springs, with a capacity of 0.3 and 2.1 m^3/h, respectively, have no documented exploitation resources. Healing water intakes: Wielka Pieniawa, Pieniawa Józef I, Pieniawa Józef II.
Entity with a water extraction license	Uzdrowiska Kłodzkie S. A. - PGU
Threats	Mixing of ordinary waters with sorrels Exploitation of the boreholes resulted in the disappearance of most of the natural springs, only two of them are still active - Józef and Żelaziste. The supply area not covered by protection - covers the area of the commune of Duszniki Zdrój, Szczytna

Source: GIG own study, based on: Struktura hydrogeologiczna wód leczniczych Polanicy-Zdroju, prof. dr hab. inż. Wojciech CIĘŻKOWSKI oraz dr Barbara KIEŁCZAWA, Politechnika Wrocławska, Wydział Geoinżynierii, Górnictwa i Geologii, Polanica-Zdrój, warsztaty HealingPlaces 24.09.2021; Mapa zagospodarowania wód podziemnych zaliczonych do kopalin w Polsce 2015, PIG PIB, Warszawa, 2017; Bilans zasobów złóż kopalin w Polsce wg stanu na 31.12.2020 r., PIG PIB, Warszawa, 2021.

2.5. Threats of natural and anthropogenic origin for healing waters

The quality of groundwater is influenced by natural (geogenic) and anthropogenic factors (connected with human activity). The basic challenge for proper management of therapeutic waters is to maintain the unchanged chemical composition and physical characteristics of these minerals. Another important aspect is maintaining a constant intake capacity, which allows for proper operation of spas and therapeutic facilities[19].

The main cause of groundwater degradation is the infiltration of substances into groundwater. There are different sources of contamination, mostly being a result of human activity that causes changes in water properties[20]. In this way of understanding, natural phenomena that may cause groundwater contamination include the following:

- co-occurrence of ordinary and mineral waters in the near-surface zone, including migration toward the surface of mineral water containing CO_2 along tectonic discontinuities;
- seawater ingression;
- bottom erosion;
- earthquakes;
- long-term changes in climatic conditions.

Anthropogenic threats include, among others:

[19] Dowgiałło J., Fistek J., Kazimierski B., Paczyński B., Sadurski A., Sokołowski A., Witczak S., 2002. Ocena zasobów dyspozycyjnych wód leczniczych i potencjalnie leczniczych. Poradnik metodyczny. Państwowy Instytut Geologiczny, Ministerstwo Środowiska, Warszawa.

[20] Paczyński, B., Sadurski, A., 2007. Hydrogeologia regionalna Polski, tom I, Wody słodkie. Państwowy Instytut Geologiczny, Ministerstwo Środowiska, Warszawa.

- agriculture;
- animal husbandry;
- industry and proximity to industrial areas,
- activities and investments carried out, especially construction investments on the land surface (services, housing),
- mining,
- construction and operation of a water supply and sewage disposal system, including the number and capacity of sewage treatment plants,
- land reclamation,
- proximity of landfills,
- transport and communication;
- existence (number, depth and proximity) of water intakes.

2.6. Analysis of threats of anthropogenic origin to the thermal and mineral waters in Lądek-Zdrój and Polanica-Zdrój

Detailed and in depth analysis of threats for mineral waters sensitive areas in Polish pilot area was elaborated within Deliverable *D.T2.1.3. Szczegółowa i pogłębiona analiza zagrożeń dla wrażliwych obszarów wód mineralnych w obszarze pilotażowym/Detailed and in depth analysis of threats for mineral waters sensitive areas in Polish pilot area*, prepared by IRT (Instytut Rozwoju Terytorialnego) team.

Graphical results for Lądek-Zdrój are presented in the figure below (Figure 4), where 5 on the scale of 0 to 5 means the highest potential threat to underground waters due to land use and 0 means the lowest potential threat. It should be noted that a spatial analysis has been performed for the area of the SPA municipality, while there curative source zones may be located away from the drainage zones due to hydrogeological circulation channels.

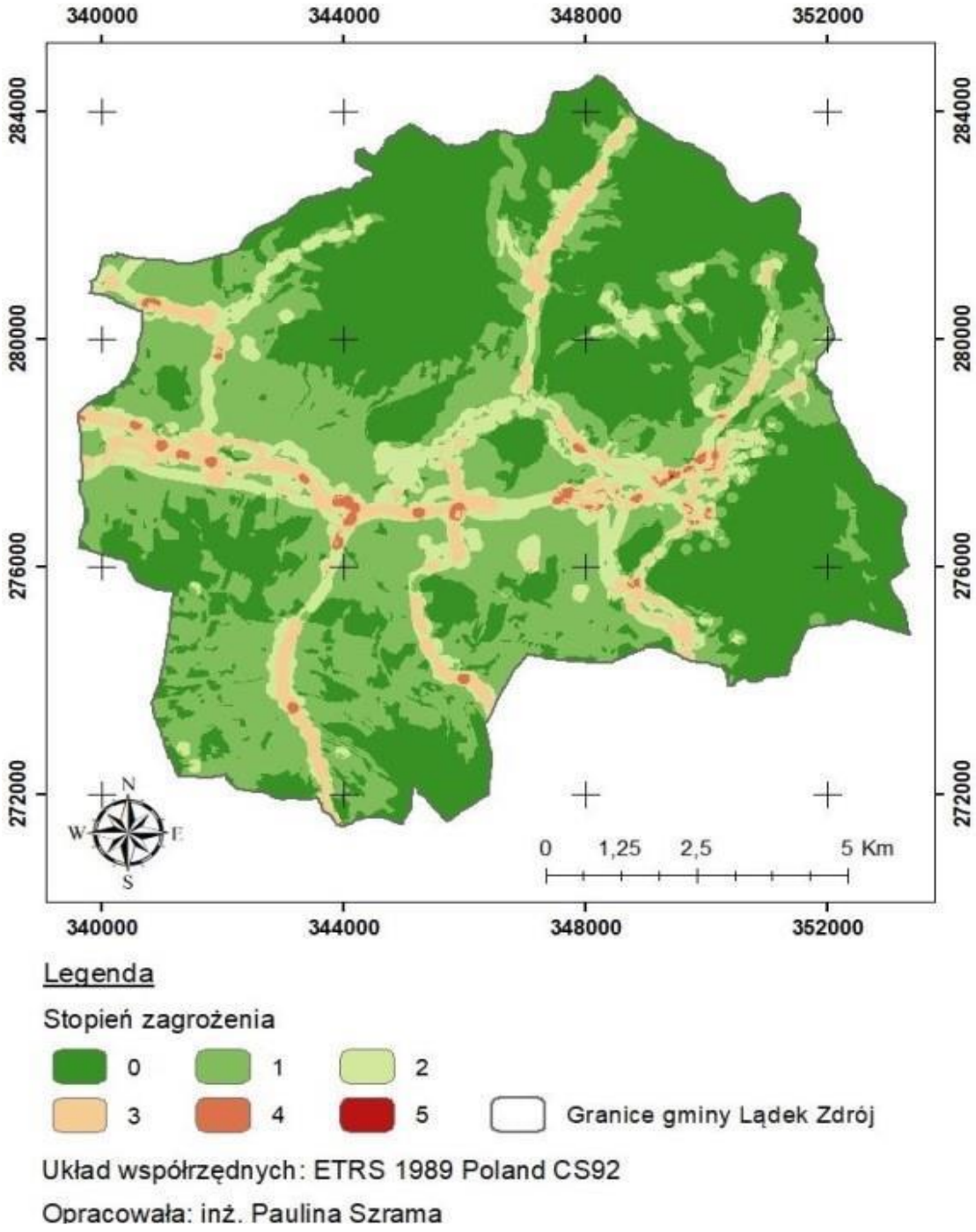


Figure 4 Occurrence of anthropogenic threats for mineral waters in Lądek-Zdrój

Source: Szrama P., Przestrzenna analiza zagrożenia zasobów wód leczniczych na przykładzie wybranej gminy uzdrowiskowej w województwie dolnośląskim - Spatial analysis of the threat to curative water resources on the example of a selected spa commune in the Lower Silesia Voivodeship.. Master Thesis, Faculty of Geoengineering, Mining and Geology, Wroclaw University of Science and Technology, Wroclaw 2019

The following were considered the most significant in each threat group:

- arable land in the group of “Agriculture”
- mining plants – in the group of “Mining”,
- industrial landfill sites – in the group of „Industry”,

- sewage discharges in group of “Water supply and sewage disposal system”
- transport and transhipment places – in the “Transport” group.

A map of the occurrence of all anthropogenic threats, including weights obtained from AHP analysis, in the mining area of the Polanica-Zdrój medicinal water deposit is presented below (Figure 5).

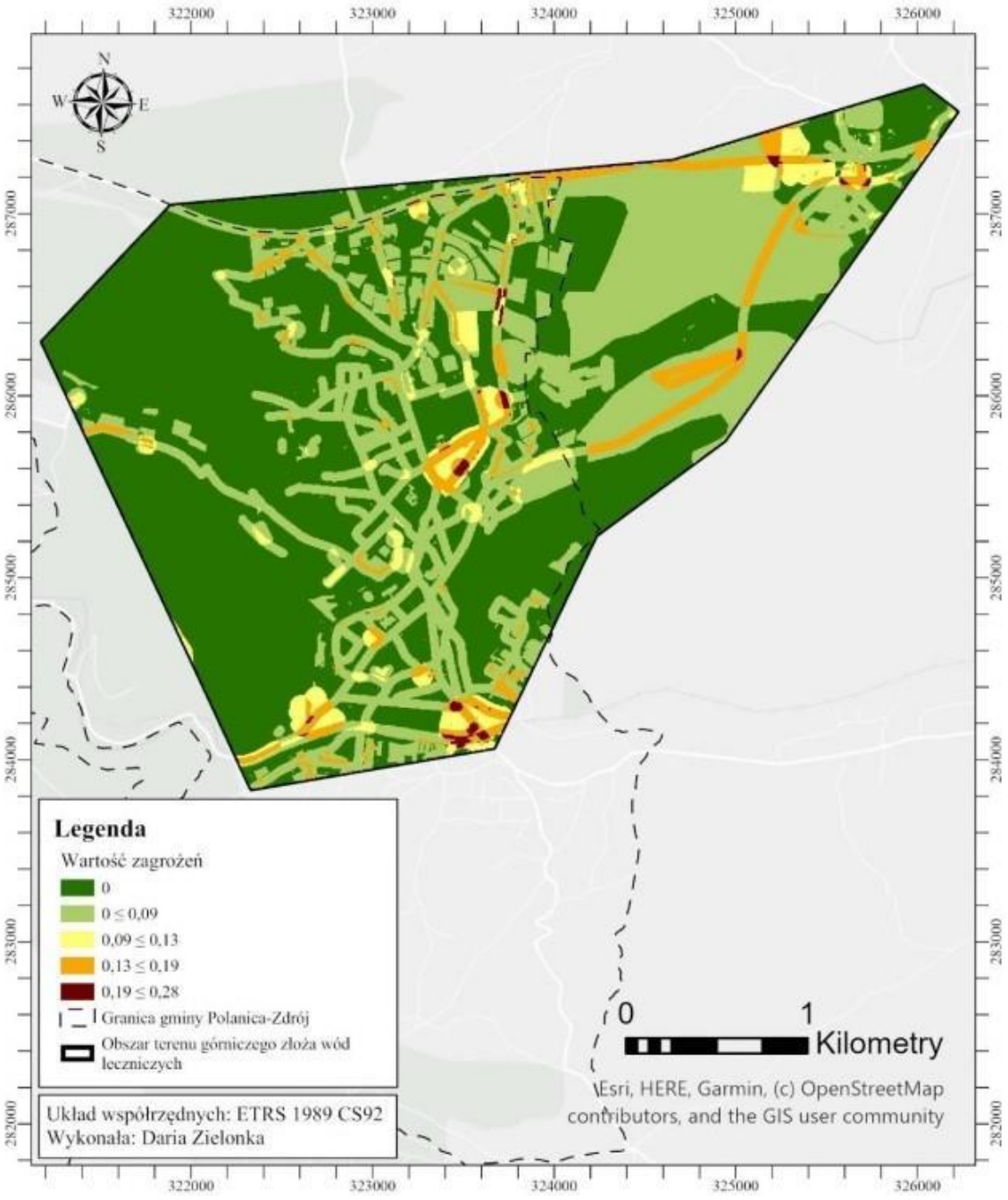


Figure 5 Occurrence of anthropogenic threats for mineral waters in Polanica-Zdrój

Source: Zielonka D. Opracowanie mapy potencjalnych zagrożeń pochodzenia antropogenicznego dla wód leczniczych w wybranej gminie województwa dolnośląskiego - Map of potential threats of anthropogenic origin for curative waters in a selected commune of the Lower Silesian Voivodship. Bachelor Thesis, Faculty of Geoengineering, Mining and Geology, Wroclaw University of Science and Technology, Wroclaw 2021

Industrial areas and mineral deposits exploitation were considered to be the most significant threat to the healing waters. The least significant were orchards and gardens, built-up areas with domestic sewage treatment plants and cemeteries.

Areas that have been identified as vulnerable to anthropogenic hazards as a result of spatial analyses should be under special control to counteract the degradation of these waters. It seems that additional prioritization of these threats using the AHP method can be very useful for performing more detailed and in-depth studies in this field.

3. Results of HealingPlaces tool for impact assessment of SPAs development aplication

3.1. HealingPlaces tool for impact assessment of SPAs development basic information

The tool is intended as a support in the decision-making process. It is dedicated to SPA municipalities (the municipalities that have at least one SPA in their area regardless of having or not having the official status of SPA municipality).

The important strategic decision that was done in cooperation with all Project Partners is that the tool for assessment of the environmental pressures should be as simple for the user as possible in order to increase the probability of its wide use after the project end throughout Central Europe space also outside the partner regions.

The main idea behind the tool is to calculate the pressures on the environment that are following the development of SPA tourism.

The tool uses algorithms related to the determination of few significant correlations, including:

- Impact of the development of the SPA and tourism industry on the availability of thermal and/or mineral water resources in quantitative terms,
- The influence of the development of spa communities and changes in land use on the threat to the quality of thermal and/or mineral water resources,
- The impact of spa development on the availability and carrying capacity of green areas.

It was agreed that the main input data required from the user is the number of new SPA guests expected, which was based on the idea of **Tourism Carrying Capacity**[21], as defined by the World Tourism Organization.

The tool for impact assessment of SPAs development allow to recalculate the number of new guests into series of individual pressures – each pressure with its own algorithm derived mainly from available statistical data for SPA regions. The individual pressures will be calculated to achieve "maximum additional tourists number" to obtain a unified overall value of the impact of SPA development on the environment.

3.2. Process of tool for impact assessment of SPAs development's update and testing

LP and PP2 (IRT) have cooperated in tool preparation in order to best tune it to local circumstances in selected SPA municipalities in Europe.

[21] Tourism Carrying Capacity = the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction.

The testing process included four main phases, from the draw tool to the final version, during which the tool was constantly evaluated and changed, responding to the emerging needs and suggestions of the testers.

The main changes related to the functionality and content of the tool for impact assessment of SPAs development were:

- updating and verification of the database,
- security and verification of algorithms,
- addition of new functionalities in the visualisation and benchmarking, and land cover index, as well as improvement of the visual layer and intuitive use by potential users.

The diagram below (Figure 6) presents the testing process and its results, which constitute the basis for changes in the tool.

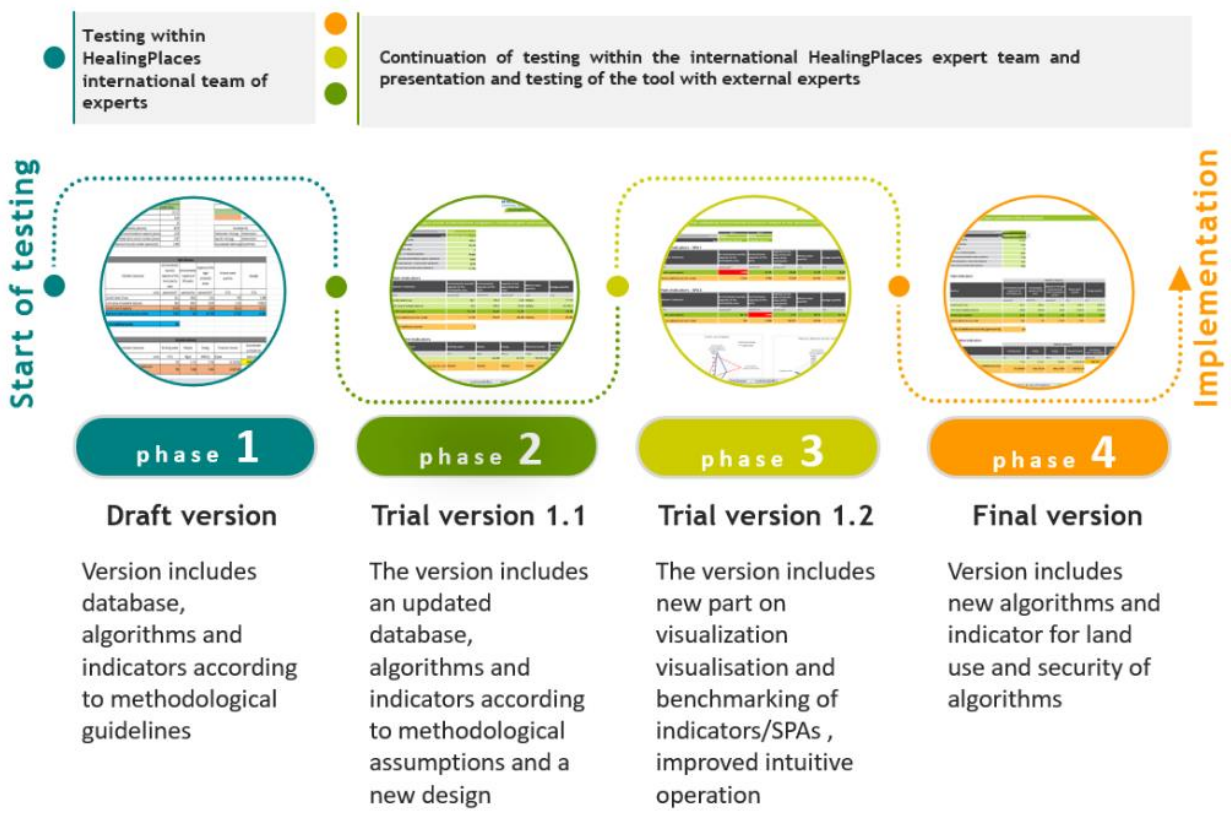


Figure 6 The testing process the tool for impact assessment of SPAs development's and its results

Source: GIG own elaboration

LP and PP2 (IRT) collaborated in the process of testing the tool with local stakeholders in two selected SPA municipalities in Poland (Lądek-Zdrój, Polanica-Zdrój), where project pilot activities are carried out.

Testing of the tool was conducted in three working groups in parallel:

- an internal one composed of GIG and LP experts responsible in the project for the development of the tool,
- a project group with international experts responsible for pilot actions and tool testing with regional stakeholder groups in each country,
- external with local stakeholders in the two selected SPA municipalities in Poland where the pilot actions are carried out.

Several online workshops were held as part of the internal and project consultation and testing of the tool.

The working online meetings were conducted, focusing on several thematic subtopics particularly important for these municipalities, including meetings on 12.10.2020, 03.11.2020 and many further workshops in one of thematic groups (water, environment and economic).

In the meantime, the changes in the tool implemented after GIG team working meetings with specific partners (e.g., on 10.02.2021, 05.03.2021 and 23.03.2021) have been implemented and tested in cooperation with regional stakeholders – including the meeting on 31.03.2021.

The key consultation with local decision makers was the testing of the tool during workshops in Ladek-Zdroj and Polanica-Zdroj in September 2021. The outcome of these consultations was the control and security of the algorithms, the completion of the visual layer, and the benchmarking of SPAs. At the same time, the process of consultation and development of the tool continued. As a result of further meetings with experts (project Partners), the spatial part of the "LandCoverIndex" tool was finalised at a decisive workshop in October 2021.

3.3. Logic of the tool and its specific indicators

The Excel-based tool is divided into three parts:

Information part

Country:	Poland
SPA:	Ladek-Zdroj
Municipality area [km2]	117,27
Area of SPA parks [ha]	6,54
Defert's index	14
Current No. of inhabitants [persons]	8276
Current tourists accommodation capacity [persons/d]	1178
Current estimated daily visitors number [persons/d]	1767
Current maximum tourists number [persons/d]	2945

Main indicators

	Indicator (resource)				
Measures	Environmental touristic capacity of the municipality area	Environmental capacity of SPA parks	Capacity of the legal protected areas within municipality borders	Mineral water quantity	Sewage quantity
	persons/km²	persons/ha	persons/km²	m³/d	m³/d
Current level of use	25,11	450,31	0,51	478,17	2 487,70
Limit value of scalable resource	58,00	500,00	25,00	1 224,00	8 000,00
Current use of capacity	43,3%	90,1%	2,0%	39,1%	31,1%
Maximum additional tourists number	3857	325	141590	17502	24864

Illustrative indicators

	Indicator (resource)					
Measures	Drinking water	Wastes	Energy	Financial income	Groundwater (GW) vulnerability	Land Cover Impact (LCI)
	m³/d	Mg/yr	MWh/yr	€/year	[descriptive]	[descriptive]
Current level of use	741,9	3174,41	3735,94	13155830,59	high risk	low risk
Predicted level of use for min. Additional tourists number *(estimated from main idicators)*	763,3880581	3266,352184	3844,146087	14607662,48		

More detailed description and logic of the tool and its development' process can be found in previous HealingPlaces deliverables, such as:

- D.T1.4.1. *Common methodology & ranking criteria for assessment of impact strength on natural resources in SPAs*, Central Mining Institute, 2020;
- D.T1.4.2. *Common tool for integrated assessment of threats & pressures on main SPAs' resources – draft version*, Central Mining Institute, 2021;
- D.T1.4.3 *User guide – draft version* (Technical protocol /guideline for impact assessment & environmental capacity matrix), Central Mining Institute, 2021;
- D.T2.1.2 *Report on WP1 tools adaptation to local & regional needs*, Central Mining Institute, 2021.

The final version of the tool is available under D.T1.4.5 *Common tool for integrated assessment of threats & pressures on main SPAs' resources – final version*, Central Mining Institute, 2021.

There are five main indicators which are used in the process of calculation of SPA development capacity. The main indicators are as follows:

1) environmental touristic capacity of the municipality area;
2) environmental capacity of SPA parks;
3) capacity of the legal protected areas;
4) sewage;

5) mineral water quantity.

For each the indicators mentioned above, the "current level of use" is calculated based on algorithms developed, taking into account the interdependencies between the values listed in the "Information section".

For each indicator the "current level of pressure" is compared to the "limiting value of the pressure". Then, for each indicator the "Maximum additional tourist number" is calculated, meaning the number of additional tourists still allowed while the limit value of the pressure is not exceeded for a given indicator. Finally, the "Maximum additional tourist numbers" are compared for each indicator and the lowest number is selected to be displayed as "Limit of additional tourists". This value represents the suggestion for decision makers about how many additional tourists are still allowed in order to keep the environmental pressure at the relevant level. Specific information about the indicators, as well as the specific instruction (methodological aspects) how they are calculated are available in Deliverable D.T1.4.3 – *User guide – draft version (Technical protocol /guideline for impact assessment & environmental capacity matrix) and* D.T1.4.4 – *User guide (Technical protocol /guideline for impact assessment & environmental capacity matrix) final version*.

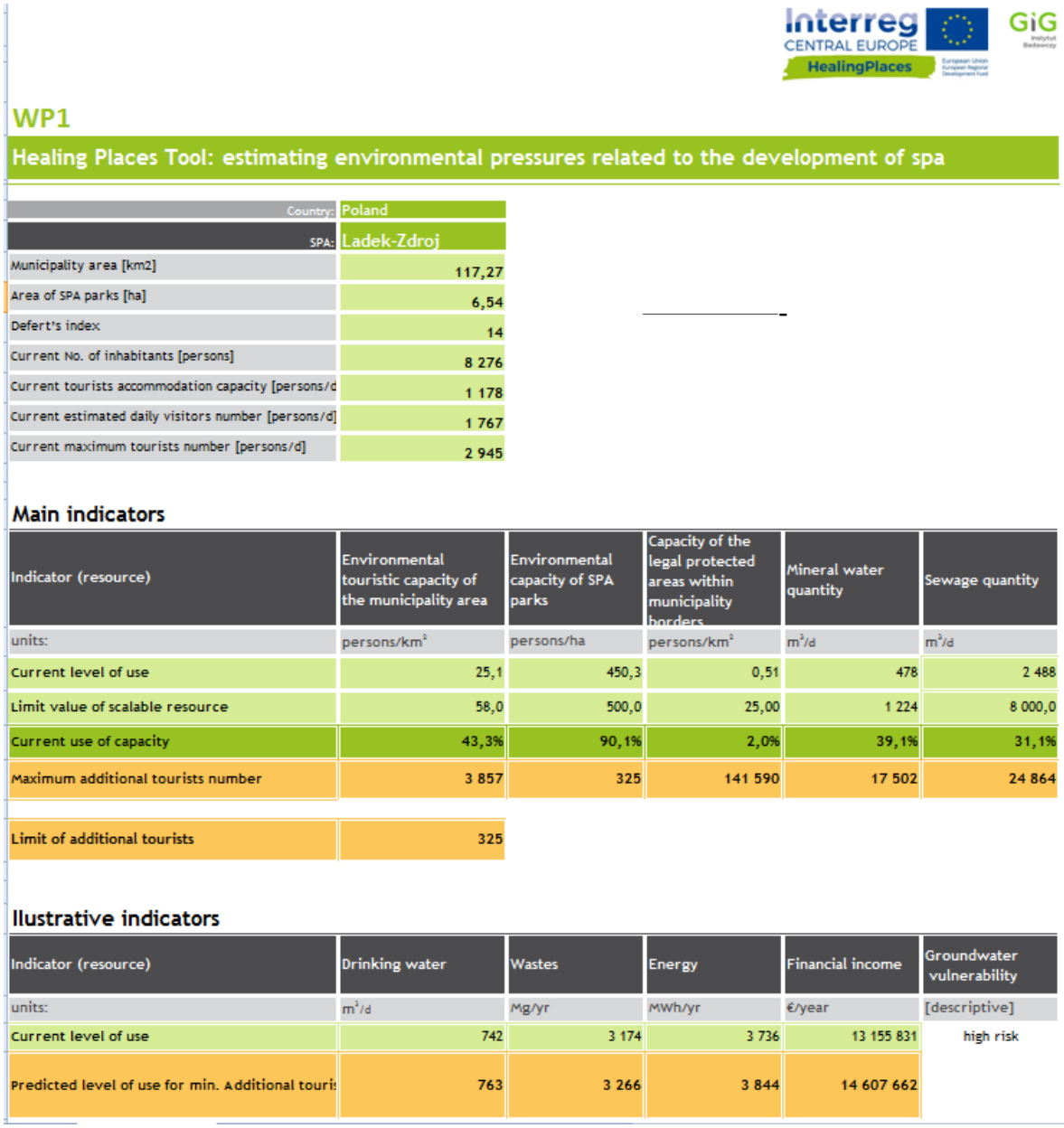
3.4. Results of tool testing

The results of tool calculations were discussion with regional and local stakeholders in summer 2021 during online meeting, as well as during two local workshops, held on 23rd September 2021 in Ladek Zdrój and on 24th September 2021 in Polanica-Zdrój.

During the discussion, a key aspect taken into account was that the waters in Polanica are waters forming a circulatory system (they are renewable resources), hence they are more sensitive to the impact of other elements and activities on the environment.

Also the differentiation of environmental conditions between these municipalities is also clear from the tool calculations themselves – including the considerable differences between the areas of the communes (Polanica is significantly smaller), as well as the fact that the urban area (built-up area) constitutes most of the area of Polanica, while in Lądek a significant part of the area is woodland, meadows and agricultural land.

Even these differences are a good basis to show that the tool catches the associated risks well. The results calculations of the tool have been shown in the examples of Lądek-Zdrój (Figure 7) and Polanica-Zdrój (Figure 8).



WP1

Healing Places Tool: estimating environmental pressures related to the development of spa

Country:	Poland
SPA:	Ladek-Zdroj
Municipality area [km2]	117,27
Area of SPA parks [ha]	6,54
Defert's index	14
Current No. of inhabitants [persons]	8 276
Current tourists accommodation capacity [persons/d	1 178
Current estimated daily visitors number [persons/d]	1 767
Current maximum tourists number [persons/d]	2 945

Main indicators

Indicator (resource)	Environmental touristic capacity of the municipality area	Environmental capacity of SPA parks	Capacity of the legal protected areas within municipality borders	Mineral water quantity	Sewage quantity
units:	persons/km²	persons/ha	persons/km²	m³/d	m³/d
Current level of use	25,1	450,3	0,51	478	2 488
Limit value of scalable resource	58,0	500,0	25,00	1 224	8 000,0
Current use of capacity	43,3%	90,1%	2,0%	39,1%	31,1%
Maximum additional tourists number	3 857	325	141 590	17 502	24 864

Limit of additional tourists	325

Ilustrative indicators

Indicator (resource)	Drinking water	Wastes	Energy	Financial income	Groundwater vulnerability
units:	m³/d	Mg/yr	MWh/yr	€/year	[descriptive]
Current level of use	742	3 174	3 736	13 155 831	high risk
Predicted level of use for min. Additional touri:	763	3 266	3 844	14 607 662	

Figure 7 Results of calculations for Lądek-Zdrój

Source: GIG own calculation based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, GIG, 2021

The results of the calculations clearly show that the current development of the Lądek-Zdrój community, especially access to green areas, including protected ones, in combination with the state and size of its technical infrastructure (including water and sewage systems), still allows for a relatively safe increase in the number of tourists (although by a small number in comparison to the current number of tourists) - without exceeding the capacity of any of the indicators.

At the same time, in the case of Polanica-Zdrój, the current number of tourists already exceeds both the “environmental capacity of municipality area”, as well the “environmental capacity of the SPA parks”.

WP1

Healing Places Tool: estimating environmental pressures related to the development of spa

Country:	Poland
SPA:	Polanica Zdrój
Municipality area [km2]	17,22
Area of SPA parks [ha]	12,851
Defert's index	42
Current No. of inhabitants [persons]	6 357
Current tourists accommodation capacity [persons/d	2 675
Current estimated daily visitors number [persons/d]	4 013
Current maximum tourists number [persons/d]	6 688

Main indicators

Indicator (resource)	Environmental touristic capacity of the municipality area	Environmental capacity of SPA parks	Capacity of the legal protected areas within municipality borders	Mineral water quantity	Sewage quantity
units:	persons/km²	persons/ha	persons/km²	m³/d	m³/d
Current level of use	388,4	520,4	16,05	616	1 269
Limit value of scalable resource	127,0	500,0	25,00	1 435	21 000,0
Current use of capacity	>100%	>100%	64,2%	42,9%	6,0%
Maximum additional tourists number	-4 501	-263	3 730	17 344	202 915

Limit of additional tourists	0

Illustrative indicators

Indicator (resource)	Drinking water	Wastes	Energy	Financial income	Groundwater vulnerability
units:	m³/d	Mg/yr	MWh/yr	€/year	[descriptive]
Current level of use	1 287	4 274	6 550	7 498 811	moderate risk

Figure 8 Results of calculations for Polanica-Zdrój

Source: GIG own calculation based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, GIG, 2021

The tool enables also the visualisation of data in the form of radar charts in terms of:

- Current use of capacity
- Maximum additional tourists number

The visualization allows the user to clearly compare with any other SPA area, chosen from all the project regions.

The first radar chart includes the indicators defined under current use of capacity, which are:

- Environmental touristic capacity of the municipality area,
- Environmental capacity of SPA parks,
- Capacity of the legal protected areas within municipality borders,

- Mineral water quantity,
- Sewage quantity.

The second graph shows the values of the indicators under the maximum additional tourist number:

- Environmental touristic capacity of the municipality area,
- Environmental capacity of SPA parks,
- Capacity of the legal protected areas within municipality borders,
- Mineral water quantity,
- Sewage quantity.

It should be remembered that the whole tool, as well as the visualizations of the values of the indicators, are **a help for the decision makers. It's a preliminary sign that informs about tourist traffic in the given SPA area and it does not replace the need for a comprehensive diagnosis taking into account local conditions.**

Discussion of the graphs is shown in the example of Polanica-Zdrój in comparison to Lądek-Zdrój, as well as Polanica-Zdrój to other SPAs in the region.

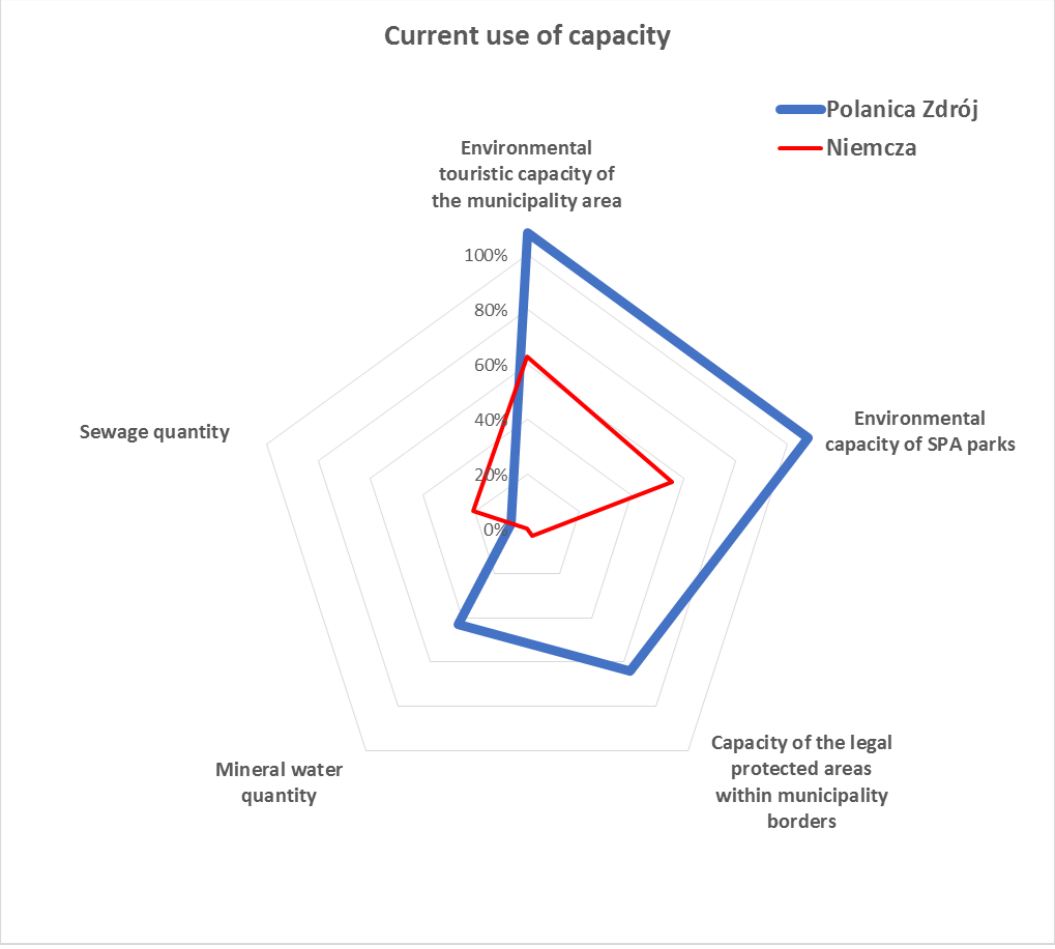


Figure 9 Comparison of current use of capacity for Polanica-Zdrój and Niemcza commune

Source: GIG own calculation based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, GIG, 2021

The above diagram shows the comparison between Polanica-Zdrój and other SPA commune-Niemcza, in which a small SPA village - Przerzeczyn Zdrój is situated[22]. The diagram shows that two indicators: "environmental tourist capacity of the municipality area" and "environmental capacity of parks" in the Polanica-Zdroj SPA area were already exceeded (>100%) while for Niemcza the values of these indicators are about 60%. For the remaining indicators the resource capacity is at an acceptable level maintaining a resource reserve allowing to serve additional tourists, although the reserve of capacity of the legal protected areas is definitely bigger in Niemcza. It is also worth noticing, that the due to the fact, that at the moment Przerzeczyn-Zdrój SPA is closed and the company is under bankruptcy, the quantity of mineral water used is 0.
The comparison between Polanica-Zdrój and Lądek-Zdrój is shown on the diagram below.

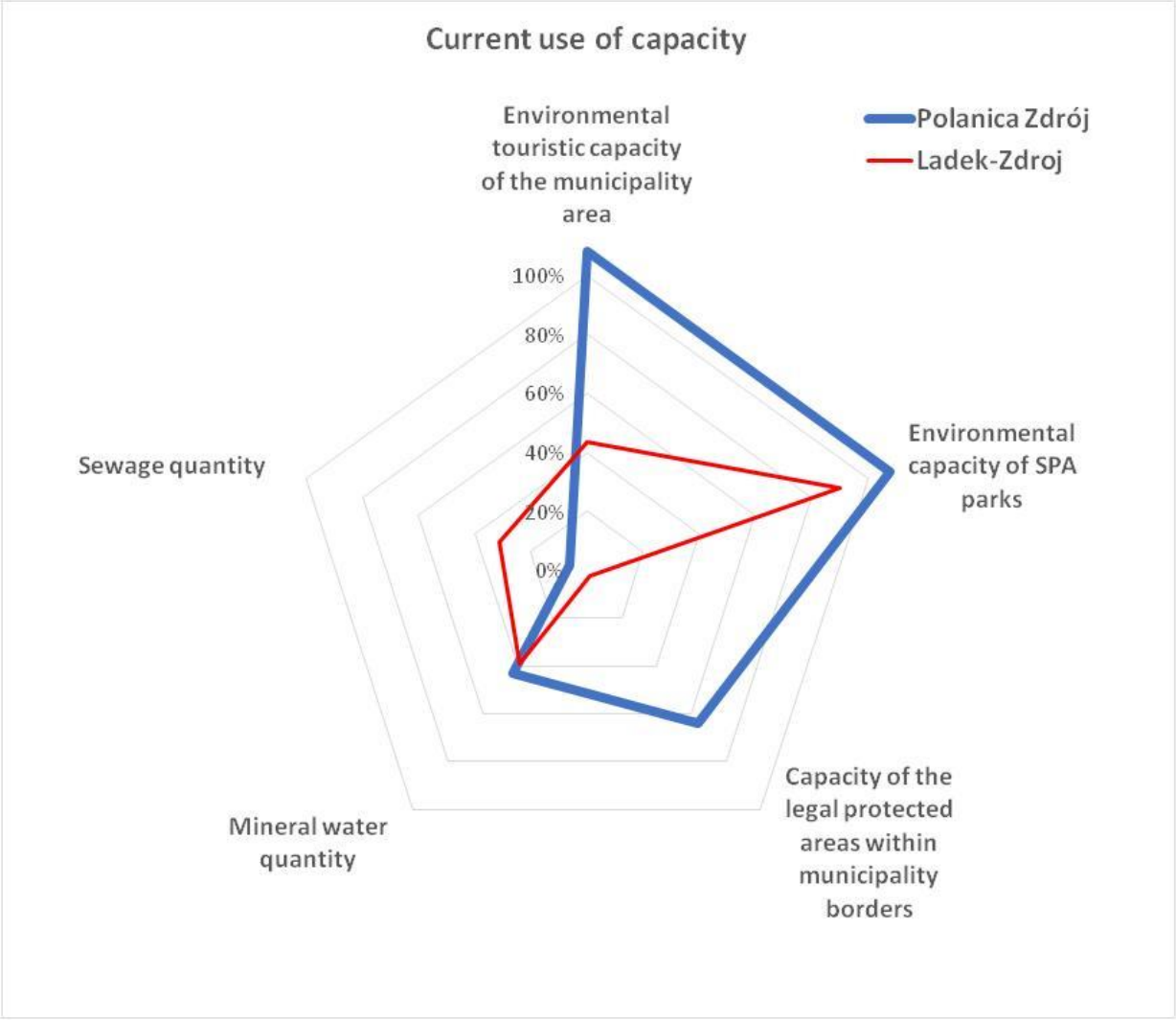


Figure 10 Comparison of current use of capacity for Polanica-Zdrój and Lądek-Zdrój

Source: GIG own calculation based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development - final version, GIG, 2021

[22] Currently, the company that owned it is in bankruptcy. Information based on source materials - Survey on "Diagnosis of health resort communes in Poland". - May 2020

When analyzing the results, it can be seen, that also in Lądek-Zdrój, all indicators, including the usage of the "environmental tourist capacity of the municipality area" and "environmental capacity of parks" are at an acceptable level.

In the following scheme, the "maximum additional number of tourists" is shown, based on the results of the capacity analyses of the area and the existing infrastructure.

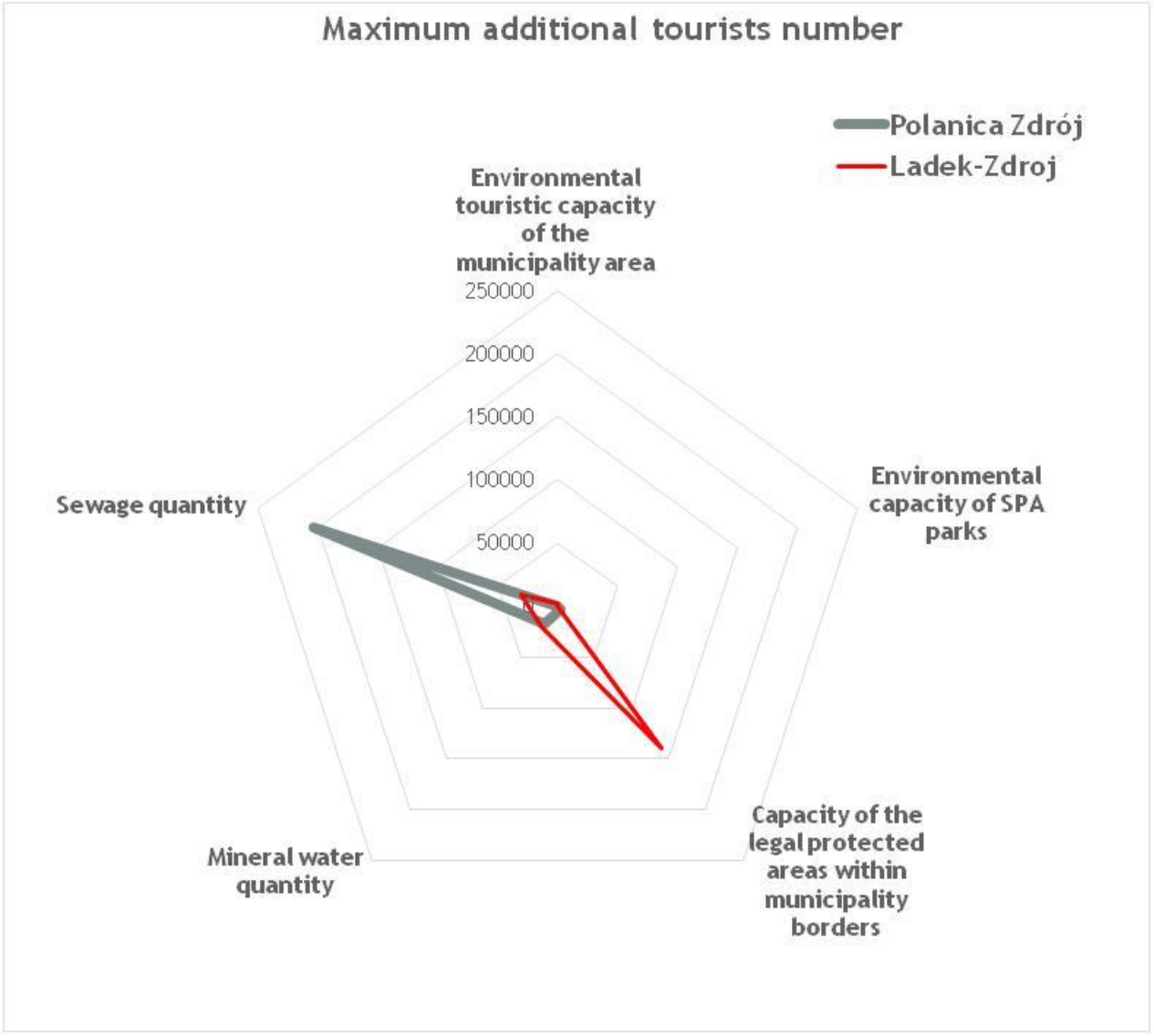


Figure 11 Maximum additional tourists number in the light of specific indicators values – comparison between Polanica Zdrój and Lądek Zdrój

Source: GIG own calculation based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, GIG, 2021

The graph indicates that the current state of "Sewage quantity" gives the greatest value and possibility to develop and accept an additional number of tourists in Polanica-Zdrój, while in Lądek-Zdrój it is "Capacity of the legal protected areas within municipality borders", although all indicators give some possibilities in light of further development.
Obviously, this graph is a supplementary graph and cannot be interpreted in isolation from the previous one (Figure 8), since it does not show negative values (the need to reduce the number

of tourists instead of adding them in the current environmental conditions and the state of infrastructure in place).

4. Results of Land Cover Impact (LCI) algorithm

4.1. The LCI algorithm - basic information

The purpose of the Land Cover Impact (LCI) algorithm is to calculate an index value that describes the amount of pressure on the curative waters derived from the designated land uses in the SPA municipality area. The index allows to determine the influence of the land development of the spa area and changes in land use on the threat to the quality of thermal and/or mineral water resources.

The main purpose of this indicator is to calculate and quantitatively and comparatively assess whether and to what extent land use and land use change increase or decrease the potential threat to curative water resources from the surface. Therefore, it is intended to be used as the part of the whole *Tool for impact assessment of SPAs development*.

The main input data provided by the project partner or – in case of lack of them - required from the user is the area of the given land use type identified as potential threat to the quality and quantity of curative waters. In total, 15 such land use types have been identified in the course of discussions with the Project Partners and experts works.

4.2. Methodology of the LCI algorithm

The methodology has been structured in the following stages:

In the first stage, 15 main land use types that have been identified based on a literature review and in the course of discussions with Project Partners. These types of land use reflect the varied characteristics of different SPA areas, as well the availability of geospatial data for the unexperienced user. The following types of land use have been selected:

- Agriculture,
- Orchards and horticulture,
- Animal breeding farms,
- Industrial sites,
- Mining sites,
- Built up areas without sewage system,
- Built up areas with individual wastewater treatment systems,
- Industrial and municipal waste sites,
- Drainage fields,
- Road transport,
- Railway transport,
- Cemeteries,

- Gas stations,
- Water intakes,
- Sport facilities and objects, Resorts, SPAs.

In the second stage, the Analytical Hierarchy Process (AHP) methodology developed by Saaty[23] has been used. The methodology enables decomposition of a complex decision problem into sub-problems and construction of a ranking for a finite set of variants using an Eigen vector approach to pairwise comparison of criteria. In this study, the AHP methodology was used to determine the weights (representing significance) of the individual types of land use.
Assessment of the degree of consistency of the derived weights has been done through calculation of the Consistency Index (CI), which according to the methodology has to be within the 10% limits. Full details of the methodology have been provided in D.T1.4.4 – *User guide (Technical protocol /guideline for impact assessment & environmental capacity matrix) final version*.

In the next stage, a prototype has been designed using a MS Excel spreadsheet and mathematical functions. It provides a form for the user to input the values representing the areas of given land use type in the SPA municipality analysed, as well as the total area. Two types of calculations are possible, using absolute and relative values. The latter offers the possibility to compare the results with other regions as it calculates results normalised with the total area.
The algorithm has been included into the tool and it allows to perform simulations and analyse different land development scenarios providing an indication of the magnitude of planned change on the increase or decrease of the threat to the curative water resources.
Pilot tests, their results, and interpretations have been described in the next chapter.

4.3. Results of LCI algorithm testing

Two of the Lower Silesia SPAs: Lądek-Zdrój and Polanica-Zdrój have been used for testing the LCI algorithm. The possibility was discussed with regional group of stakeholders, and the final fine-tuning and testing of the LCI part was carried out between October and December 2021 - as a result of prior agreements with the partners.

The selected SPAs municipalities have different characteristics, i.e.,: size, area, and proportion of particular land use types, types of aquifers in different hydrological settings, (e.g., confined or unconfined). resulting in different sensitivity of these waters to threats from the surface, as well as different types of curative waters.

The application of the LCI algorithm has been described on the example of the Lądek-Zdrój data, while the performance of the tool has been interpreted based on the results for all of the ten SPA communes.

Actual and illustrative calculations for the Lądek-Zdrój municipality has been shown in Figure 12 and 13 respectively.

[23] Saaty T.L. (1980) The analytic hierarchy process. McGraw-Hill, USA and Saaty R.W. (1987) The analytic hierarchy process-what it is and how it is used. Math Model 9(3-5):161-176

Country:	Poland
SPA:	Lądek - Zdrój

Threat	Area	Total area	Weight
	[m sq]	[m sq]	
Agriculture	44 629 905	117 172 051	10
Orchards and horticulture	488 657		1
Animal breeding farms	0		10
Industrial sites	93 136		1000
Mining sites	47 864		1000
Built up areas without sewage system	0		10
Built up areas with individual wastewater treatment systems	2 810 997		1
Industrial and municipal waste sites	22 945		100
Drainage fields	0		10
Road transport	387 835		10
Railway transport	138 766		10
Cemeteries	38 173		10
Gas stations	946		10
Water intakes	0		10
Sport facilities and objects, Resorts, SPAs	104 188		10
LCI_{prop}	5,12		
LCI	272294,31		

Figure 12. Calculation of the LCI for Lądek Zdrój based on real data from database of topographical objects

Source: IRT calculations based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, IRT, 2021

Country:	Poland
SPA:	Lądek - Zdrój

Threat	Area	Total area	Weight
	[m sq]	[m sq]	
Agriculture	44 582 041	117 172 051	10
Orchards and horticulture	488 657		1
Animal breeding farms	0		10
Industrial sites	93 136		1000
Mining sites	95 727		1000
Built up areas without sewage system	0		10
Built up areas with individual wastewater treatment systems	2 810 997		1
Industrial and municipal waste sites	22 945		100
Drainage fields	0		10
Road transport	387 835		10
Railway transport	138 766		10
Cemeteries	38 173		10
Gas stations	946		10
Water intakes	0		10
Sport facilities and objects, Resorts, SPAs	104 188		10
LCI_{prop}	5,52		
LCI	293813,40		

Figure 13. Illustrative calculation of the LCI for Lądek Zdrój based on real data from database of topographical objects - scenario of doubling the size of mining area at a cost of the agricultural land

Source: IRT calculations based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, IRT, 2021

In the simulation shown in Figure 12, the hypothetical development of a new mining site that would double the current area used for this type of land use at the cost of decreasing the area of land used for agriculture has resulted in an increase of the LCI of 0.40 (7.8%). This is a clear negative change.

In general, the lower the values of LCI and LCI_{prop} the smaller the pressure of land use on curative water resources. The absolute values allow to assess the effect of land use change for a given SPA municipality. The relative values allow to compare the magnitude of pressure between SPA municipalities. The tool enables to compare statistically and graphically the LCI values for selected SPAs in the form of column charts. This functionality for the ten SPA municipalities has been shown in Figure 14. Five of the SPAs have a relatively low value of LCI_{prop} (3.96 to 5.70), four in the range of 8.48 to 11.50 and one almost double of that value at LCI_{prop} = 20.71. It must be noted that this municipality (Jelenia Góra) is the most urbanized one (Table 6).

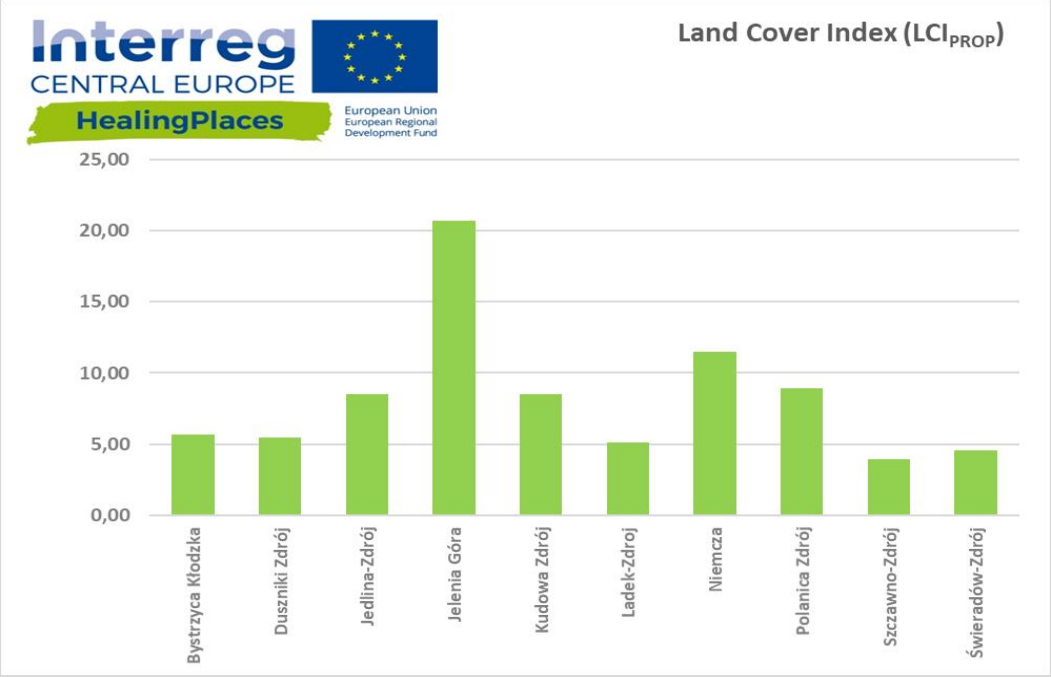


Figure 14 Comparative analysis of the level of pressures from the current land use - LCI based on real data from database of topographical objects

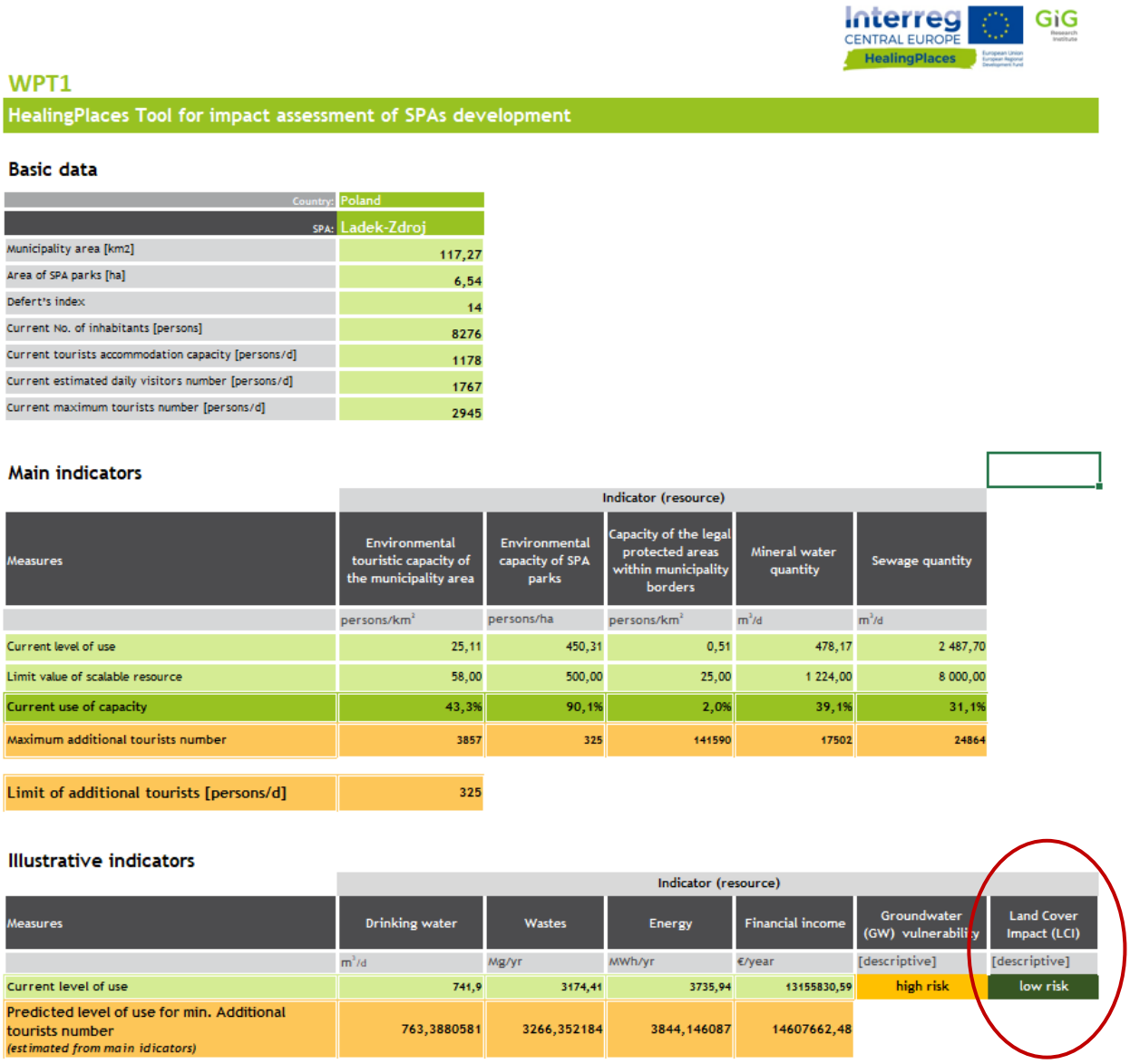
Source: IRT calculations based on the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, IRT, 2021

Table 6 LCI and LCI_{PROP} values for the analysed SPA municipalities

SPA municipality name	LCI	LCI_{PROP}
Bystrzyca Kłodzka	875072	5.70
Duszniki Zdrój	55528	5.49
Jedlina-Zdrój	63574	8.50
Jelenia Góra	990599	20.71
Kudowa Zdrój	130528	8.48
Ladek-Zdroj	272294	5.12
Niemcza	369918	11.50
Polanica Zdrój	70182	8.95

SPA municipality name	LCI	LCI_{PROP}
Szczawno-Zdrój	22679	3.96
Świeradów-Zdrój	38211	4.57

The summarized results of LCI calculations for Lądek-Zdrój are shown in figure below:



WPT1

HealingPlaces Tool for impact assessment of SPAs development

Basic data

Country:	Poland
SPA:	Ladek-Zdroj
Municipality area [km2]	117,27
Area of SPA parks [ha]	6,54
Defert's index	14
Current No. of inhabitants [persons]	8276
Current tourists accommodation capacity [persons/d]	1178
Current estimated daily visitors number [persons/d]	1767
Current maximum tourists number [persons/d]	2945

Main indicators

	Indicator (resource)				
Measures	Environmental touristic capacity of the municipality area	Environmental capacity of SPA parks	Capacity of the legal protected areas within municipality borders	Mineral water quantity	Sewage quantity
	persons/km²	persons/ha	persons/km²	m³/d	m³/d
Current level of use	25,11	450,31	0,51	478,17	2 487,70
Limit value of scalable resource	58,00	500,00	25,00	1 224,00	8 000,00
Current use of capacity	43,3%	90,1%	2,0%	39,1%	31,1%
Maximum additional tourists number	3857	325	141590	17502	24864

Limit of additional tourists [persons/d]	325

Illustrative indicators

	Indicator (resource)					
Measures	Drinking water	Wastes	Energy	Financial income	Groundwater (GW) vulnerability	Land Cover Impact (LCI)
	m³/d	Mg/yr	MWh/yr	€/year	[descriptive]	[descriptive]
Current level of use	741,9	3174,41	3735,94	13155830,59	high risk	low risk
Predicted level of use for min. Additional tourists number *(estimated from main idicators)*	763,3880581	3266,352184	3844,146087	14607662,48		

Figure 15. Result of LCI calculation within the tool for impact assessment of SPAs development

Source: Indicators's calculation sheet of the tool, - D.T1.4.5. Tool for impact assessment & environmental capacity of further SPAs development – final version, GIG, 2021

5. Conclusions

During meetings with stakeholders in Lądek-Zdrój and Polanica-Zdrój in September 2021, the assumptions and the operation of the tool were presented to local and regional stakeholders. During the discussion, the correct selection of indicators in the tool was indicated.
The selected indicators have been confirmed to be important for local communities in the context of the functioning of SPAs.
As a result of these meetings and the following workshops of HealingPAlces project partners have allowed of fine-tuning of the tool and inclusion into it all aspects identified as important.

It was pointed out that the necessity to adjust the tool to highly diversified European regions makes it impossible to focus on problems specific to a given SPAs. Therefore, it was indicated that it would be necessary to amend the input data and some of tool characteristics, by adjusting it to the problems occurring in individual SPAs, and this enabling its full usefulness for decision makers.

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7. List of figures

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