USER GUIDE FOR HEALINGPLACES IMPACT ASSESSMENT TOOL

Technical protocol/ guideline for impact assessment & environmental capacity matrix - final version

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DT1.4.4

Project Partners

Study provided by: Central Mining Institute, LP

Report elaborated as **D.T1.4.4**

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.

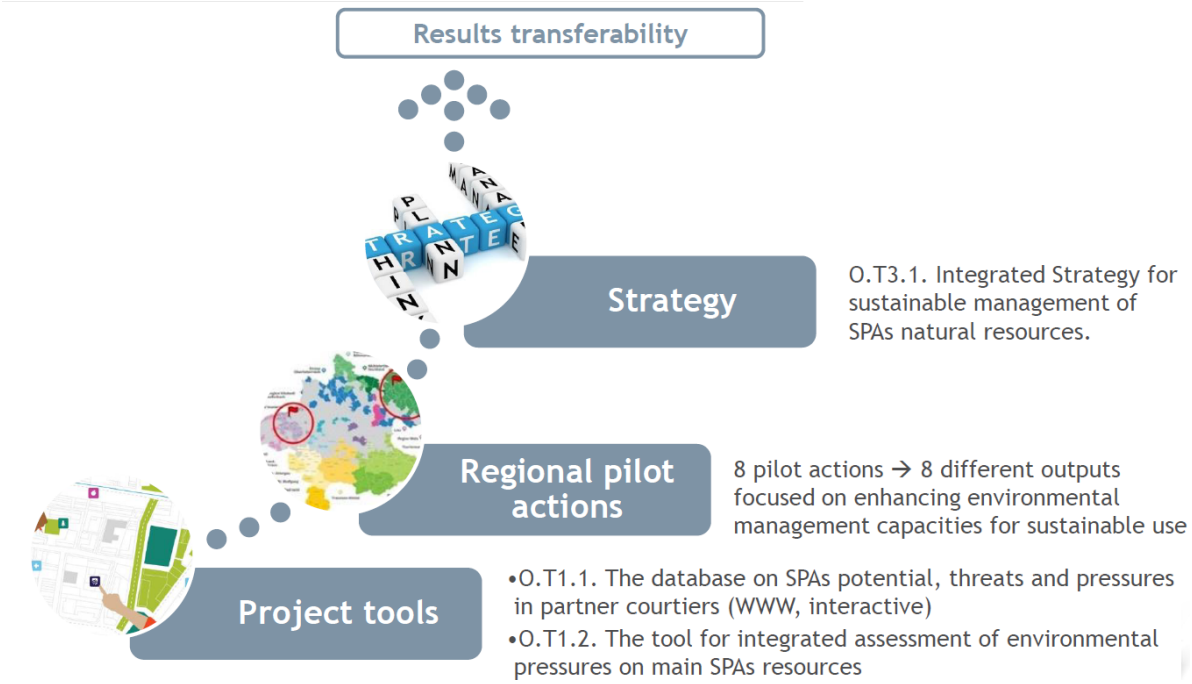
co-financed by the European Union from the European Regional Development Fund within the scope of the INTERREG Central Europe Programme.

Table of contents

1 Introduction and Overview

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 running between April 2019 and March 2022. The project is coordinated by Central Mining Institute (GIG) as a lead partner, and implemented together with 9 Central European partner institutions from Hungary, Austria, Croatia, Italy, Slovenia, and Czech Republic.

Within the project, works are organized in three technical work-packages and focused on three aspects: tools, pilot actions developed in eight project regions and strategy & guidance for sustainable management.



WPT1 "Environmental mapping and assessment" is technical work-package focused on development of common tools for an integrated assessment of present-day and expected threats and pressures on mineral and thermal water resources in SPAs.

One of the tools - *Tool for impact assessment & environmental capacity of further SPAs development* is focused on strength of impact of SPAs on natural resources in different regions of Central Europe area with a special focus on the regions that take part in the HealingPlaces project.

For that tool GIG team have prepared the guideline (user guide) regarding the use of impact assessment of environmental capacity of further SPAs development matrix – to enable partners and end-users to adapt & test the tool in their local/regional conditions.

The purpose of this material is to provide an overview of Excel-based *tool for impact assessment & environmental capacity of further SPAs development*[1] and its functions. This user guide should be used together with that Excel-based tool.

[1] Final version of Excel spreadsheet tool developed under Deliverable D.T1.4.5, tool 1.3.xlsx

2 Why the HealingPlaces impact assessment tool was created?

Health tourism, including SPA activities, is one of the important elements of economic development of health resort communities. However, it is necessary to pay attention that it should be carried out in a sustainable way. Therefore, it is important that it should take place with minimized environmental damage and functional-spatial conflicts. It should contribute to creation of durable and stable spatial systems in relation between people, economy and environment. Therefore, paying special attention to protection of environmental resources, thanks to which the activity can function at all, should be especially important for regional and local authorities as well as for private companies which base their activity on those resources.

As the legal regulations and competencies of all the entities involved in the field of water protection are not always clear and the awareness of the consequences of land development decisions in the areas where mineral water deposits occur is still insufficient, it may lead to unintended conflicts and in the worst case to destruction of natural resources. Moreover high attractiveness is connected with the continuous pressure on the development of areas valuable in terms of nature and landscape related to the development of the tourist base. So it is also important to build coalitions between representatives of various sectors, including administration, industry and citizens, nurturing a level of development that is sustainable.

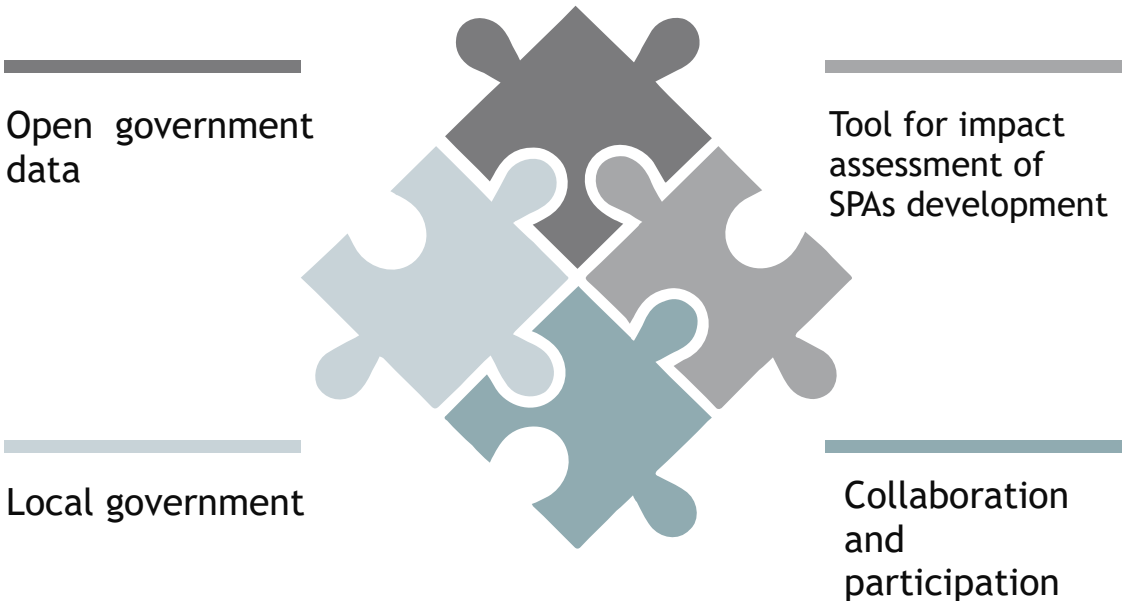
The developed tool is in a way a response to the problems outlined above. It is intended as a support in decision-making process. The aim of the tool is to determine strength of impact of SPAs on natural resources in different regions of Central Europe area with a special focus on the regions that take part in the HealingPlaces project.

The main idea behind the HealingPlaces impact assessment tool is to calculate pressures on the environment that are following the development of SPA tourism. Starting from the idea of **Tourism Carrying Capacity**[2]**,** as defined by the World Tourism Organization, we have focused on the ecological (environmental) carrying capacity, which is related to the impacts of tourism on the natural environment and the long-term viability of the natural resources.

Although there are also many other dimensions of carrying capacity – physical, psychological, social and economic, due to HealingPlaces project specifics, developed **Excel-based tool** assesses how the impact on and use of resources may change under specific (known) local conditions with an increase in number of tourists.

The tool has been tested in frame of HealingPlaces project at each of pilot actions regions. The major strategic decision that was established 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.** Moreover, due to the specificity of each pilot action, development of assumptions for AT14 tool adaptation to local needs was necessary.

[2] 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.



2.1 Intended Users of the Impact assessment tool

The HealingPlaces Impact assessment tool is dedicated for the SPA municipalities (the municipalities that have at least one SPA in their area regardless of having or not having official status of SPA municipality).

The tool is intended to assess the impact of SPA development counted in growing tourist number on the environment. The intention is to provide the decision makers at municipal level with information on the possible level of growth of tourist sector still without excessive pressure on the environment. The tool results should be taken into consideration also because it gives the information on the structure of possible growth capacity for SPA tourism branch in relation to individual main indicators.

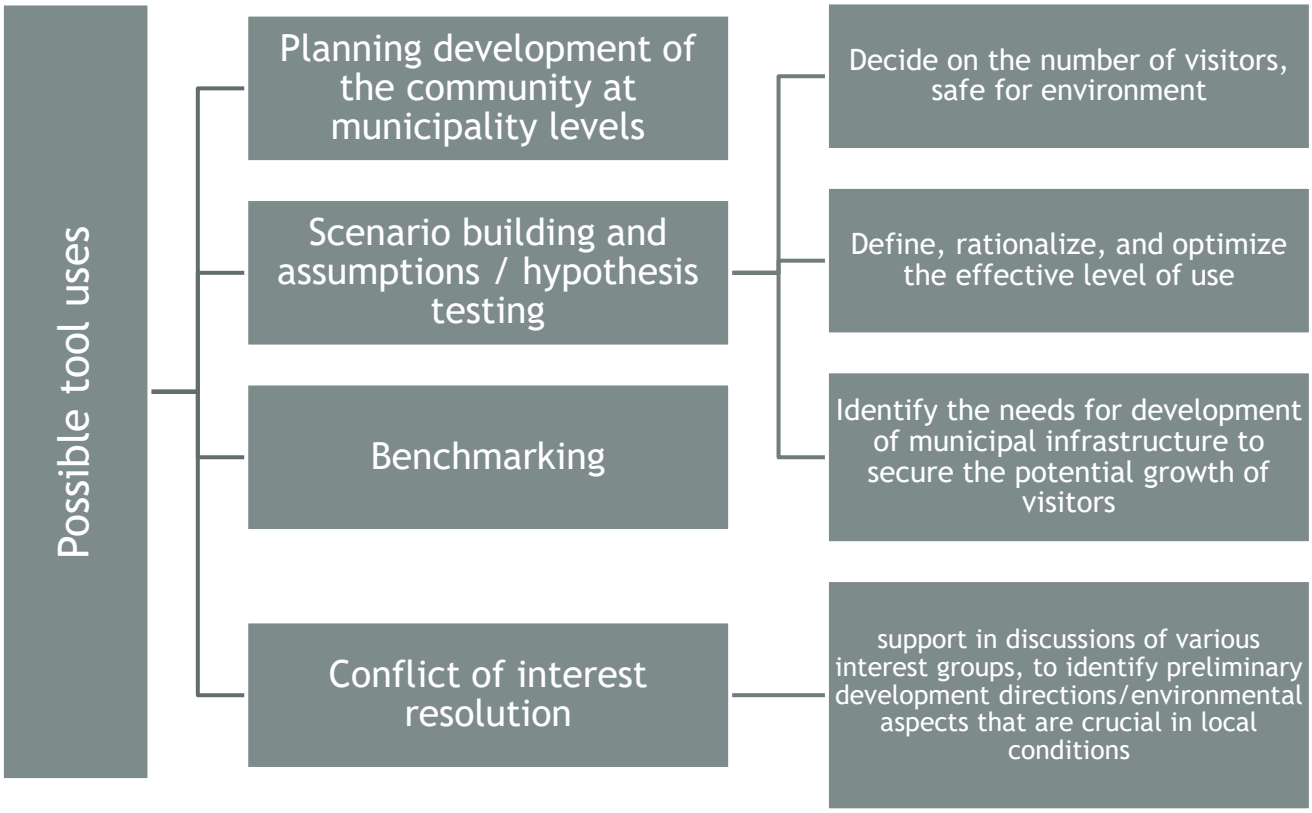
For the proper functioning of the impact assessment tool it is strictly necessary to fill in the database with data required for calculation of individual indicators (especially the main indicators).

By default, the calculations within the spreadsheet are available for the selected pilot SPA municipalities from Central Europe regions that were participating in the Healing Places project.

2.2 What can I use the Impact assessment tool for?

The tool is focused on:

- assessment of current environmental pressure (resulting from tourism/spa/wellness) and the associated current level of resource use,
- assessment of possibilities of further development (in the sense of increasing the number of serviced tourists/bathers) while ensuring a safe level of use of natural resources.



IMPORTANT:

The analysis of the tool's results must respect the knowledge of local stakeholders and local conditions.

It cannot be treated as the only answer. It is only a support to the decision making process.

2.3 What does the tool for impact assessment of SPAs development contain?

HealingPlaces tool for impact assessment of SPAs development has been made for 41 SPA areas in 7 countries: Austria, Croatia, Czechia, Hungary, Italy, Poland and Slovenia, from pilot regions involved in the HealingPlaces project - Mühlviertler Alm Freistadt, Innviertel; Koprivnica-Križevci County, Međimurje County; Moravian-Silesian Region (Bruntál District & Šumperk District), Olomouc Region (Jeseník District, Olomouc District); Borsod-Abaúj-Zemplén County, Hajdú-Bihar County; Piemonte Region, Veneto Region, Friuli Venezia Giulia Region; Lower Silesia Region; Southeast Slovenia).

It is an analytical tool using algorithms related to the determination of few significant correlations:

- The impact of spa and tourism development on the availability of thermal and/or mineral water resources in quantitative terms,
- The impact of spa community development and land use changes 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,

Spa development is - for simplicity - shown as a function of the change in the number of tourists/visitors to a given area.

These relationships are represented in the tool by **Main indicators** (5) and **Illustrative indicators** (6) and following measures:

- Current level of use
- Limit value of scalable resource
- Current use of capacity
- Maximum additional tourists number
- Limit of additional tourists.

The chart below shows the main and illustrative indicators.

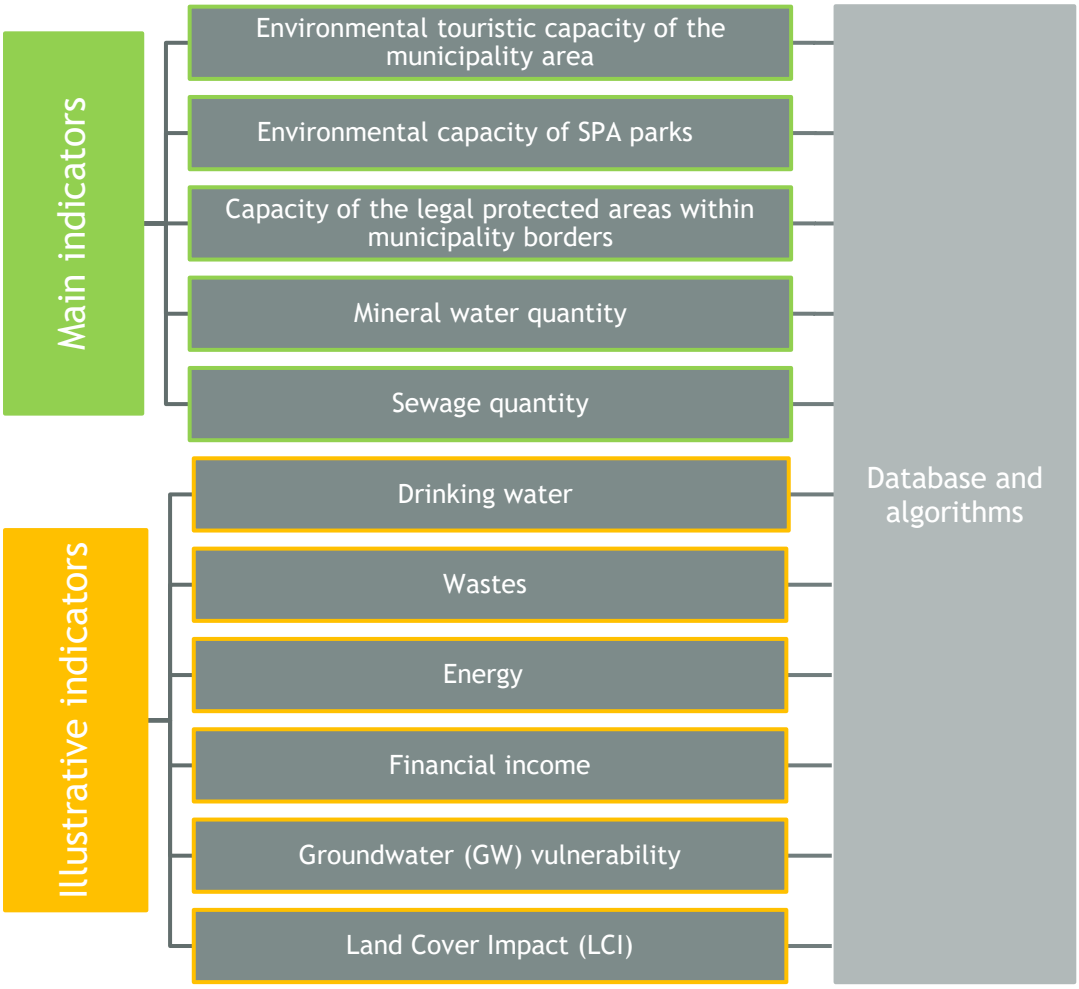


Figure 1 The main and illustrative indicators

3 HealingPlaces tool for impact assessment of SPAs development structure

The HealingPlaces tool for impact assessment of SPAs development consists of sections presenting the results of the calculations (**„Indicators calculations“** and **„Visualisation & benchmarking“** sheets) dedicated to the user and sheets providing the necessary data and algorithms for the calculation of indicators. The tabs containing detailed data are „Main database“, „Groundwater (GW) vulnerability algorithm“ and „LandCover database“.

Figure 2 Scheme of the structure of the tool for impact assessment of SPAs development

Thanks to this structure, all above-mentioned indicators are automatically calculated (algorithms already included into the tool), so the user doesn't have to do anything aside of choosing the country and SPA.

Three steps (Inputs, assumptions, outputs and engagement with data) that can be used

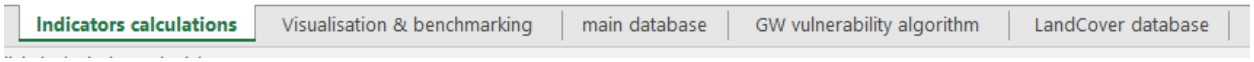
Input and basic calculations	The tool incorporates data, which facilitate the estimates the impacts based on number of tourists and its change.
Assumptions	This usually requires working with local stakeholders to clarify and known all local specifics. It's important, as carrying capacity and visitor impacts are also affected by tourist behaviour, developer practices and resilience of the destination's socioeconomic-physical environments.
Outputs and engagement with data	It allows conducting rapid "what if" exercises. It allows different variants to be carried out, where the variable is the number of tourists. It is not rare that, after seeing the output data, users will want to question and clarify outputs. The challenge are further detailed expert analyses, addressing issues specific to the SPA area, with necessary involvement of local stakeholders.

The detailed information about tool navigation and indicators are presented in next sections.

4 Navigation of HealingPlaces tool for impact assessment of SPAs development

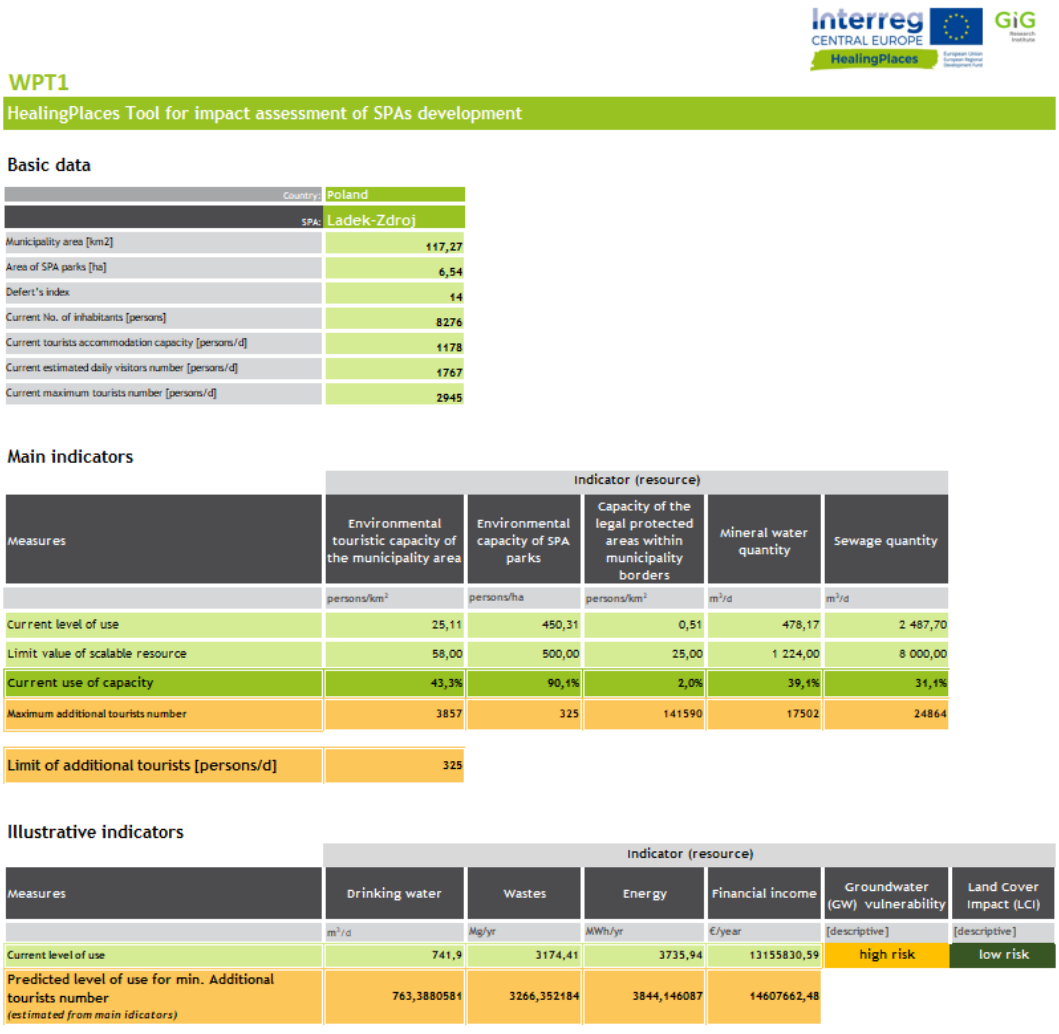
Part / sheets	Content
Indicators' calculations	• Information (basic data) section
	• Main indicators section (results of calculations)
	• Illustrative indicators section (results of calculations)
Visualisation & benchmarking	Possibility of comparison of two chosen SPAs: • Main Indicators – SPA 1 • Main Indicators – SPA 2 • Charts for SPA 1 and SPA 2 Current use of capacity Maximum additional tourists number
Main Database	• List of SPAs • Statistical data and calculated indexes
Groundwater (GW) vulnerability algorithm	• Algorithm for calculation of groundwater vulnerability
LandCover database	• Different (15) landcover types areas in specific SPAs • Calculated percentage of LandCover types • Algorithm for categories of LandCover impact

4.1 Indicators‘ calculations Sheet



This is the main part of the tool.

It shows the basic statistical data and calculated indicators based on current, available statistical data (provided in “database” section). The layout of this section is shown 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

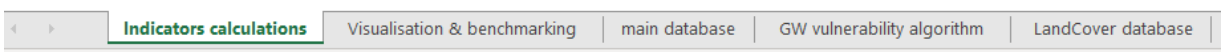
Main indicators

	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

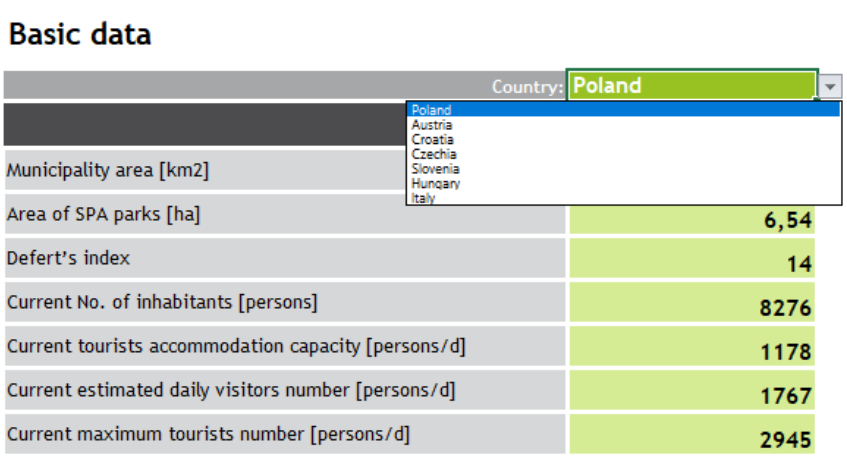
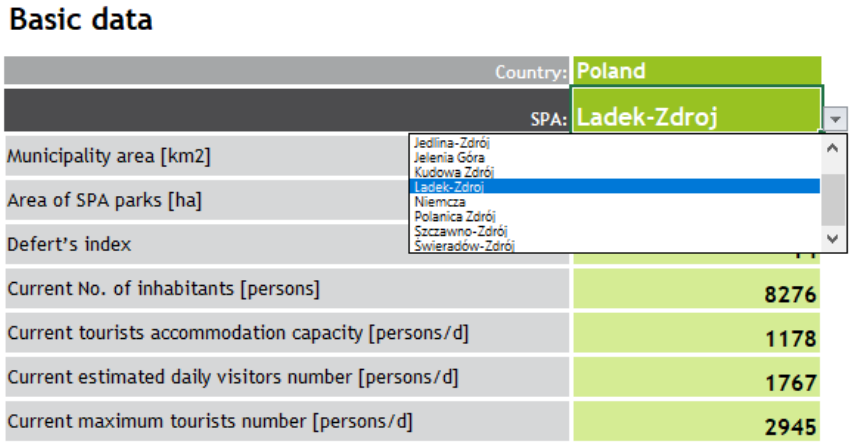
	Indicator (resource)					
Measures	Drinking water	Wastes	Energy	Financial income	Groundwater (GW) vulnerability	Land Cover Impact (LCI)
	m³/d	Mg/yr	MWh/yr	€/year	[descriptive]	[descriptive]
Current level of use	741,9	3174,41	3735,94	13155830,59	high risk	low risk
Predicted level of use for min. Additional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



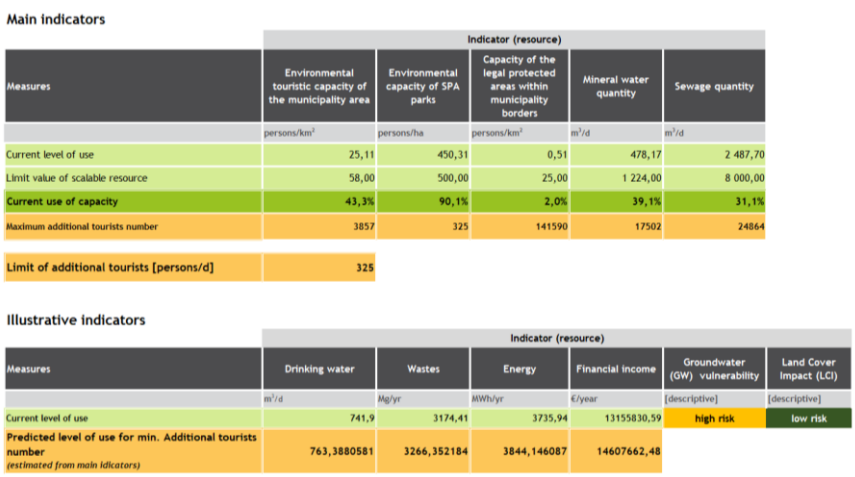
What’s important from the user point: all indicators’ calculations are automatic (algorithms already included into the tool), so the user doesn’t have to do anything aside of choosing the country and SPA.

The aim of this part is to show the general overview of chosen SPA.

Basic data

Steps	
Step1: **choose country from the list (cell C11)**	
Step 2: **choose SPA from the list (cell C12)**	

For the chosen SPA the following information will be shown, which are in more details described in following chapter of this guideline.

Steps	
Step 3 Display of results	

Main indicators

Measures	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
	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

Measures	Indicator (resource)					
	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		

Parts of the sheet are described below:

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

measure / value	
Municipality area [km²]	Statistical data
Area of SPA parks [ha]	The area of SPA parks, in regions where it's applicable[3]

[3] For some countries (e.g. Czech Republic, Poland) SPA Parks surrounding the main SPA building or main mineral/thermal springs are treated as an asset of the whole health resort & their availability is crucial aspect of functioning of SPA. The risk

Defert's index	Result of calculations from formula: **Current tourists accommodation capacity /Current No. of inhabitants.** As it's a base for one of main indicators, it's described more broadly in Annex 1.
Current No. of inhabitants [persons]	Statistical data, gathered by HealingPlaces project partners from national, regional and local statistics → based on the **"total population"** indicator
Current tourists accommodation capacity [persons/d]	Statistical data – gathered by HealingPlaces project partners, based on national, regional and local statistics → based on **"number of bed places in a tourist accommodation"** and **"number of beds in health resort hospitals and health resort sanatoria"** indicators
Current estimated daily visitors number [persons/d]	All tourists spending less then 24h in SPA. Based on data gathered by HealingPlaces partners from associated SPA municipalities / enterprises and on national, regional and local statistics, when available (including such indicators as **"number of patients receiving SPA (sanatorium) treatment (mineral baths, carbon dioxide baths, mud and inhalation treatment)"**, etc.)
Current maximum tourists number [persons/d]	Sum of **"Current tourists accommodation capacity"** and **"Current estimated daily visitors number"**

Main indicators

This part covers the most important calculations.

There are 5 main indicators (resources) which are used in the process of calculation of SPA development capacity:

1) environmental touristic capacity of the municipality area;
2) environmental capacity of SPA parks;
3) capacity of the legal protected areas within municipality borders;
4) mineral water quantity;
5) sewage quantity.

of their overcrowding and subsequent overrunning their biological capacity is important. Therefore SPA Parks capacity is important indicator to be calculated.

At the same time, for some countries officially separated SPA Parks do not exist (do not function officially or are not designated in land use), hence the less importance of the perception of their value. In these countries it was therefore impossible to have definite statistical data about the SPA parks areas / capacity.

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/km^2	persons/ha	persons/km^2	m^3/d	m^3/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

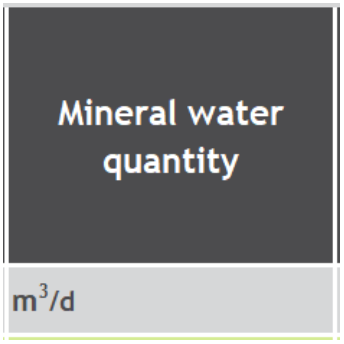
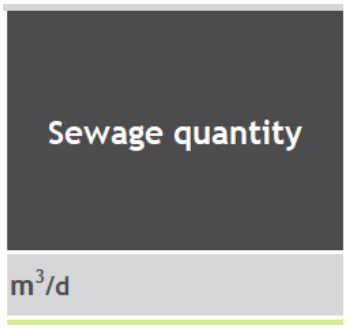
For each indicator, following **measures** are shown:

"Current level of use" Current level of use	It's calculated based on developed algorithms, taking into consideration interdependencies between the values listed in "Information section".
"Limit value of scalable resource" Limit value of scalable resource	Values for are based on extensive desk research, including literature analysis and many earlier projects and works in health resorts topic results analysis, as well as internal and external experts works.
"Current use of capacity" Current use of capacity	Is calculated by comparing the "current level of use" to "Limit value of scalable resource". It shows if the value of the pressure is still safe or if it already should be taken into consideration, due to being too high.
"Maximum additional tourists number Maximum additional tourists number	For each indicator the "Maximum additional tourists number" is calculated, meaning the number of additional tourists still allowed while the "current use of the capacity" ("limiting value of the pressure") is not exceeded for a given indicator.
"Limit of additional tourists" **Limit of additional tourists [persons/d]**	Finally, the "Maximum additional tourists numbers" of all main indicators are compared and the lowest number is selected to be displayed as "Limit of additional tourists". **Indicator "Limit of additional tourists"** represents the suggestion for decision makers about how many additional tourists may visit / how much the number of tourists may be increased in order to keep all of the environmental pressures at the acceptable level. Or - in case of the indicators already exceeding 100 % load percentage for any/all of the indicators - how much the number of tourist should be decreased.

Below, short methodological explanation of all main indicators is shown.

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
persons/km^2	persons/ha	persons/km^2	m^3/d	m^3/d

"Environmental touristic capacity of the municipality area" Environmental touristic capacity of the municipality area persons/km^2	**Current level of use**: Current maximum tourists number [persons/d]/ Municipality area [km^2]. Based on the Defert's index, often used for showing the number of tourist bed places per 100 inhabitants of the study area. **Limit value of scalable resource**: basing on *Defert's index* has been set. To ensure the connection with the spatial planning, the results of Defert's index have been checked with the surface of researched area, represented in km^2. *(see more ANNEX 1)*
"Environmental capacity of SPA parks" Environmental capacity of SPA parks persons/ha	Parameter describing the limits of the spa parks' environmental capacity. **Current level of use**: Current maximum tourists number [persons/d]/Area of SPA parks [ha] **Limit value of scalable resource**: safe attendance - more than 50 people; accepted as the maximum acceptable limit - max. 500 people/ha. *(see more ANNEX 1)*
"Capacity of the legal protected areas" Capacity of the legal protected areas within municipality borders persons/km^2	Parameter describing the limits of the legal protected area (in SPA municipality) capacity. **Current level of use**: Current maximum tourists number [persons/d]/area of protected areas in SPA municipality. **Limit value of scalable resource**: based on literature, it is assumed that a safe attendance for the protected area is 0,25 person/ha/day.

“Mineral water quantity” 	Available mineral/thermal water amount, basing on google form data. **Current level of use**: value from google form calculated from field “10a. Water abstraction flow rate (annual)”. **Limit value of scalable resource**: value from google form calculated from field “9a. Exploitation reserves of water”.
“Sewage quantity” 	**Current level of use**: amount of sewage discharged in 24h to local sewage treatment plant. **Limit value of scalable resource**: hydraulic capacity of local sewage treatment plant.

Illustrative indicators

In this section, additional illustrative indicators are presented. There are 6 more indicators for which no clear limit of SPA tourism development could be defined, however the indicators have been identified as relevant for increasing the awareness about the environmental pressures connected with the SPA development.

The illustrative indicators are as follows:

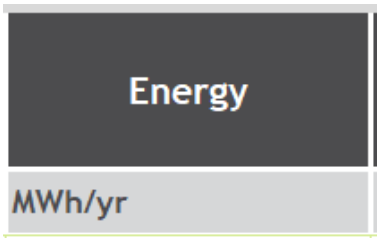
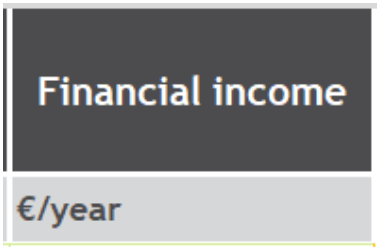
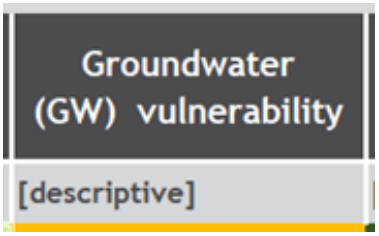
1) Drinking water
2) Wastes
3) Energy
4) Financial income
5) Groundwater (GW) vulnerability calculation
6) Land Cover Impact (LCI)

Illustrative indicators

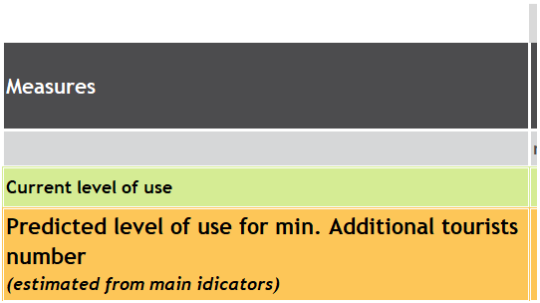
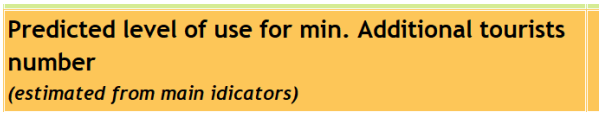
	Indicator (resource)					
Measures	Drinking water	Wastes	Energy	Financial income	Groundwater (GW) vulnerability	Land Cover Impact (LCI)
	m^3/d	Mg/yr	MWh/yr	€/year	[descriptive]	[descriptive]
Current level of use	741,9	3174,41	3735,94	13155830,59	high risk	low risk
Predicted level of use for min. Additional tourists number *(estimated from main idicators)*	763,3880581	3266,352184	3844,146087	14607662,48		

Indicator (resource)					
Drinking water	Wastes	Energy	Financial income	Groundwater (GW) vulnerability	Land Cover Impact (LCI)
m^3/d	Mg/yr	MWh/yr	€/year	[descriptive]	[descriptive]

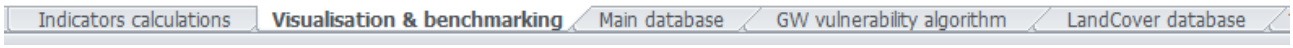
"Drinking water" Drinking water m^3/d	Current level of use: average amount of drinking water used in SPA municipality in 24h, data source: statistical office.
"Wastes" Wastes Mg/yr	Average amount of waste produced in SPA municipality by year, data source: statistical office.

“Energy” 	Average amount electric power used in SPA municipality by year, data source: statistical office
“Financial income” 	Average amount financial income in SPA municipality by year, data source: statistical office
“Groundwater (GW) vulnerability” 	Level of risk of mineral / thermal water contamination (calculated in ‘vulnerability’ sheet)
“Land Cover Impact (LCI)” 	The purpose of the LCI algorithm is to calculate an index value that describes the amount of pressure on the curative waters derived from the designated land uses (15 landuse types identified) in the SPA municipality area. The index allows to determine the influence of the land development of spa area and changes in land use on the threat to the quality of thermal and/or mineral water resources. The calculation are based on the data included in LandCover database tab, in accordance with the methodology described in Annex 3.

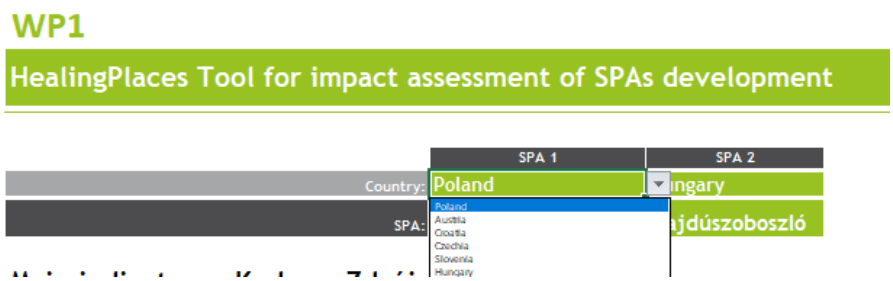
For each illustrative indicators measure such as current level of use and predicted level of use for min. Additional tourists number were estimated.

<table>
<tr><td colspan="2">Illustrative indicators
 
</td></tr>
<tr><td>“Current level of use”
 
</td><td>Is calculated based on developed algorithms, taking into consideration interdependencies between the values listed in “Information section”.</td></tr>
<tr><td>“Predicted level of use for min. Additional tourists number”
 
</td><td>Estimated from main indicators: predicted level of use with additional tourist number from Limit of additional tourists.</td></tr>
</table>

4.2 Visualisation & benchmarking sheet



This part of the tool enables the visualisation of the results. The visualization allows the user to make a comparison between two SPA areas, chosen from all project region. The steps to be undertaken are similar as in part “Indicators calculations”.

Steps	
Step1: **choose country from the list (cell C11 and C12)**	
Step 2: **choose SPA from the list (cell D11 and D12)**	 For the chosen SPAs the following information will be shown, which are in more details described in following chapter of this guideline.

Steps

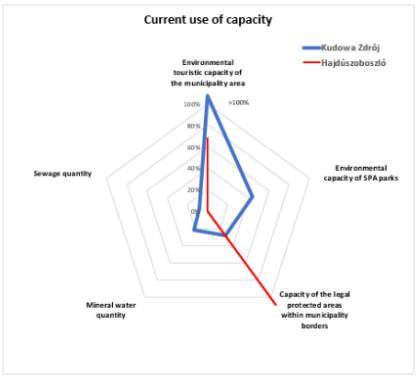
Step 3 **display of results**

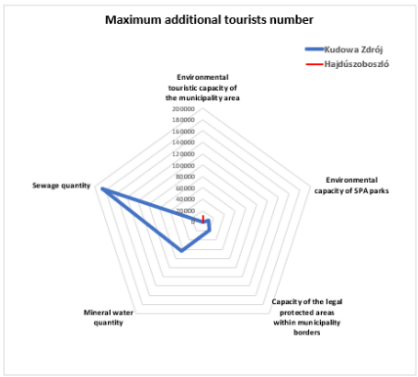
Main indicators - Kudowa Zdrój

Measures	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 use of capacity	>100%	43,9%	28,8%	21,8%	8,7%
Maximum additional tourists number	-5 834	9 985	19 320	63 620	185 694

Main indicators - Hajdúszoboszló

Measures	Indicator (resource)				
	Environmental touristic	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 use of capacity	67,9%	-	>100%	-	-
Maximum additional tourists number	9 734	NoData	-20 558	NoData	NoData



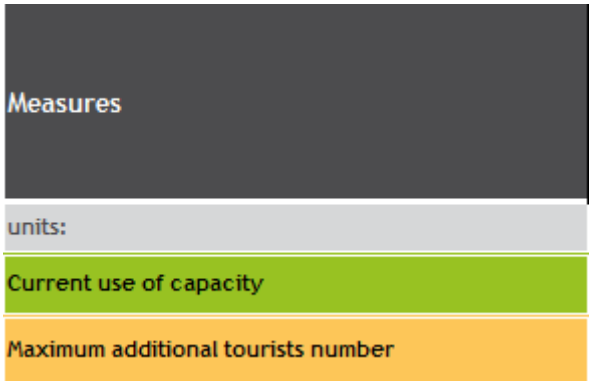


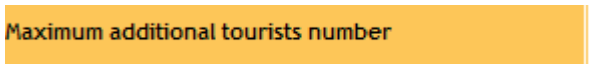
In this section you can compare chosen SPA1 and SPA 2 against the **main indicators**

1) environmental touristic capacity of the municipality area;
2) environmental capacity of SPA parks;
3) capacity of the legal protected areas within municipality borders;
4) mineral water quantity;
5) sewage quantity.

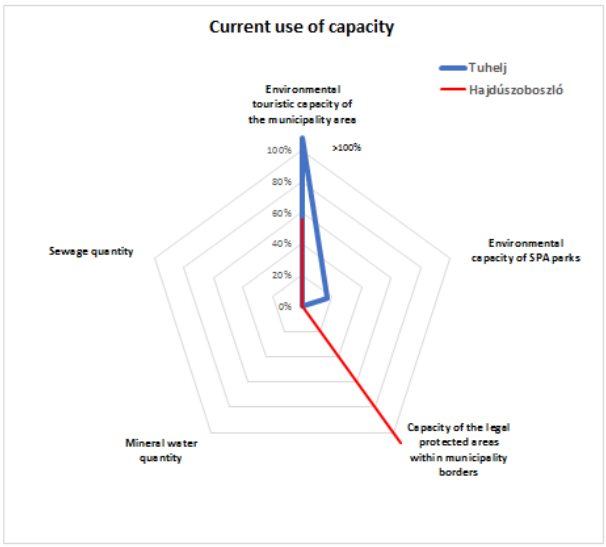
The logic of all these indicators has been described in more details in earlier chapter / section “indicators’ calculations”.

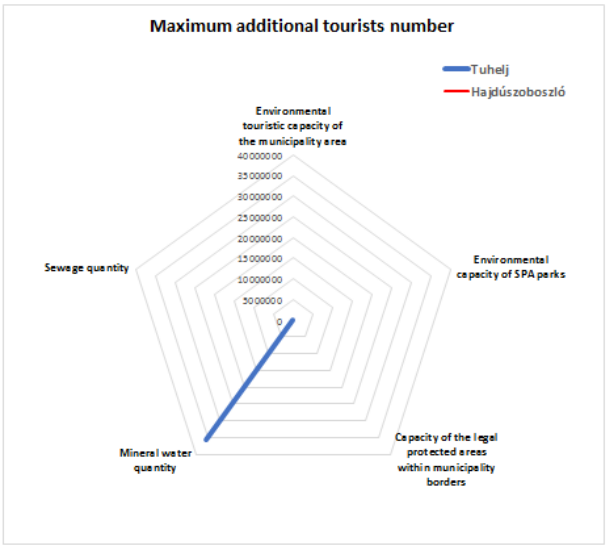
For each indicator, following measures are shown:



"Current level of use" 	It's calculated for two for pre-selected SPAs
"Maximum additional tourists number" 	It's calculated for two for pre-selected SPAs

Charts





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

- Current use of capacity
- Maximum additional tourists number

The first radar chart includes the indicators defined under current use of capacity 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.

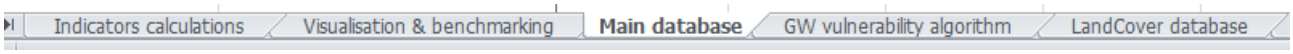
The second graph shows the values of the indicators under the maximum additional tourists number:

- 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.

Proceed with caution ☺

It should be noted that the two charts should not be interpreted separately. Moreover it should be remembered that the visualisations of the values of the indicators are a help for the decision makers. It's a preliminary sign informing about tourist traffic in the given SPA area and it does not replace the need of comprehensive diagnosis taking into account local conditions

4.3 Main Database sheet



The database sheet is an internal sheet, covering all data, on which calculations are based.

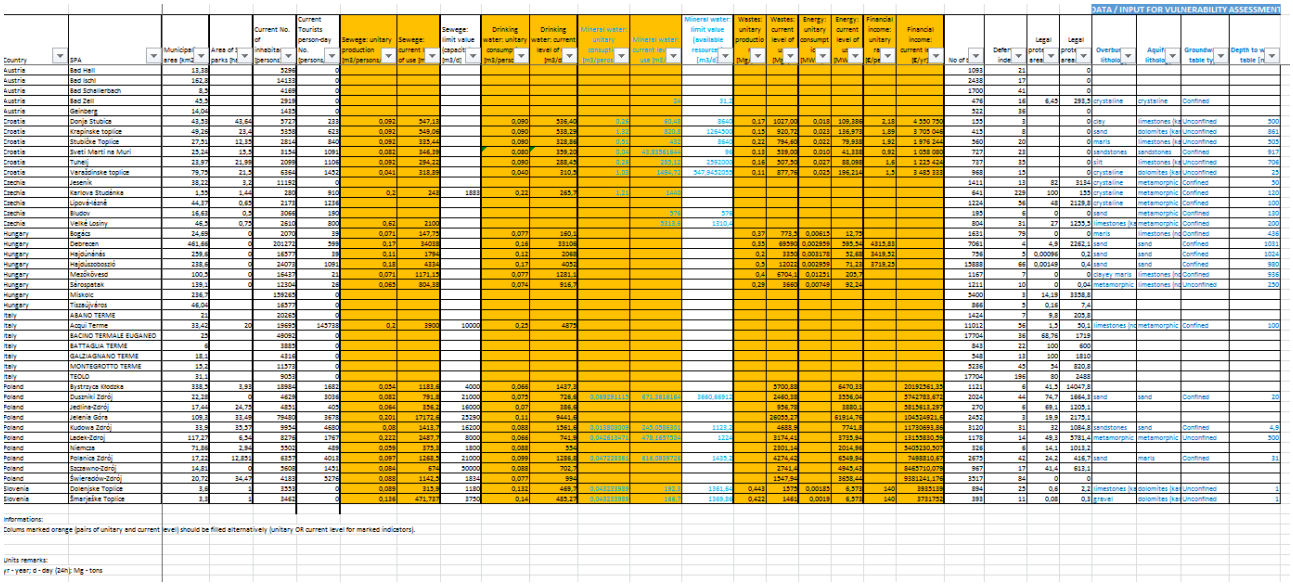
By definition, the database is closed / updated at the end of the project. And verified for correct operation.

Main Database sheet contains the following raw data:

- Municipality area [km^2]
- Area of SPA parks [ha]
- Current No. of inhabitants [persons]
- Current Tourists person-day No. [persons/d]
- Sewage: unitary production [m^3/persons/d]
- Sewage: current level of use [m^3/d]
- Sewage: limit value (capacity) [m^3/d]
- Drinking water: unitary consumption [m^3/person/d]
- Drinking water: current level of use [m^3/d]
- Mineral water: unitary consumption [m^3/person/d]
- Mineral water: current level of use [m^3/d]
- Mineral water: limit value (available resources) [m^3/d]
- Wastes: unitary production [Mg/person/yr]
- Wastes: current level of use [Mg/y]
- Energy: unitary consumption [MWh/person/d]
- Energy: current level of use [MWh/d]

- Financial income: unitary rate [€/persons/yr]
- Financial income: current level [€/yr]
- No of beds
- Defert's index
- Legal protected areas [%]
- Legal protected areas [ha]
- Overburden lithology
- Aquifer lithology
- Groundwater table type
- Depth to water table [m]

It contains the following raw data and the necessary recalculations as input to the main and descriptors.



ONLY For more advanced user, who has their own data and would like to add them (especially if there is no data available in original database).

Proceed with caution ☺

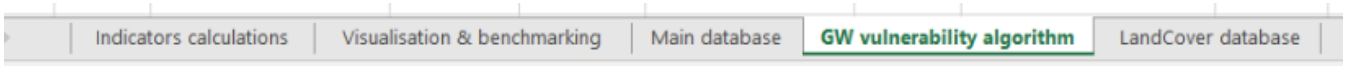
Entering your own data into database file is at your own risk.

Incorrect data entry (e.g. in wrong units) may cause malfunction of the tool / show incorrect results.

The project is not responsible for this.

Annex 2 provides descriptions of the raw data used in the tool.

4.4 Groundwater (GW) vulnerability algorithm sheet



The main logic of this algorithm is based on known and widely used methods of groundwater vulnerability assessment, such as DRASTIC (Aller et al. 1987) or GOD(S) (Foster 1987). However, as these methods are developed for ordinary groundwater aquifers used mainly for drinking water purpose and therefore they are focused on much lower depths compared to mineral and thermal water. Therefore, within HealingPlaces project, a significant modification of the vulnerability assessment methodology had to be developed based on GODS method.

Modified GODS method for vulnerability assessment is presented below

Geology of Thermal/Mineral Water Aquifer

- subdivided into closed list of categories based on the typical horizontal conductivity of various rock types
- used for assessment of horizontal migration risk of potentially contaminated water through the mineral & thermal water aquifer to reach the the SPA intake as a function of geology of the aquifer

Geology of Overburden

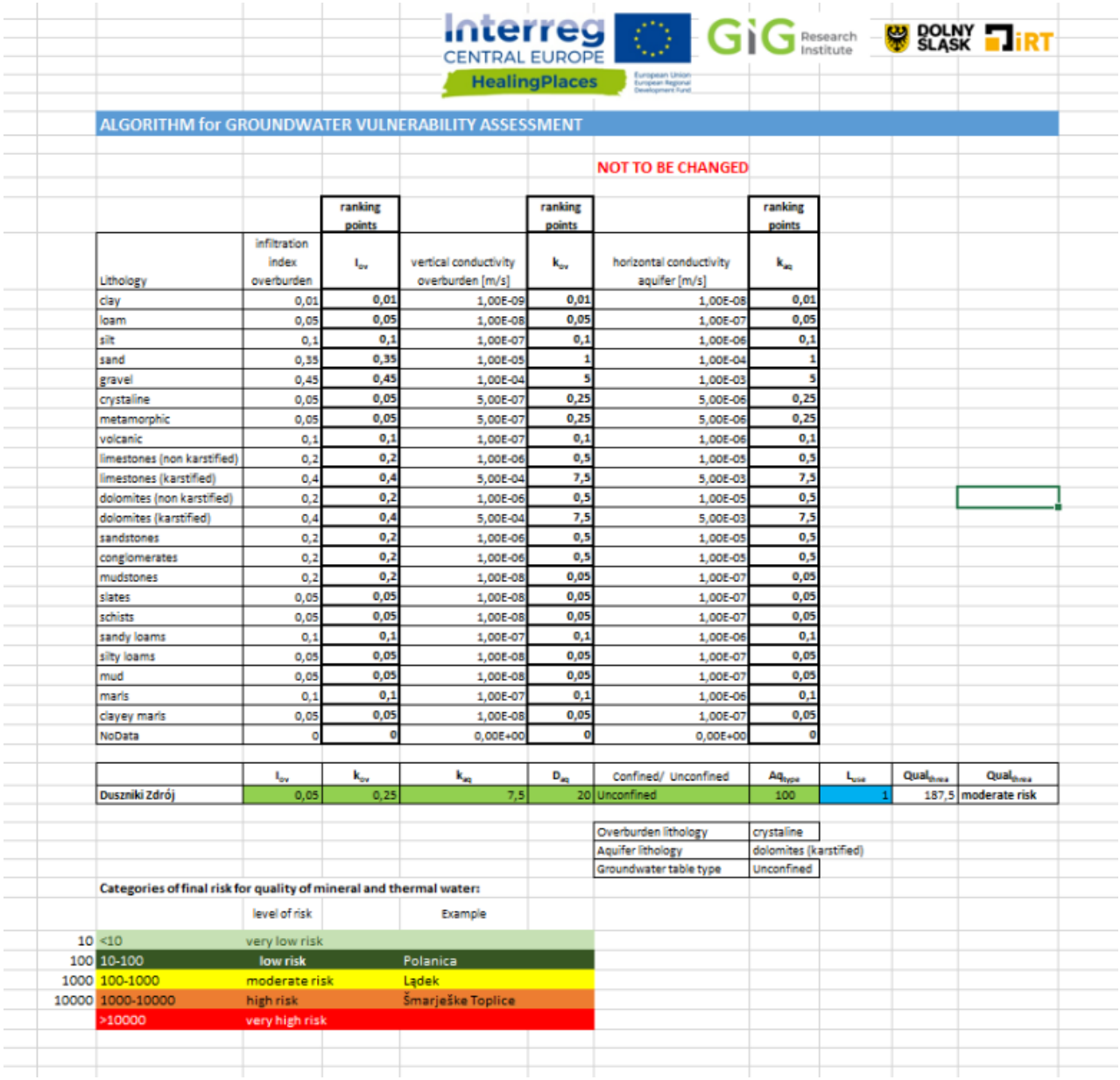
- subdivided into closed list of categories based on the typical infiltration index and vertical conductivity of various rock types
- used for assessment of vertical migration risk of potentially contaminated water through overburden –

Depth to Water Table

- time needed for potentially contaminated water to reach the mineral & thermal water aquifer calculated as a function of depth to water table and geology of overburden

Soil type

- percentage of potentially contaminated water (infiltration index) infiltrating from the surface calculated as a function of protective properties of various soil types



ALGORITHM for GROUNDWATER VULNERABILITY ASSESSMENT

NOT TO BE CHANGED

Lithology	infiltration index overburden	ranking points I_{ov}	vertical conductivity overburden [m/s]	ranking points k_{ov}	horizontal conductivity aquifer [m/s]	ranking points k_{aq}
clay	0,01	0,01	1,00E-09	0,01	1,00E-08	0,01
loam	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
silt	0,1	0,1	1,00E-07	0,1	1,00E-06	0,1
sand	0,35	0,35	1,00E-05	1	1,00E-04	1
gravel	0,45	0,45	1,00E-04	5	1,00E-03	5
crystaline	0,05	0,05	5,00E-07	0,25	5,00E-06	0,25
metamorphic	0,05	0,05	5,00E-07	0,25	5,00E-06	0,25
volcanic	0,1	0,1	1,00E-07	0,1	1,00E-06	0,1
limestones (non karstified)	0,2	0,2	1,00E-06	0,5	1,00E-05	0,5
limestones (karstified)	0,4	0,4	5,00E-04	7,5	5,00E-03	7,5
dolomites (non karstified)	0,2	0,2	1,00E-06	0,5	1,00E-05	0,5
dolomites (karstified)	0,4	0,4	5,00E-04	7,5	5,00E-03	7,5
sandstones	0,2	0,2	1,00E-06	0,5	1,00E-05	0,5
conglomerates	0,2	0,2	1,00E-06	0,5	1,00E-05	0,5
mudstones	0,2	0,2	1,00E-08	0,05	1,00E-07	0,05
slates	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
schists	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
sandy loams	0,1	0,1	1,00E-07	0,1	1,00E-06	0,1
silty loams	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
mud	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
marls	0,1	0,1	1,00E-07	0,1	1,00E-06	0,1
clayey marls	0,05	0,05	1,00E-08	0,05	1,00E-07	0,05
NoData	0	0	0,00E+00	0	0,00E+00	0

	I_{ov}	k_{ov}	k_{aq}	D_{aq}	Confined/ Unconfined	Aq_{type}	L_{use}	$Qual_{Area}$	$Qual_{Area}$
Duszniki Zdrój	0,05	0,25	7,5	20	Unconfined	100	1	187,5	moderate risk

Overburden lithology	crystaline
Aquifer lithology	dolomites (karstified)
Groundwater table type	Unconfined

Categories of final risk for quality of mineral and thermal water:

	level of risk	Example
10 <10	very low risk	
100 10-100	low risk	Polanica
1000 100-1000	moderate risk	Lądek
10000 1000-10000	high risk	Šmarješke Toplice
>10000	very high risk	

The data included are taken from "Main database" being the base for calculations carried out in vulnerability sheet. Then the result (descriptive risk level) is shown in "Indicators calculation' sheet.

Overburden lithology

Dominating lithology of rocks situated above the mineral/thermal water deposit (selected from pre-defined drop-down menu)

Aquifer lithology

Dominating lithology of rocks that host the mineral/thermal water deposit (selected from pre-defined drop-down menu)

Groundwater table type

The type of groundwater table of mineral/thermal water of concern (selected from drop down menu) as follows:

- Unconfined - the level of groundwater table changes with changing pressure of mineral/thermal water in the aquifer; there are no rocks of low permeability in the overburden
- Confined - the level groundwater table is constant, as there are low permeable rocks in the overburden and therefore mineral/thermal water is under pressure; there is no change of water table level with changing pressure of the water in the aquifer

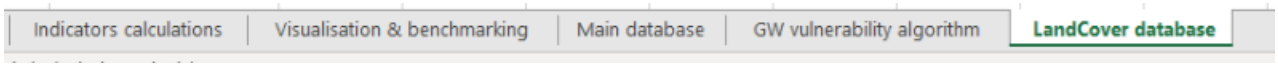
Data source: partner's data from Google form (within D.T1.2.1)

Assumptions:

- ***calculate the current consumption of thermal and/or mineral waters per person (person = tourist spa tourist)***
- ***forecast the maximum permissible number of spa tourists in terms of thermal and/or mineral water consumption in relation to the limits resulting from the concession documents (exploitation resources***

The calculation process assumes that the volume of unit intake will not change, so knowing this value it is possible to determine it in relation to the forecast number of tourists and available exploitation resources.

4.5 LandCover database sheet



The purpose of the LancCover 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 spa area and changes in land use on the threat to the quality of thermal and/or mineral water resources.

The main input data provided by 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 discussion with the Project Partners.

LandUse areas [m2]

		Land Use / Land Cover types														
Country	SPA	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
Poland	Bystrzyca Kłodzka	149119581	1145861,186	40319,2984	354764,8872	58149,0629	0	6886146,446	0		974713,5564	255365,6589	162507,6211	6321,18925	0	37496,4973
Poland	Duszniki Zdrój	6274058,002	147539,9183	0	54102,9009	0	0	996199,1849	0		236534,7185	43938,78084	35798,0008	7197,99345	0	105151,0554
Poland	Jedlina-Zdrój	2430000	380000	0	110000	0	910000	0	0	0	200000	160000	30000	0	0	50000
Poland	Jelenia Góra	12780000	2460000	80000	2010000	0	9140000	0	10000	0	1670000	650000	330000	50000	0	310000
Poland	Kudowa Zdrój	13330256,6	390318,1972	0	148359,0567	0	0	2228486,888	0		176531,6883	17231,43374	42597,46665	33926,40844	0	43924,0026
Poland	Ladek Zdroj	44629904,98	488657,4778	0	93136,08269	47863,6798	0	2810996,573	22945,17375		387835,2703	138766,4739	38172,6226	945,58205	0	104187,8664
Poland	Niemcza	43320000	710000	120000	150000	220000	1310000	0	10000	0	430000	190000	40000	4000	0	50000
Poland	Polanica Zdrój	4077621,307	109916,7192	0	105649,4411	0	0	2072940,564	15248,06328		120371,4757	79260,19997	77369,92712	4332,06075	3990,69	155326,7304
Poland	Szczawno-Zdrój	2580000	270000	30000	20000	0	970000	0	0	0	130000	0	40000	0	0	90000
Poland	Świeradów Zdrój	2990000	50000	0	40000	10000	1180000	0	0	0	130000	40000	20000	1000	0	110000
Slovenia	Dolenjske Toplice															
Slovenia	Šmarješke Toplice															

LandUse percentage

Country	SPA	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
Poland	Bystrzyca Kłodzka	0,44053052	0,003385114	0,000119112	0,00104805	0,000171785	0	0,020343121	0	0	0,002879508	0,000754404	0,000480082	1,86741E-05	0	0,000110773
Poland	Duszniki Zdrój	0,281600449	0,006622079	0	0,002428317	0	0	0,04471271	0	0	0,01061646	0,001972118	0,001606733	0,00032307	0	0,004719527
Poland	Jedlina-Zdrój	0,139334862	0,021788991	0	0,006307339	0	0,052178899	0	0	0	0,01146789	0,009174312	0,001720183	0	0	0,002866972
Poland	Jelenia Góra	0,116925892	0,022506862	0,00073193	0,018389753	0	0,083623056	0	9,14913E-05	0	0,015279048	0,005946935	0,003019213	0,000457457	0	0,002836231
Poland	Kudowa Zdrój	0,393222908	0,011513811	0	0,004376373	0	0	0,065737076	0	0	0,005207424	0,000508302	0,001256562	0,001000779	0	0,001295693
Poland	Ladek Zdroj	0,380573932	0,004166944	0	0,000794202	0,000408149	0	0,023970296	0,000195661	0	0,003307199	0,001183308	0,000325511	8,06329E-06	0	0,000888444
Poland	Niemcza	0,602838853	0,009880323	0,001669914	0,002087392	0,003061508	0,018229891	0	0,000139159	0	0,005983858	0,00264403	0,000556638	5,56638E-05	0	0,000695797
Poland	Polanica Zdrój	0,236795662	0,006383085	0	0,006135275	0	0	0,120379824	0,000885486	0	0,006990213	0,004602799	0,004493027	0,000251571	0,000231747	0,009020135
Poland	Szczawno-Zdrój	0,174206617	0,018230923	0,002025658	0,001350439	0	0,065496286	0	0	0	0,008777853	0	0,002700878	0	0	0,006076975
Poland	Świeradów Zdrój	0,144305019	0,002413127	0	0,001930502	0,000482623	0,056949807	0	0	0	0,006274131	0,001930502	0,000965251	4,82625E-05	0	0,005308988
Slovenia	Dolenjske Toplice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	Šmarješke Toplice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weights		10	1	10	1000	1000	10	1	100	10	10	10	10	10	10	10

Country	SPA	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	Result	Result scalled
Poland	Bystrzyca Kłodzka	4,41	0	0	1,05	0,17	0	0,02	0	0	0,03	0,01	0	0	0	0	5,69	low risk
Poland	Duszniki Zdrój	2,82	0,01	0	2,43	0	0	0,04	0	0	0,11	0,02	0,02	0	0	0,05	5,5	low risk
Poland	Jedlina-Zdrój	1,39	0,02	0	6,31	0	0,52	0	0	0	0,11	0,09	0,02	0	0	0,03	8,49	low risk
Poland	Jelenia Góra	1,17	0,02	0,01	18,39	0	0,84	0	0,01	0	0,15	0,06	0,03	0	0	0,03	20,71	high risk
Poland	Kudowa Zdrój	3,93	0,01	0	4,38	0	0	0,07	0	0	0,05	0,01	0,01	0,01	0	0,01	8,48	low risk
Poland	Ladek Zdroj	3,81	0	0	0,79	0,41	0	0,02	0,02	0	0,03	0,01	0	0	0	0,01	5,1	low risk
Poland	Niemcza	6,03	0,01	0,02	2,09	3,06	0,18	0	0,01	0	0,06	0,03	0,01	0	0	0,01	11,51	moderate risk
Poland	Polanica Zdrój	2,37	0,01	0	6,14	0	0	0,12	0,09	0	0,07	0,05	0,04	0	0	0,09	8,98	low risk
Poland	Szczawno-Zdrój	1,74	0,02	0,02	1,35	0	0,65	0	0	0	0,09	0	0,03	0	0	0,06	3,96	very low risk
Poland	Świeradów Zdrój	1,44	0	0	1,93	0,48	0,57	0	0	0	0,06	0,02	0,01	0	0	0,05	4,56	very low risk
Slovenia	Dolenjske Toplice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NoData
Slovenia	Šmarješke Toplice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NoData

Categories of final risk for Land Cover impact

5	<5	very low risk
10	5-10	low risk
20	10-20	moderate risk
50	20-50	high risk
	>50	very high risk

The LCI part of tool then calculates the overall value of the index. The final result of calculation is presented in “Indicators calculations” tab.

The LandCover Impact can be used for example to assess how a change in a given land use type increases or decreases the potential threat exerted on the waters from the surface.

For the database the geospatial data collected and distributed openly by the relevant public authorities have been use. For additional use it's recommended to use the data collected by relevant public authorities in all the European Union member states in accordance with the Inspire Directive. These could be for example databases of topographical objects, alternatively Corine Land Cover (CLC) data or Open Street Map data could also be used.

The methodology is described in details in **Annex 3.**

5 Annexes

ANNEX 1. METHODOLOGICAL INFORMATION ABOUT INDICATORS

Environmental touristic capacity of the municipality area

Based on the Defert's tourist function index, often used for showing the number of tourist bed places per 100 inhabitants of the study area. The index is presented with the following formula:

$$DTFI = T(f) = \frac{Nx100}{P}$$

Where:

- DTFI = T(f) represents Defert's tourist function index or Defert's indicator,
- N is the number of beds,
- P is the number of local residents,

The analysis makes use of a division of the values of the index examined accepted by Boyer (1972) and D.G Pearce (1989[4], 1995). Authors grouped tourism regions in six categories according to their DTFI values as follows:

- >500 : 'hypertouristic' resort,
- 100–500 : large tourist resort,
- 40–100: predominantly tourist commune,
- 10–40: communes with an important but not predominant tourist activity,
- 4–10: little tourist activity or tourist function 'submerged' in other urban functions,
- <4: practically no tourist activity[5]

For HealingPlaces project needs and more clear approach, these have been grouped into three categories:

(i) <10,
(ii) between 10-40,
(iii) > 40.

To enable comparison of categories and touristic capacity under "Directional plan for tourism development in Poland", with specific limit values basing on three categories of areas (Table 1).

[4] Pearce, D. (1989) Tourist Development (2nd edn). Harlow: Longman.
Pearce, D., Barbier, E. and Markandya, A. (1990) Sustainable Development: Economics and Environment in the Third World. London: Edward Elgar.
[5] Pearce, D. G. (1979). *Towards a geography of tourism. Annals of Tourism Research, 6(3), 245-272.* doi:10.1016/0160-7383(79)90101-4

Table 1 Categories of areas

Category	Description	Carrying capacity
I	Tourism is a dominant function	127 persons / km^2
II	Tourism is an equal function to others	58 persons / km^2
III	Tourism is a complementary function	18 persons / km^2

Therefore:

Limit value of scalable resource: basing on *Defert's index:*

- *Defert's index* <10 (little touristic activity) → limit value: 18
- *Defert's index* >10 and < 40 (tourism is important function, but equal to others) → limit value: 58
- *Defert's index* >40 (tourism is a dominant function) → limit value: 127

To ensure the connection with the spatial planning, the results of Defert's index have been checked with the surface of researched area, represented in km^2.

Environmental capacity of SPA parks

Parameter describing the limits of the spa parks' environmental capacity. The result of exceeding the limits of the absorption capacity of SPA parks in spa areas may be the progressive degradation of valuable natural values.

Current level of use: Current maximum tourists number [persons/d] / Area of SPA parks [ha]

Limit value of scalable resource:

In the literature, it is assumed that a safe attendance for the area of the historic SPA park is no more than 50 people/ha. Unfortunately, the recommended such low attendance is practically impossible to enforce in the conditions of popular parks, which are a real magnet for tourists. Therefore, 500 people/ha is accepted as the maximum acceptable limit.

ANNEX 2. INFORMATION ABOUT DATA SOURCES IN DATABASE

no	Name of data	Unit	Source	Definition
1.	Municipality area	[km^2]	public statistical data on national & regional level	Municipality area
2.	Area of SPA parks	[ha]	public statistical data on national & regional level	The area of SPA parks, in regions where it's applicable[6]
3.	Current No. of inhabitants	[persons]	public statistical data on national & regional & local level	based on the "total population" indicator in public statistics
4.	Current Tourists person-day No.	[persons/d]	Estimated by PPs	
5.	Sewage: unitary production	[m^3/persons/d]	public statistical data on local level, PPs local sources	
6.	Sewage: current level of use	[m^3/d]	public statistical data on local level, PPs local sources	

[6] For some countries (e.g. Czech Republic, Poland) SPA Parks surrounding the main SPA building or main mineral/thermal springs are treated as an asset of the whole health resort & their availability is crucial aspect of functioning of SPA. The risk of their overcrowding and subsequent overrunning their biological capacity is important. Therefore SPA Parks capacity is important indicator to be calculated.

At the same time, for some countries officially separated SPA Parks do not exist (do not function officially or are not designated in land use), hence the less importance of the perception of their value. In these countries it was therefore impossible to have definite statistical data about the SPA parks areas / capacity.

no	Name of data	Unit	Source	Definition
7.	Sewage: limit value (capacity)	[m^3/d]	Reports from Water Framework Directive implementaion, available expertises on local level, PPs local sources	
8.	Drinking water: unitary consumption	[m^3/person/d]	public statistical data on local level, PPs local sources	Consumption rate per 1 person of water "Water consumption" is the portion of water use that is not returned to the original water source after being withdrawn.
9.	Drinking water: current level of use	[m^3/d]	public statistical data on local level, PPs local sources	Average amount of drinking water used in SPA municipality in 24h.
10.	Mineral water: unitary consuption	[m^3/persons/d]	PPs data provided in Google form	
11.	Mineral water: current level of use	[m^3/d]	PPs data provided in Google form	
12.	Mineral water: limit value (available resources)	[m^3/d]	PPs data provided in Google form	
13.	Wastes: unitary production	[Mg/person/yr]	public statistical data on local level, PPs local sources	
14.	Wastes: current level of use	[Mg/y]	public statistical data on local level, PPs local sources	

no	Name of data	Unit	Source	Definition
15.	Energy: unitary consumption	[MWh/person/d]		
16.	Energy: current level of use	[MWh/d]		
17.	Financial income: unitary rate	[€/persons/yr]		
18.	Financial income: current level	[€/yr]		
19.	No of beds		Statistical data - gathered by HealingPlaces project partners, based on national, regional and local statistics	Based “number of bed places in a tourist accommodation” and “number of beds in health resort hospitals and health resort sanatoria“ indicators I public statistics
20.	Defert’s index		Result of calculations from formula: Current tourists accommodation capacity /Current No. of inhabitants.	Defert’s tourist function index, which measures tourist 'intensity' or 'activity' by comparing the number of tourist bed places per 100 inhabitants of the study area. Specific information – in Annex 1.
21.	Legal protected areas	[ha]	Statistical data - gathered by HealingPlaces project partners, based on national, regional and local statistics	A protected area is a clearly defined geographical space that is recognised as and dedicated to achieving the long-term conservation of nature

no	Name of data	Unit	Source	Definition
22.	Legal protected areas	[%]	Statistical data - gathered by HealingPlaces project partners, based on national, regional and local statistics	Percentage of legal protected area in total area
23.	Overburden lithology		data provided in Google form by HealingPlaces project partners	Dominating lithology of rocks situated above the mineral/thermal water deposit
24.	Aquifer lithology		data provided in Google form by HealingPlaces project partners	Dominating lithology of rocks that host the mineral/thermal water deposit
25.	Groundwater table type		data provided in Google form by HealingPlaces project partners. Selected from drop-down menu	Two options: ▪ Unconfined - the level of groundwater table changes with changing pressure of mineral/thermal water in the aquifer; there are no rocks of low permeability in the overburden ▪ Confined - the level groundwater table is constant, as there are low permeable rocks in the overburden and therefore mineral/thermal water is under pressure; there is no change of water table level with changing pressure of the water in the aquifer
26.	Depth to water table	[m]	data provided in Google form by HealingPlaces project partners	

ANNEX 3. METHODOLOGICAL INFORMATION ABOUT LANDCOVER INDEX (LCI) CALCULATIONS

It was decided in cooperation with all the Project Partners that the Land Cover Index tool 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 area also outside the partner regions.

The main purpose of this indicator is to calculate and quantitatively and comparatively assess if and to what extent land use and land use change increases or decreases potential threat to curative water resources from the surface. Therefore, it is intended to be used as the part of the whole assessment tool.

The methodology has been structured in the following stages:

a) Identification of the relevant land use types,
b) Assessment of the significance of land use types,
c) Construction of the LCI tool prototype,
d) Pilot tests of the tool,
e) Analysis of the results and fine tuning the tool,
f) Distribution of the tool as a standalone application and incorporated in the Web application.

As has been mentioned, in stage a) 15 main land use types that have been identified in the course of discussions with Project Partners. These land use types reflect the varied characteristics of different SPA areas, as well as geospatial data availability for unexperienced user. The following land use types 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 stage b) the Analytical Hierarchy Process methodology developed by Saaty[7] 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 pair-wise comparison of criteria. In this study, the AHP methodology has been used to determine weights

[7] Saaty T.L. (1980) The analytic hierarchy process. McGraw-Hill, USA

(representing significance) of individual land use types. The procedure consisted of the following main steps:

- Structuring the hierarchy of levels constituting objective, criteria, and variants,
- Construction of the comparison matrix and assessment of each criterion,
- Calculations to determine the maximum Eigen value, and normalized values for each criterion,
- Test for the degree of consistency of the derived weights to check the consistency of experts' judgements.
- Ranking of the significance of the criteria.

The comparison matrix has been designed according to the formula (1):

$$M = \begin{bmatrix} a_{11} = 1 & a_{12} & a_{1n} \\ a_{21} & 1 & a_{2n} \\ a_{n1} & a_{n2} & a_{nn} = 1 \end{bmatrix} \quad (1)$$

Where, a_{11} is the result of comparison of C1 vs. C1, a_{21} is the result of comparison of C2 vs. C1 and so on. As C1 to C1 has to be equal the diagonal of the matrix is always 1 and the other (upper or lower) elements are the reciprocals of the earlier comparisons.

The comparisons can be derived from real measurements or a grading scale reflecting decision-maker's preferences. The preferences are determined with relative grades expressed as numerical values, usually 1–9, where 1 indicates that the compared criteria are equivalent and 9 indicates that the first of the compared elements is strongly preferred with respect to the other element (Table 2).

Table 2. The 9-point scale for pairwise comparison of criteria

Intensity of pairwise comparison	Importance
1	Equal importance, two activities contribute equally to the object
3	Moderate importance, slightly favours one over another
5	Essential or strong importance, strongly favours one over another
7	Demonstrated importance, dominance of the demonstrated importance in practice
9	Extreme importance, evidence favouring one over another of highest possible order of affirmation
2, 4, 6, 8	Intermediate values, when compromise is needed

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 AHP method have been presented in Saaty (2008)[8].

[8] Saaty T.L. (2008) Relative measurement and its generalization in decision making why pairwise comparisons are central in mathematics for the measurement of intangible factors the analytic hierarchy/network process. Rev R Acad Cien Ser A Mat 102:251–318.

The pairwise comparison matrices have been provided by members of Project Partner institutions who represented different fields of specialisations in accordance with the AHP methodology. These included for example: geology, hydrogeology, spatial planning, environmental protection, infrastructure, academia, etc. In the last step of the AHP procedure the ranking list of criteria has been developed based on the averaged assessments of the experts. The range of weights is 0.052 – 0.103(Table 3). The weights sum up to 1.0.

Table 3. **Land use types for the LCI tool and their weights**

Number of Criterion	Land use type	Weight derived from AHP	Weight from transformation
C1	Agriculture	0.062	10
C2	Orchards and horticulture	0.054	1
C3	Animal breeding farms	0.061	10
C4	Industrial sites	0.097	1000
C5	Mining sites	0.103	1000
C6	Built up areas without sewage system	0.056	10
C7	Built up areas with individual wastewater treatment systems	0.052	1
C8	Industrial and municipal waste sites	0.086	100
C9	Drainage fields	0.062	10
C10.	Road transport	0.063	10
C11	Railway transport	0.065	10
C12	Cemeteries	0.055	10
C13	Gas stations	0.062	10
C14	Water intakes	0.066	10
C15	Sport facilities and objects, Resorts, SPAs.	0.056	10

The calculated weights have then been used to scale the importance of the criteria in a 1 to 1000 range. Thus, according to the expert's judgements, the most significant land use types in terms of their negative influence on underground waters, i.e. industrial sites (weight 0.097) and mining sites (weight 0.103) have been rescaled to 1000, slightly less significant industrial and municipal waste sites (weight 0.086) have been rescaled to 100 and so on. The classification of the weights range for the recalling procedure has been done with the natural breaks method.

In stage c) a prototype tool has been designed using MS Excel spreadsheet and mathematical functions. Two types of calculations are possible, using absolute values 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 developed tool 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.