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Rapid Impact Assessment Matrix: Case Study for the Sliač Spa

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Abstract: Sustainability science repeatedly accents a need to account on an interaction between environment and humans while reporting to use of natural resources and recalling on sustainable production. Praxis around a world has shown that whatever positive an impact on environment a particular project is supposed to pose, it may, in fact, come true. It is because a benefit may come with negative effects on environment during a project construction, or a project may limit or increase human needs by reducing a general wealth of publics. This paper presents construction of Rapid Impact Assessment Matrix (RIAM) and analysis of sustainable development model for the Sliač Spa, an object of remarkable (inter)national reputation, somewhat operated since Late Medieval. Results show that the project contributes on sustainable development of the region, playing major positive impact on regional to national scale, compared to those negative ones related to a local area surrounding the areal mostly. However, a fact that $S_{EB} > S_E$ and, thus $S_{EB} = 0.33$ and $S_E = 0.21$ means the environment around is more sensitive to a pressure on physical-chemical factors than to biota, even the physical-chemical components (PC) has the highest capacity for "consumption" to satisfy human needs during site operation, maintenance or development. Indeed, ran scenarios on optimistic and pessimistic assumptions show that while groundwater depletion and consequent change in chemistry would have had devastating effect onto nature and wealth, improvement in status of houses may contribute to drop in human needs only.

Key words: sustainability, groundwater, Rapid Impact Assessment Matrix, Sliač Spa

5.1 Foreword

It has become a habitual praxis referring to the term of sustainable development only when discussing an issue of energy resources depletion or concerning a climate change. In point of its definition, the sustainable development basically means meeting "*needs of present without compromising the ability of future generations to meet their own needs*" (e.g. Nel & Cooper, 2009). To approach a sustainable society, it is a must to pay sensitivity to the future not dictating welfare criterion at now, meanwhile paying sensitivity to the present avoiding a dictate on a welfare by the future (Chichilnisky, 1997). Indeed, the crux in approaching the goal is to understand fundamental relationship between the environment and humankind, requiring acceptation of complexity of the environment itself (Schellnhuber, 2001). The environment, however, composes not only of (natural) planetary subspheres, but of a human component as well, including its actions and products (Schellnhuber, 1998). If the human interaction with the environment means on how this is treated, then it comes to analogy with, e.g. sustainability of geothermal resources, which is a problem of how these are operated (Rybach, 2007). Thus, amongst energy resources, the sustainable development shall apply to developing, utilization or "conservation" of welfare activities and actions, such as spas, natural and cultural heritage, mineral and drinking water resources etc.

Numerous methods and models have been introduced to quantify a level of sustainability since a concern on sustainable development intensified, divert in approach, clarity of evaluation and an impact of subjectivity (Thompsen, 1990). Strategic Environmental Assessment (SEA) approach evaluates environmental consequences of a planned initiative or a project on par with economic and social considerations to address them for the earliest possible decision making stage, identifying and anticipating possible impacts (Dalal-Clayton & Sadler, 1996). The Sustainability Appraisal approach (SA) develops a framework consisting of objects or targets to achieve social, economical and environmental sustainability for a given action or a project, measurable through a set of quantitative indicators (Shortall, 2010). Application of EIA became a most frequent tool in Slovakia, aimed at minimizing impacts of an activity or a project on environment. Yet this is a most subjective assessment tool, based on a holistic approach only (Pastakia & Madsen, 1995). To minimize a risk of subjectivity, a Rapid Impact Assessment Matrix (RIAM) was proposed, identifying criteria to play role in overall sustainability of a project, evaluated through collating independent semi-quantitative values per each of these (Pastakia, 1998). Praxis has shown that the RIAM contributed to a site-environment analysis with assessment of a level of sustainability, updated with introduction of classification on a nature of sustainability (Phillips, 2010a, b).

Mineral and thermal springs in Sliač area are amongst first described within the territory of the Slovak Republic (Franko, 1998). Earliest quote on their existence comes from 1243 – 1244 when Hungarian King Bela IV granted town privileges to a city of Zvolen, pointing out existence of several thermal springs named *Thermae Ribariensis*, according to a cadastre of Rybár to which they belonged to. An official Sliač Spa settlement dates to a beginning of 19th Century. At this time, three thermal springs: the Dominorum for nobility, the Civium for burgesses, and Rusticorum for publics; and five cold springs: Dorota, Jozef, Lenkey, Adam and Medokýš, serving to all; donated natural pools directly. In 1860 a Count Russeger planted a base for nowadays known spa park. For comparison, a capacity of the resort increased from 300 patients in 1833 to 7,000 patients in 1959. Remediation activities and monitoring in Vlkanová have pointed out a risk of some contamination of mineral and thermal groundwater with benzene and toluene, resultant to dislocation of the Soviet Army in 1968 – 1992 (Gálisová et al., 2012). Nowadays the Sliač Spa is still active, providing service in tourism and balneotherapy. Utilizing isothermal springs as one of a few in the world only, the location has an enormous potential to gain its previous reputation.

This contribution aims to develop a RIAM for Sliač Spa, to classify a level of sustainability of its existence in a first. Then, a nature of the sustainability is identified through describing environmental, biological / ecological, social and economical aspects. This shall help to identify goals necessary to achieve a harmony with a global idea of sustainable development. Authors believe a conduction of RIAM can be beneficial to balneological community as well as a it may represent a background for onward detailed studies, e.g. in defining RIAM criteria values and components strictly related to a sustainability of spa resorts.

5.2 Approach

Early studies on environmental assessment of projects in 80's and 90's repeatedly recorded suffering from inconsistent judgement as lacking a transparent framework, impact significance determination standardization (Wood et al., 2006) and multicriteria assessment tools (Hajkowicz, 2007). Evaluation of a level of heuristic or holistic reasoning in unguided frameworks of individual involved panelists became impossible (Ijäs et al., 2008).

5.2.1 Rapid Impact Assessment Matrix

The RIAM is the matrix-based method developed to balance a risk of subjectivity in holistic and heuristic EIA evaluations (Pastakia, 1998). To achieve the goal, five (Pastakia & Jensen, 1998) or six (Ijäs et al., 2008) criteria have been identified, crucial for sustainable development analysis. A guided approach is secured through setting means by which semi-quantitative criteria are assigned. This yields an individual score per each condition selected for four basic components (Pastakia & Jensen, 1998). Indeed, development of guided evaluation scheme allows use of various conditions or factors grouped according to a component they belong to. The RIAM has been already applied to environmental loads (Al Malek & Mohamed, 2005; El-Naqa, 2005), public water supply (e.g. Kuitunen et al., 2008; Kankam et al., 2005), geothermal energy supply (Arevalo, 2003; Yousefi et al., 2009; González et al., 2015), tourism, transportation or urban planning (e.g. Wei et al., 2014) etc.

5.2.1.1 RIAM criteria

According to (Pastakia & Madsen, 1995), representative criteria for guided evaluation shall meet two principal conditions:

- universality to allow its use in different EIAs;
- must be assigned a value determining its affiliation with a criteria group A or B.

Subsequently (Pastakia & Jensen, 1998) presented clustered groups of criteria (Tab. 5.1). Complexity of the RIAM was, however, improved by implementing a criterion of environments susceptibility (Ijäs et al., 2008) to a condition (Tab. 5.1). As such, the framework shall represent a fundamental tool, meeting claims on objectivity and universality (Phillips, 2010a).

5.2.1.2 RIAM components

A component means a part of biota, abiotic system or service, expected to get under an impact of a project or to be subjected to a change by project activity (Pastakia, 1998): environmental, socio-cultural (SC) and economical (EC). Yet environmental component consists of physical-chemical (PC) and biological-ecological (BE) subcomponents (Tab. 5.2). Each component is then a group of variable aspects describing detailed situation and performance of evaluated project (Pastakia & Jensen, 1998), apparently individual for different cases due to obvious selection of different conditions.

5.2.1.3 RIAM environmental score

Once criteria are given, a semi-quantitative value is assigned to its description (Tab. 5.1). Then, each of individually found active aspect included in a respective group is subjected to an evaluation (Fig. 5.1) based on simple formulae (Pastakia & Jensen, 1998). First, an importance of the aspect to human needs or spatial boundaries is calculated (Eq. 5.1):

$$\boldsymbol{a}\mathbf{T} = (\boldsymbol{a}\mathbf{1}).(\boldsymbol{b}\mathbf{1}) \qquad \text{(Eq. 5.1)}$$

where: $\boldsymbol{a}\mathbf{T}$ – total importance or a score per group A, (a1) – spatial or interest condition value, (a2) – magnitude of impact (or change) of a condition.

Use of multiplier to calculate a total importance ensures that the weight of each score is representatively expressed, whereas summation could yield identical results for different conditions. Then, performance and impact on a situation of a condition is calculated (Eq. 5.2):

$$\boldsymbol{b}\mathbf{T} = (\boldsymbol{b}\mathbf{1}) + (\boldsymbol{b}\mathbf{2}) + (\boldsymbol{b}\mathbf{3}) + (\boldsymbol{b}\mathbf{4}) \qquad \text{(Eq. 5.2)}$$

where: $\boldsymbol{b}\mathbf{T}$ – total performance or a score per group B, (b1) – value for a condition permanence, (b2) – value of reversibility, (b3) – value of cumulativity, , (b4) – value of susceptibility.

Here, the bT is a sum of all B-conditions. This ensures that the individual value scores cannot influence the overall score, but that the collective importance of all values are completely accounted. Then, a relative environmental score per each condition/aspect is a product of condi-

Tab. 5.1 Review on RIA criteria and semi-quantitative evaluation matrix. Modified after: Pastakia (1998), Pastakia & Jensen (1998), Philips (2010b), Ijäs et al. (2010)

RIAM criteria	Scale	Semi-quantitative value	Description or note
Group A – importance			
(a1) – importance of the impact/aspect	+4	important to national interests/extreme societal importance	extended to the country and international boundaries or a subject of extreme rarity or special protection in the country
	+3	important regionally/significant societal importance	impacts single region or several neighbouring regions, subject of rarity in the region or a subject of some protection
	+2	important to areas outside the local context/ some societal importance	extended to an instant area around a project or a few municipalities, a subject potentially endangered with occasional protection and importance to the society
	+1	important locally/minor societal importance	typically a point-formed area or immediate areal of the evaluated project, or subject of no protection or rareness
	0	no geographical or other recognized significance	an impact or an aspect does not play a significance or is not present currently in the region, country
(a2) – magnitude of impact or change in status-quo	+3	major positive benefit or complete preservation/ conservation	e.g.: preservation of undisturbed groundwater deliverability, forest restoration
	+2	significant improvement in status-quo	e.g.: contribution on significant increase of a soil productivity potential
	+1	improvement or positive benefit	e.g.: decelerates a rate of resource depletion (use of more efficient technologies)
	0	no change in status-quo, no impact on performance	e.g.: no contamination in the surface stream
	-1	negative change to status-quo or some negative impact	e.g.: weakly excesses allowance to groundwater exploitation
	-2	significant negative disbenefit to status-quo	e.g.: build of landfill in environmentally unstable land
	-3	major negative disbenefit or complete destruction	e.g.: destructs special protection area
Group B – performance			
(b1) – permanence	+4	permanent and long-term impact	exposure to the impact is for more than 15 years
	+3	temporary and medium-term impact	exposure to the impact is usually 1-15 years
	+2	temporary and short-term impact	exposure to the impact is usually less than 1 year
	+1	no impact, not applicable, no change to status-quo	an impact or an aspect does not play a significance or is not present currently in the region, country
(b2) – reversibility	+4	irreversible impact on status-quo	permanent change to environment, which restoration is impossible or will take more than 15 years, or no plans to change the actual impact on environment
	+3	slowly reversible impact on status-quo	long-term change to environment, restoration of 1-10 years, or long-term plans to change a project performance
	+2	reversible impact on status-quo	initial status can be restored quickly up to 1 year or there is a plan to modify current site performance
	+1	no impact, not applicable, no change to status-quo	an impact or an aspect does not play a significance or is not present currently in the region, country
(b3) – cumulativity	+4	explicitly synergic impact	aspect or condition has an intrinsic impact on other aspects
	+3	synergic impact	aspect or condition has known impact on other aspects, but it has not been quantified yet
	+2	individual impact	aspect is of individual impact, not interacting with other impacts
	+1	no impact, not applicable, no change to status-quo	an impact or an aspect does not play a significance or is not present currently in the region, country
(b4) – susceptibility	+4	environment extremely sensitive to change	areas of international and national protection, special protection, endangered species etc., risk to human
	+3	environment sensitive to change	areas of local interest, minor protection, less endangered species, no risk to human
	+2	environment stable / unsusceptible to change	areas not protected, not significant or relevant to the society
	+1	no impact, not applicable, no change to status-quo	an impact or an aspect does not play a significance or is not present currently in the region, country

Tab. 5.2 Review on RIAM components, aspects and example on conditions. Modified after: Pastakia & Jensen (1998), Ijäs et al. (2008), Philips (2010b)

Sustainability component cloud	Component/ subcomponent group	Acronym	Example on aspects	Description
Environment	Physical and chemical components	PC	resource quality resource quantity landscape issues site installation	all physical and chemical aspects related to finite and infinite resource or land, including impacts of potential hazards and pollution
	Biological and ecological components	BE	biology ecology land management	all aspects with impact on biota and initial land, species preservation or conservation and interaction with ecological systems or subsystems
Human needs	Social and cultural components	SC	public performance public activities society culture	social and cultural issues affecting individuals and groups, human development and conservation or preservation of heritage
	Economical components	EC	microeconomics macroeconomics site maintenance operation	includes project activities and management, economical impact on environment or society in both, micro and macro scales

tions` importance and performance (Eq. 5.3) in a range of ES = <-192;+192> (Philips, 2010b). Then, each individual score is classified (Tab. 5.3):

$$ES = aT \, . \, bT \qquad \text{(Eq. 5.3)}$$

where: *ES* – relative environmental score.

At the end, the RIAM is presented in a form of matrix leaving reasoned and permanent record about a judgment conducted (Ijäs et al., 2008), available to get broken down into smaller problems according to given components or aspects.

5.2.2 Sustainable development model

Apparently, the environmental score yields negative values for any disbenefitial impact indicated. To avoid issues in interpreting negative scores, the initial count must be upscaled by +192 to each aspect, transforming preliminary rangeband $-192 \leq ES \leq +192$ (Pastakia, 1998) to more applicable positive range $0 \leq ES \leq 384$ (Ijäs et al., 2008).

5.2.2.1 Level of sustainability

According to a concept of sustainable development (e.g. Nel & Cooper, 2009), human actions and needs (H_{NI}) should not compromise an environment (E), so that $E > H_{NI}$, thus an action or a project is sustainably developing if its sustainable score (Eq. 5.4) is $S > 0$. While an environment is described by its actual interaction over total capacity (Eq. 5.5), human needs are defined along social, cultural and economic aspects (Eq. 5.6). Consequently, for a case where human needs exceed a capacity of the environment, an evaluated project cannot be considered sustainable, so that $H_{NI} > E$ and $S < 0$ (Philips, 2010a,b). Evaluation of a level of sustainability then proceeds towards semi-quantitative description (Fig. 5.1) based on E versus H_{NI} relations (Philips, 2010a):

Tab. 5.3 Environmental score evaluation. Modified after: Pastakia & Jensen (1998), Ijäs et al. (2008)

Environmental score range-band	Sustainability classification	Sustainability performance description
+192 to + 108	D (or +4)	major positive impact
+107 to +54	C (or +3)	significant positive impact
+53 to +31	B (or +2)	moderate positive impact
+30 to +1	A (or +1)	slight positive impact
0	N (or 0)	no impact on status-quo
-1 to -30	-A (or -1)	slight negative impact
-31 to -53	-B (or -2)	moderate negative impact
-54 to -107	-C (or -3)	significant negative impact
-108 to -192	-D (or -4)	major negative impact

$$S = E - H_{NI} \qquad \text{(Eq. 5.4);}$$

$$E = \frac{\sum PC + \sum BE}{PC_{max} + BE_{max}} \qquad \text{(Eq. 5.5);}$$

$$H_{NI} = \frac{(SC_{max} - \sum SC) + (EO_{max} - \sum EO)}{SC_{max} + EO_{max}} \qquad \text{(Eq. 5.6)}$$

where: E – environment, H_{NI} – human needs, PC_{max} – capacity of PC component, BE_{max} – capacity of BE component, SC_{max} – capacity of SC component, EO_{max} – capacity of environmental component, S – level of sustainability, thus:

- $S \leq 0 \rightarrow$ not sustainable
- $S = 0.001$ to $0.250 \rightarrow$ very weak sustainability
- $S = 0.251$ to $0.5 \rightarrow$ weak sustainability
- $S = 0.501$ to $0.75 \rightarrow$ strong sustainability

- S = 0.751 to 1 → very strong sustainability

According to (Eq. 5.4), with increasing H_{NI}, there must be a determined value of E, otherwise $E > H_{NI}$ will not occur, meaning that for uncompromised increase in H_{NI}, there shall be an infinite source of E to maintain $S > 0$, that is, of course, impossible (Phillips, 2010a).

where: S_X – sustainability score for subcomponent or aspect X, X_{act} – actual performance of subcomponent X and X_{max} – capacity of the component X.

In general, a capacity (Phillips, 2010a) of various component X (Eq. 5.8) which systematically enters equations Eq. 5.5 to Eq. 5.9 is given by maximum possible environmental score (ES_{max}) score of number of subcomponents (n_X) comprising a set X, thus:

$$X_{max} = n_X \,.\, ES_{max} = n_X \,.\, 384 \qquad \text{(Eq. 5.9).}$$

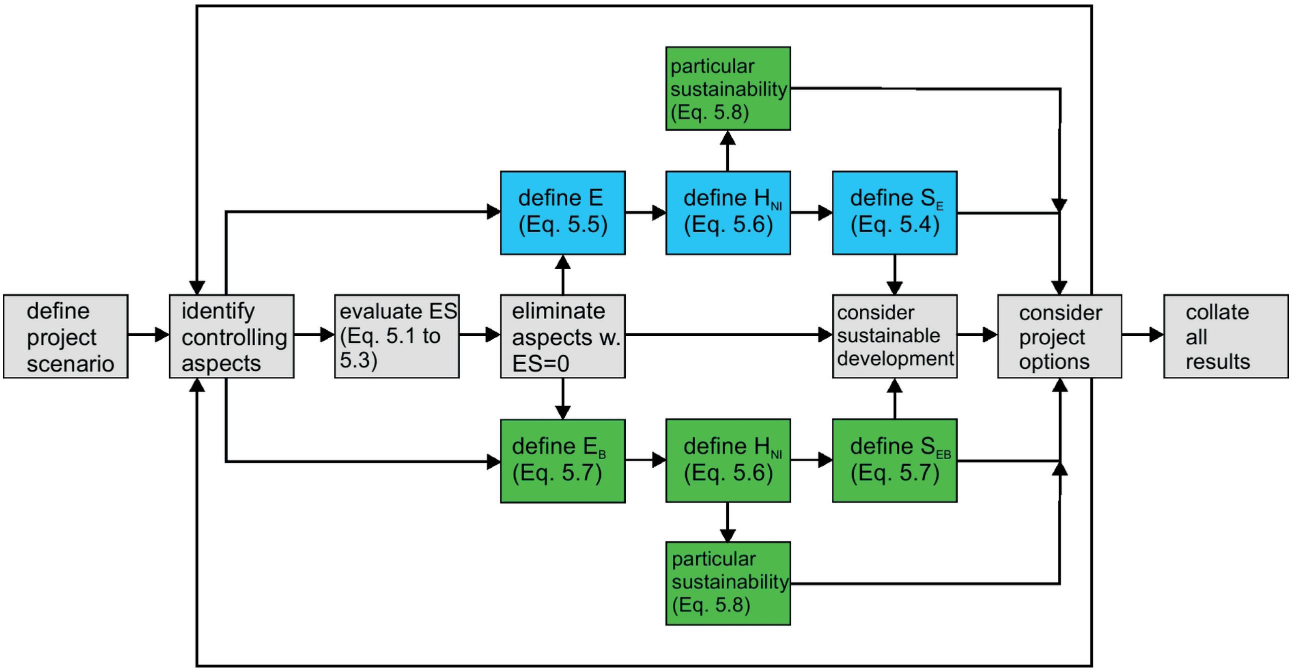

Fig. 5.1 Rapid Impact Assessment Matrix and sustainable development model workflow. Modified after: Pastakia&Jensen (1998), Phillips (2010a), Ijäs et al. (2008)

5.2.2.2 Nature of sustainability

A problem of environmental sustainability model by Pastakia (1998) is that summing up both components (PC + BE) may lap over their lows compared to H_{NI} (Eq. 5.5), yielding apparent sustainability if $E > H_{NI}$ or $(PC+BE) > H_{NI}$ and, thus, $S = S_E > 0$. A model of ecological sustainability (Eq. 5.7) sums all subcomponents (atmosphere – A, biosphere – B, lithosphere – L and hydrosphere- H) and turns them against a capacity of the system, which is calculated as maximum possible score per each (Phillips, 2010a):

$$S_{EB} = \frac{\sum(B + A + H + L)}{B + \sum A_{max} + H_{max} + L_{max}} \qquad \text{(Eq. 5.7).}$$

Analogously, a procedure in (Eq. 5.7) may be applied to each sphere if its actual state, given by an impact of humans posed, is confronted with its capacity, that is a maximum score possible. Schellnhuber (1998, 2001) accents that sustainability requires understanding a dynamic relationship between E and H_{NI}. It means, that the higher is the sustainability performance for E, the less is the performance of H_{NI}. If $H_{NI} = \sum SC + \sum EO$, a general concept of sustainability (Eq. 5.8) allows proportion of each subcomponent and aspect to an intensity of human needs, providing additional options to approach a picture of sustainability at a site:

$$S_{EB} = \frac{X_{act}}{X_{max}} - H_{NI} \qquad \text{(Eq. 5.8)}$$

5.2.3 Problem definition

Historical documents say the Sliač Spa were founded at the very beginning of 19th Century. Thus, depending on a timescale, their existence may appear sustainable – either with some reference to a necessary scale for, in an example, sustainable operation of geothermal resources, requiring at least 100 – 300 years long production (Axelsson et al., 2001) without decline in production or deliverability over 10 % to the initial (Williams, 2010). However, considering a real on-line project, there is more with it than just a production of waters. Thus, besides the history of site foundation, the problem is to determine and analyze:

- level of sustainable performance of the Sliač Spa at an overall scale;
- identify nature of sustainability;
- analyze capacity the environment provides to the project available for sustainable use.

5.3 Site description

5.3.1 Geology

Geological structure in the Sliač Spa region reflects its geodynamic evolution and geological position, covering a vertical profile from Palaeozoic to Quaternary. The Ľubietová Group of the Veporic Superunit is represented by the Brusno Formation in its typical rhyolite and dacite volcanoclastics, to the SE from the areal (Fig. 5.2). Existence, extension and thickness of Mesozoic nappes is, in major, assumed only, based on deep boreholes data. Mesozoic surface exposure terminates along a Čerín-Vlkanová line to the N, than sinks beneath Neogene volcanosedimentary complexes (Konečný et al., 1983). The Krížna Nappe is the bottom system, exposing with Early Triassic quartzites and arkose sandstones of the Lúžna Formation to the SE. The Choč Nappe system composes of Mid Triassic Ramsau and Main Dolomites, usually dissected into multiple tectonic outliers. The Drienok Nappe represents a superpositioned Mesozoic system, with rare records of Reifling Limestone (organogeneous, cherty) and Wetterstein Limestone (reef, organogeneous limestones) documented to the N, near towns of Vlkanová and Čerín (Bondarenková, et al., 1986).

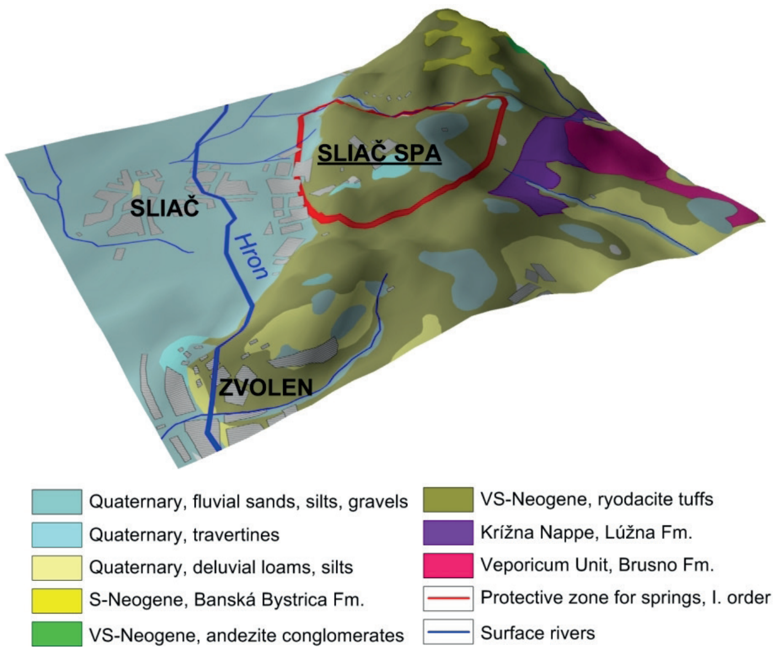

Fig. 5.2 Generalized geological map of the Sliač Spa area

Neogene – Early Sarmatian pumice and rhyodacite tuffs of the Strelnica Formation form a most extended lithotype exposing on the surface in the area (Fig. 5.2), representing external zone of the Poľana Stratovolcano. External zone of the Javorie Stratovolcano exposes to the NW by Mid to Late Sarmatian epiclastic andesite sandstones with conglomerates. The Pliocene aged Banská Bystrica Formation is the only member of the sedimentary Neogene, forming spatially limited surface positions of gravels and silty sands NE from the Spa.

Quaternary fluvial accumulations represent a dominant sedimentary cover in the entire region. Early Pleistocene high terraces show up in form of residual gravels. Mid Pleistocene is developed to the W from the Sliač Town, recording increased proportion of sands and sandy loams. Holocene levee plains compose of loams, sands and gravels. Deluvial formations form slope talus and occasional landslides of sandy loams facies. Pleistocene to Holocene foam sinters and travertines are rare in the region, however, are a clear record on mineral water presence and open type of local hydrogeological structures.

5.3.2 Hydrogeology

Complexity in local hydrogeology reflects variation in geological structure of the entire area. By classification of groundwater regime (Franko et al., 1975) the structure is best described as open with semi-covered discharge area.

Bondarenková et al. (1986) assume the infiltration zone extends to the NWN at slopes of the Kremnické vrchy Mts., as given by piezometry, after gaslift and thermolift effect neglecting. Although there are multiple mineral-thermal water transition pathways distinct in filtration depth and residential longevity within the system. Effective transition realizes in environment of different proportion between intergranular and fissured permeability, according to a host rock. Limestones are, however, typical with kart-fissured permeability (Ryšavá et al., 2008). Vertical extension is then controlled along open longitudinal SW-NE and transverse NW-SE regional and local fault systems (Dzúrik, 2012).

Accumulation zone hosts groundwater in shallow and deep circulation. While the first consists of Neogene volcanosedimentary complexes, the latter forms within Mid Triassic carbonates, drained at a contact with heavily incompact Early Triassic quartzites (Böhm et al., 1993).

Two different discharge zones are documented in the Sliač area, at different elevations. A top one drains deep circulation regime by the Kúpeľný prameň spring, but discharges at the bottom one by Bystrica, Lenkey, Adam springs as well. This has been already expected by Bondarenková et al. (1986). The Štefánik spring represents a natural discharge of shallow circulation (Dzúrik, 2012).

5.3.3 Hydrogeochemistry

Groundwater at the Sliač area is vadose in origin, infiltrated into volcanosedimentary or carbonate environment straight by rainfall, or seeped deeper by hydraulic connection between different aquifers and, apparently, along open fault systems. The free CO_2 is, however, juvenile, originated in buried crystalline, evading shallow aquifers at fault intersections mostly (Dzúrik, 2012).

A difference is evident by groundwater chemistry (Fig. 5.3). Deep drained groundwater is of Ca-SO_4 to SO_4-Ca type, gaining a sulphate compound by dissolution of evaporates (Bondarenková et al., 1986), preferentially gypsum of the Lúžna Formation. A deep circulation and longevity of the group is seen along offset from the rainfall precipitation region on a Gibbs plot (Fig. 5.4), implying tendency to vary the chemistry through deposition of solid phases at (hence the Na/Ca + Ca low region) atmospheric pressure (Gibbs, 1970). This is what exactly happens by sintering and travertine formation nearby the spa areal.

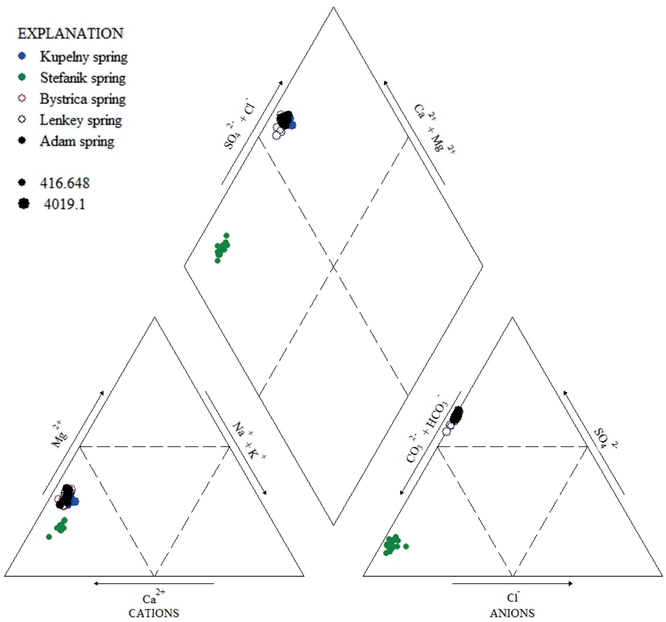

Fig. 5.3 Piper plot of documented Sliač Spa springs in a period 1994-2016

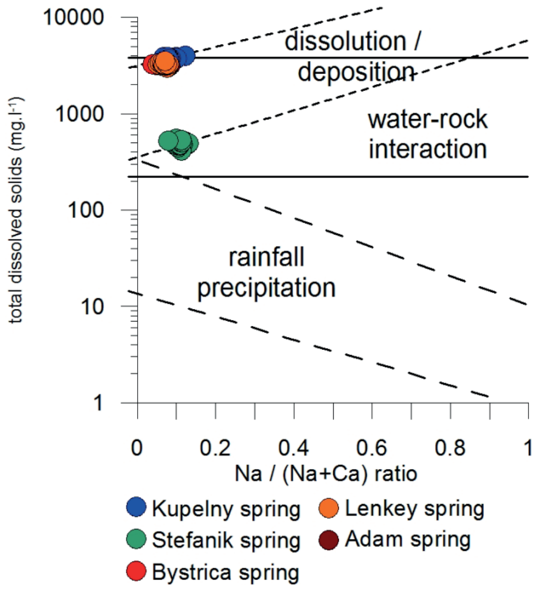

Fig. 5.4 Gibbs plot of documented Sliač Spa springs in a period 1994 – 2016

A good evidence is also given on a maturity plot (Giggenbach, 1991), where region of immature, acid type waters (Fig. 5.5) implies longer circulation and less sensitivity to rainfall variation (at least in terms of groundwater chemistry).

Shallow groundwater distinctly varies in bicarbonate compound and low sulphate content (Fig. 5.3) as lacking a contact with the SO_4 source zone (Early Triassic horizon), preserving Ca-HCO_3 type of chemistry. Apparently, rainfall and rock dissolution control its chemistry (Fig. 5.4), and (after Gibbs, 1970) groundwater shall be in some partial equilibrium with a host rock. An evidence the groundwater chemistry is a product of shallow and fast filtration is given by position of samples of the Štefánik spring in the peripheral region (Ármansson, 2007), given by high bicarbonate proportion.

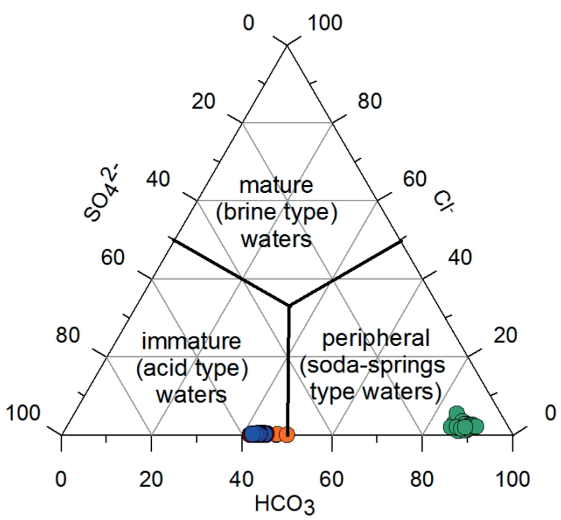

Fig. 5.5 Giggenbach's maturity plot for Sliač Spa springs in a period 1994 – 2016. See previous plot for colour symbols

5.4 Site performance

5.4.1 Physical and chemical components

5.4.1.1 Site installation subcomponents

The site has been founded in woodlands, by the eastern limit of the Sliač Town. An areal consists of 10 buildings and park (Kolonáda) with no outer fence. A situation of the Spa in primary nature promotes use of initial land (PC1) by existence of protective zone. Yet the same areal increases a natural light intensity in the woods (PC9) and cultural or human activities through a year, which produce a level of noise (PC3) above 120 dB, which is critical (Tester et al., 2006), thus negative impact onto biota must be accounted. Similarly, the need for infrastructure operation and maintenance contribute on noise level, however, with negative score limited at its longevity (PC2). Odour production (PC8) has been eliminated, finding no source for so (Tab. 5.4).

5.4.1.2 Resource quantity subcomponents

Since foundation, Sliač Spa use mineral-thermal groundwater at Kúpeľný prameň (T = 33 °C), Štefánik (T = 12 °C), Bystrica (T = 23 °C), Lenkey (T = 22,5 °C) and Adam (T = 23 °C) springs, along with free carbon dioxide yield of 10 l . s^{-1}.

A resource production is given by allowances (Dzúrik, 2012), at Q = 4.8 l . s^{-1} for groundwater and Q = 10 l . s^{-1} for CO_2. Actually, a production (PC17) does not exceed 25 – 75 % of allowed yield, marking a strong positive effect on deliverability (PC15), not recording any decline in discharge or temperature (Fig. 5.6). Accessibility to groundwater resources is, however, restrained by extension of protective zones, contravening principles of sustainable development (Tab. 5.4). Although this is a situation typical for all mineral-thermal and healing springs sensitive to external components (PC18).

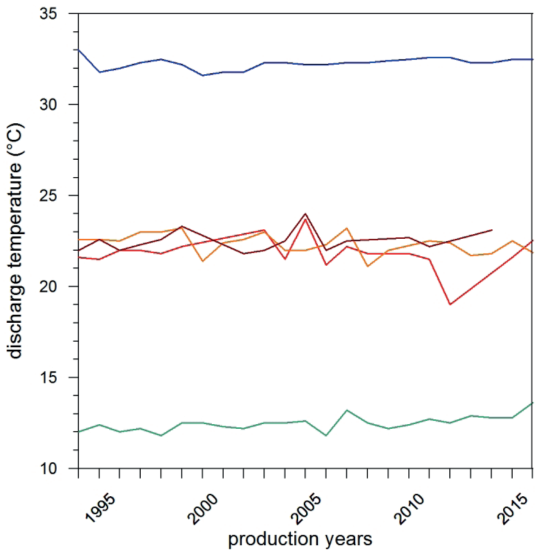

Fig. 5.6 Mean annual discharge temperature record of Sliač springs

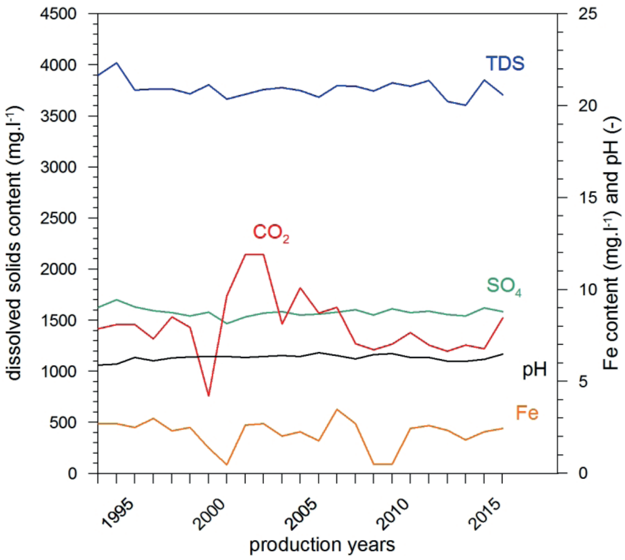

Fig. 5.7 Variation in specific components of the Kúpeľný prameň spring

5.4.1.3 Resource quality subcomponents

Operation of spa is determined on groundwater healing effect preservation. At a site, mineral-thermal water applies in gynecological and cardiovascular diseases, movement and gastroenteritis disorders, and carcinoma treatment. Resource quality is, thus, a crucial performance not only to physical-chemical, but economic and social aspects as well.

Stable production under a critical yield restrains change in groundwater filtration longevity and depth. Periodical measurements at springs record no damage on groundwater quality (PC5), keeping stable chemistry (Fig. 5.7) of exploited water (PC16) in its main components. Finding of Gálisová et al. (2012) on presence of organogeneous pollution originated at the Vlkanová shall not be accounted to activity of the Spa. Areal coverage of protective zone and zone of specific provision contribute positively on a final air quality (PC6).

Currently, water from the Kúpeľný prameň spring is disposed into local drainage channel (PC4) at TDS = 3.5-4.1 $g.l^{-1}$, increasing dissolved solids in a water above its dilution capacity, posing a damage on a surface stream quality and risk on local microbiota. Unfit condition of buildings poses a risk on a soil quality (PC7) amongst (Tab. 5.4).

5.4.1.4 Landscape issues and dynamics subcomponents

Aspects are controlled along possible geodynamics and hazards, caused or limited by human intervention, as well as on surface manifestations of groundwater presence.

No decline in natural springs discharge preserves their manifestation (PC10) at a positive level (Tab. 5.4). An effect is strengthened as these are most important landscape features and propagation of resource existence. Although of high land use efficiency, early construction of hotels at the break of Medieval along with "recent" installation

Tab. 5.4 Rapid impact assessment matrix for physical-chemical (PC) components

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
PC1	Land use efficiency	3	2	4	1	2	2	6	9	54	C
PC2	Infrastructure impact	2	-1	4	1	2	2	-2	9	-18	-A
PC3	Noise	2	-1	4	2	2	2	-2	10	-20	-A
PC4	Surface water quality	2	-1	4	4	3	3	-2	14	-28	-A
PC5	Groundwater quality	4	3	4	4	3	4	12	15	180	D
PC6	Air quality	3	3	4	3	4	3	9	14	126	D
PC7	Soil quality	1	-1	3	3	3	2	-1	11	-11	-A
PC8	Odour	0	0	1	1	1	1	0	4	0	N
PC9	Light pollution	2	-1	4	2	2	2	-2	10	-20	-A
PC10	Springs manifestations	4	3	4	2	4	4	12	14	168	D
PC11	Erosion	0	0	1	1	1	1	0	4	0	N
PC12	Landslides	4	0	1	1	1	1	0	4	0	N
PC13	Subsidence	0	0	1	1	1	1	0	4	0	N
PC14	Landscape modification	2	-1	4	4	2	4	-2	14	-48	-B
PC15	Deliverability	4	3	4	4	4	4	12	16	192	D
PC16	Geochemical stability	4	3	4	4	4	4	12	16	192	D
PC17	Production stability	4	2	4	4	4	4	8	16	128	D
PC18	Accessibility	1	-3	4	4	4	2	-3	14	-42	-B

of infrastructure have consumed initial relief negatively (PC14).

Geodynamics (PC11 to PC13) have been eliminated as there is no interaction between the Spa and occurrence of landslides, erosion or subsidence, neither of these was observed.

5.4.2 Biological and ecological components

Identification of project impact on biotic systems in surroundings of the spa set a target to search for species of local to national importance in terrestrial or aquatic environment. Evaluation includes possible limits to biota for migration, breeding or wintering rests.

5.4.2.1 Biology subcomponents

Terrestrial ecosystem (BE1 to BE2) plays regional role in importance through fauna (Black stork, Lynx, Brown bear, deers, boars etc.) or flora species. Presence of Spotted eagle (protected) or *Gentiana*, *Agrostemnia*, *Iris*, *Lilium*, *Vinca* or *Cornus* increases performance of the Spa to the biota by extended protection (Tab. 5.5).

While aquatic flora is limited to banks (BE4), mineral water disposal plays negative impact on aquatic microfauna (BE3).

5.4.2.2 Ecology subcomponents

Ecology aims at analysis of pressure posed on living forms and environmental interaction of the Spa with ecosystems of variable capacity and importance.

Specific provisions zone covers entire woods around areal, restraining negative activity within (BE5). An effect rises up because of inhaling therapy realized in woods. Legal protection promotes ecological stability of the entire area (Tab. 5.5), accented through good performance towards biodiversity by extension of pastures and forests of specific provision (BE9).

Natural habitat (BE7), endemism (BE8), relicts (BE9), geodiversity (BE10) and special protection area (BE11) were eliminated. No presence has been recorded until now.

5.4.2.3 Land / country management subcomponents

In sustainability science, land and country management identifies capacity of a surface to provide products supplying a demand, thus the human needs resulted from their interaction with primary and secondary environment.

By Atlas of Landscape SR (2002), the entire region is of low soil productivity (BE13) and low agricultural potential (BE14) sensitive to occasional trashes pollution yielding a negative score (Tab. 5.5).

Primary land (BE6) and land aesthetics (BE16) are, by a contrast, in positive response to existence of the Spa. This is because pastures are situated within protective zone of Ist order for mineral water and the entire areal is seated in primary woods, with, if any, low modification.

5.4.3 Social and cultural components

Social and cultural components aim on human aspects in the environment (Mihaiescu et al., 2015) defining a rate of human wealth, leading towards its conservation, damage, restoration or preservation, including natural and cultural/historical heritage. Then, human needs are inverse to the social and cultural condition of publics (Pastakia & Jensen, 1998).

5.4.3.1 Public performance subcomponents

The subcomponent of public performance evaluates a level of societal development and acceptance of the project status with its impact to the environment and initial country.

Stability in therapeutic and recreation effect of the Spa promotes local public services (SC1), safety (SC4) and health (SC5) with importance extended not only towards local but foreign visitors as well (Tab. 5.6).

Tab. 5.5 Rapid impact assessment matrix for biological-ecological (BE) components

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
BE1	Terrestrial fauna	3	1	4	2	4	3	3	13	39	B
BE2	Terrestrial flora	3	2	4	2	4	3	6	13	78	C
BE3	Aquatic fauna	1	-1	4	2	3	2	-1	11	11	-A
BE4	Aquatic flora	1	1	4	2	3	2	1	11	11	A
BE5	Forests	4	1	4	4	3	2	4	13	52	B
BE6	Primary agricultural land	1	1	4	4	3	2	1	13	13	A
BE7	Habitat	0	0	1	1	1	1	0	4	0	N
BE8	Endemism	0	0	1	1	1	1	0	4	0	N
BE9	Relicts	0	0	1	1	1	1	0	4	0	N
BE10	Biodiversity	3	3	4	4	3	2	9	13	117	D
BE11	Geodiversity	0	0	1	1	1	1	0	4	0	N
BE12	Special protection area	0	0	1	1	1	1	0	4	0	N
BE13	Soil productivity	2	-1	4	2	2	3	-2	11	-22	-A
BE14	Agricultural potential	2	-1	4	2	2	3	-2	11	-22	-A
BE15	Ecological stability	3	3	4	3	4	3	9	14	126	D
BE16	Land aesthetics	3	1	4	2	3	3	3	12	36	B

Besides, abandonment of 7 out of 9 housing objects calls on negative reactions of publics and its acceptability (SC2) and adaptability (SC3) of the Spa under actual conditions, substantially decreasing a general wealth and increasing human needs.

5.4.3.2 Public activities subcomponents

The group identifies possibilities of environment – human interaction at a scale of capacity it can provide to satisfy general needs of public wealth and conditions.

International importance of the Spa supports a region promotion (SC6) through therapeutics (SC9) improving life quality status, which is of synergic interaction with local socioeconomics. Legal protection of the region, however, reduces opportunities on recreation (SC8) as given by specific provisions in use of the country, yet they do not limit possibilities on tourism (SC10) hence a direct contact of the open Spa areal with a wildlife (Tab. 5.6), creating high confidence in climatic adaptability (SC11) by yield allowances and resource stability.

5.4.3.3 Culture subcomponents

A level of society and its intervention with history and environment is defined along with impact of its activities on heritage. Hence sustainable development shall at least conserve a natural status and makings of a past for the future, an accent is given to its preservation.

There are four declared objects of cultural heritage in the areal: Bratislava (ex Buda), Slovensko (ex Hungaria), Detva (ex Pešť) and the Palace (Fig. 5.8 – 5.9), with the latter active only. The rest is currently abandoned with no special protection or conservation campaigns, technical and historical status drops, contravening principles of sustainability (Tab. 5.6).

By a contrast, there is high cultural habitats (SC15) expected, as the Spa is still performing online, including bathing habitats and cultural events since Medieval. There is no presence of natural (SC13), neither historical (SC14) heritage in a meantime.

5.4.3.4 Society subcomponents

A wealth and development of society shall be given along existing opportunities on education and research, in terms of understanding the environment (nature) and past (history, culture) with empirical consequences for the future (Chichilniski, 1997). The higher is a societal performance, the less are the human needs.

Fig. 5.8 Cultural heritage: hotel Palace at its current condition

Based on historical tradition, education (SC16) opportunities are interdisciplinary, increasing their positive impact onto social wealth, whether it is geology, hydrogeology, archaeology, balneology or life-sciences.

Actually, according to its legal form, the Spa is not a research training centre (SC17). Increasing consensus on potential toluene and benzene groundwater resources contamination as originated in Vlkanová (Gálisová et al., 2012) provides opportunities on external activities.

5.4.4 Economical and technical components

Performance of a project must be identified through its economical performance and level of operation conditions. After Pastakia & Jensen (1998), the higher is the performance, the less environment is needed to reach a

Tab. 5.6 Rapid impact assessment matrix for social-cultural (SC) components

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
SC1	Public services	4	2	4	1	4	3	8	12	96	C
SC2	Public acceptability	3	-2	3	3	2	3	-6	11	-66	-C
SC3	Public adaptability	3	-1	3	3	2	3	-3	11	-33	-B
SC4	Public safety	3	3	4	4	3	3	9	14	126	D
SC5	Public health	4	2	4	3	3	3	8	13	104	C
SC6	Region promotion	4	1	4	3	3	4	4	14	56	C
SC7	Local migration	1	3	3	4	3	2	3	12	36	B
SC8	Recreation	1	2	3	3	3	2	2	11	22	A
SC9	Therapeutics	4	3	4	4	4	4	12	16	192	D
SC10	Tourism	3	3	4	4	4	2	9	14	126	D
SC11	Climatic adaptability	3	2	3	4	2	2	6	11	66	C
SC12	Cultural heritage	4	-2	3	3	4	3	-8	13	-104	-C
SC13	Natural heritage	0	0	1	1	1	1	0	4	0	N
SC14	Historical heritage	0	0	1	1	1	1	0	4	0	N
SC15	Cultural habitats	2	3	4	4	4	2	6	14	84	C
SC16	Education	1	3	4	4	3	2	3	13	39	B
SC17	Research and science	0	0	1	1	1	1	0	4	0	N
SC18	Archaeology	0	0	1	1	1	1	0	4	0	N

sustainable (well-shaped) level. At such situation, good project economics and technical condition decreases human needs, reducing pressure on the natural resources by consumption. In other words, similar to previous components, economic and technical wealth is inverse to the human needs.

5.4.4.1 Site maintenance subcomponents

Here an accent is put towards external interaction with environment, giving a prioritz to a level of resource (energy, environment) consumption and efficiency of its operation (i.e. primary energy efficiency) compared to initial or expected capital and level.

With a backnote on actual condition of bathhouses, there is no thermal insulation applied to buildings causing intense energy losses during a winter season (EO3), decreasing efficiencies in primary energy supply and consumption, and eliminates an effect of project lifetime by not preserving a technical condition of these (EO2). It is a site paradox that operation of 2 buildings only drops costs (EO4) down by less energy emissions. Yet the project is restrictive to third parties by setting protective and specific provision zones on natural resources (groundwater, woods, initial country land), causing negative (Tab. 5.7) conflicts of interests (EO1).

5.4.4.2 Site operation subcomponents

A current level of a site is most pronounced as a site operation performance, for which a focus is paid for comparison between ideal or primary technical status of objects and effectivity in use and occupation of environment to the current or actual situation.

In fact, current technical condition of bathhouses (EO7) is an essential problem of the Spa, serving in accommodation at only two out of nine buildings: the Palace and the Kúpeľný dom. The houses shut down suffer some level of degradation (Fig. 5.9), with substantial damage on status of equipment (EO8). Abandonment of the Hron, Starý Partizán, Poľana and Amália houses significantly reduces the built-up area efficiency (EO9).

Negative intervention of a problem objects is, however, fairly reduced by low traffic and transport in the area (EO5) and generally sufficient conditions of infrastructure (EO6), limiting a need for onward intervention into primary land and nature (Tab. 5.7).

5.4.4.3 Macroeconomics subcomponents

According to a sustainable development, each environment consumption shall provide a relative wealth to the publics. A way in use of resources shall not then reach a level of break, at which a nature could not balance needs resulted from a poor public status, consequent to ineffective resource management.

Fig. 5.9 Current state of the Slovensko hotel/bathhouse

Tab 5.7 Rapid impact assessment matrix for economical-operation (EO) components

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
EO1	Conflicts of interests	1	-1	4	3	3	2	-1	12	-22	-A
EO2	Project lifetime	2	-1	3	3	2	2	-2	10	-20	-A
EO3	Energy losses	1	-1	3	3	3	4	-1	13	-13	-A
EO4	Operation costs	4	1	4	3	4	3	5	14	56	C
EO5	Traffic and transport	3	3	4	4	3	4	9	15	135	D
EO6	Infrastructure built-up	2	3	3	4	3	3	6	13	78	C
EO7	Tech. condition-buildings	3	-3	3	3	4	3	-9	13	-117	-D
EO8	Tech. condition-equipment	3	-2	3	3	4	3	-6	13	-78	-C
EO9	Built-up area efficiency	3	-2	4	4	3	3	-6	14	-84	-C
EO10	Health costs	4	2	4	4	4	2	8	14	112	D
EO11	Employment	3	2	3	3	4	3	6	13	78	C
EO12	State donation	0	0	1	1	1	1	0	4	0	N
EO13	International donation	0	0	1	1	1	1	0	4	0	N
EO14	Economic self-sufficiency	4	-1	2	3	4	3	-4	12	-48	-B
EO15	Local pricing	1	-1	3	3	3	3	-1	12	-12	-A
EO16	Housing quality	0	0	1	1	1	1	0	4	0	N
EO17	Property value impact	2	2	4	3	4	3	4	14	56	C

Therapeutic activities and promotion of a public health (Tab. 5.6) systematically reduce primary health costs (EO10), including contribution of good environmental (Tab. 5.4) and ecological (Tab. 5.5) project performance (Tab. 5.7). As far as the Spa exists, there is a potential for work opportunities creation (EO11) increasing social and economic wealth of local publics.

Hence the Spa is actually privately owned, there is no option to apply for neither international (EO13) nor domestic (EO12) financial support, thus those aspects are not applicable, therefore they are eliminated for the RIAM (Tab. 5.7).

5.4.4.3 Microeconomics

Microeconomics considers local region and economic interaction of a project with publics and environment, defining local wealth status.

Because of a worsening driven reduction in visitors and accommodation capacity of the Spa economic self-sufficiency (EO14) declines continuously, turning local pricing (EO15) higher over possible level, as spas attempt to balance a drop in income. Existence of the Spa itself in combination with fairly well status of local environment keeps profitable value of estates (EO17). A potential is to increase a property value with revitalizing the abandoned bathhouses. We could not identify any impact on a housing quality around (EO16).

5.5 Sustainability model

Together 69 aspects clustered into four groups were identified according to their potential to pose an impact on human – environment interaction and human needs (Tab. 5.4 to 5.7; Fig. 5.10). To account only those performing a least, 16 aspects had must been eliminated as irrelevant or inapplicable.

5.5.1 Level of sustainability

Given by (Eq. 5.4) a project may be considered sustainable if score of environment (E) is higher than a score of human needs (H_{NI}) thus $E > H_{NI}$ yielding $S = S_E > 0$ (Phillips, 2010b). The concept in its essence displays positive or negative interaction of humans with environment and its environmental efficiency of resource consumption. Thus, any development (increase of human needs) shall conserve at least a half of resources available (environment) not recording a limitation to the recent wealth ($\sum X_{act} / X_{max} > 0.5$).

5.5.1.1 The Environment (E)

According to a sustainable science, the environment is defined as a sum of PC and BE components. Its size is than actual performance of its aspects over its total capacity (Eq. 5.5).

The size of the environment is $E_{act} = \sum PC_{act} + \sum BE_{act}$. The actual PC is a sum of partial scores (Tab. 5.4) after eliminating those of ES = 0, modified to $ES = ES_{act} + 194$ (Phillips, 2010a). This gives an actual size of PC at $\sum PC = 3,561$. The same procedure has been applied to define a size of biological-ecological components, yielding a score of $\sum BE = 2,529$. If total capacity is given by (Eq. 5.9), the maximum capacity of the physical-chemical component counts $PC_{max} = 5376$ and $BE_{max} = 4,224$ respectively, including 14 PC and 11 BE aspects. The size (Eq. 5.5) of the environment is then a dimensionless value of E = 0.63.

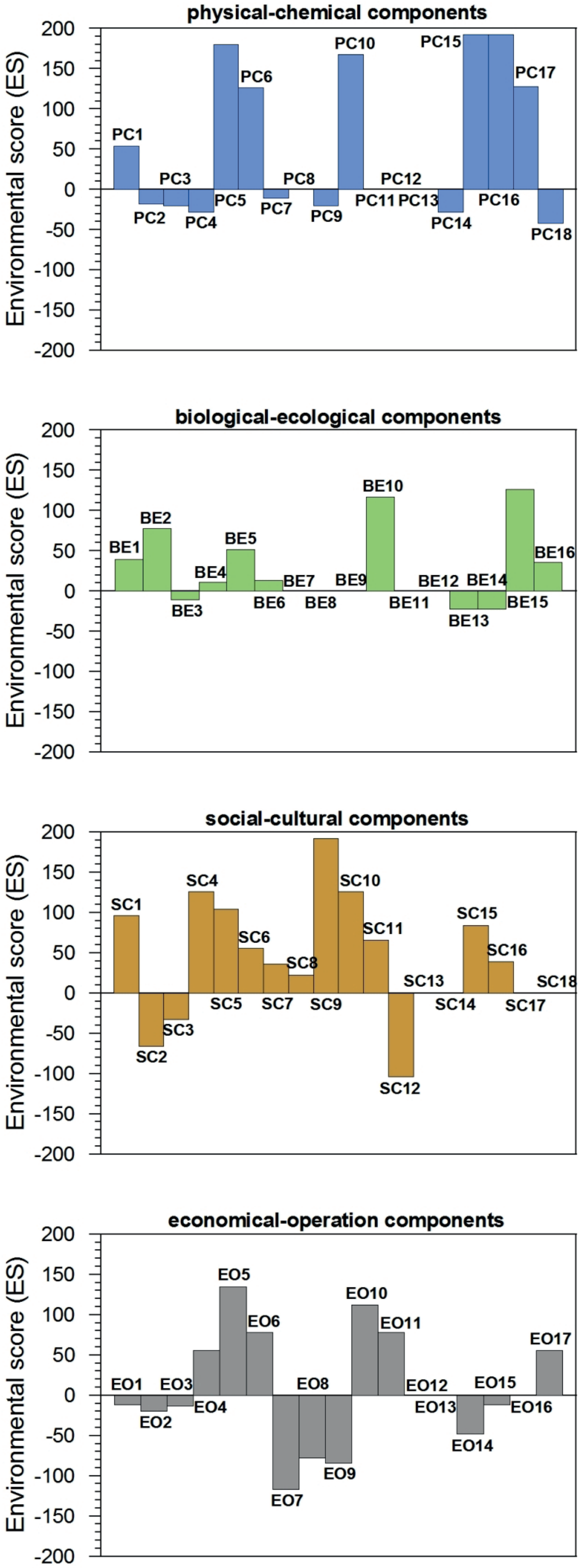

Fig. 5.10 Summary on environmental scores of selected aspects per clustered components

5.5.1.2 The Human needs (H_{NI})

The Human needs represent all actions and interventions of a society towards environment in attempt to provide or sustain a high level of wealth. The higher is the status of actual human performance, the more efficient is the consumption of resources, and, thus, the less environment is limited for the future hence the needs recalled minimize.

Human needs (Eq. 5.6) represent then a pressure on the environment, resultant from insufficient wealth of the publics.

Analogous substitution of relative environmental scores (Tabs. 5.6 to 5.7) after elimination of those of irrelevancy, the actual societal-cultural status accounts $\sum SC = 3{,}432$ and economical status $\sum EO = 2{,}819$, compared to a similar capacity, $EO_{max} = SC_{max} = 5{,}376$. Then, by (Eq. 5.6), the final human needs account $H_{NI} = 0.42$.

5.5.1.3 Environmental sustainability level

Two quantities describe actual performance of the project towards human needs and environment. The $E = 0.63$ and the $H_{NI} = 0.42$. According to a model of sustainable development (Eq. 5.4), the $E > H_{NI}$ and, thus $S_E = E – H_{NI} = 0.63 – 0.42 = 0.21$.

Following a scheme of (Phillips, 2010a), the recent interaction of the Spa with the environment, and, thus, human needs reflected by existence and impact of the Spa, may be considered as sustainable, even at very weak sustainability level.

When Tabs. 5.4 and 5.5 are grouped with Fig. 5.10, there is only 12 % probability of high environmental score, i.e. $ES > 299$ that would imply a „major positive impact“ by (Phillips, 2010b). Meanwhile, by the probability distribution constructed from modified ES scores per PC and BE components, there is only 56 % chance of positive impact only. The low score is given by combination of several aspects:

- moderate performance of PC components, as $\sum PC/PC_{max} = 0.66$, given by half of aspects yielding a negative impact onto environment (Tab. 5.4);
- weak performance of BE components, as $\sum BE / BE_{max} = 0.59$, where the most of a performance is held by low areal importance and weak positive impact (Tab. 5.5);
- combination of limited areal importance in social-economic components, where $\sum SC / SC_{max} = 0.64$;
- weak economical performance of the project, hence $\sum EO / EO_{max} = 0.52$. The higher would the $\sum EO$ be, the less H_{NI} will yield better sustainability results.

Disproportions between calculated score and general expectations settle a need to apply for study of a nature of development, providing more detailed hint onto.

5.5.1.4 Ecological sustainability level

A model of ecological sustainability of the site (project) applies when at least three components of the ecological sphere are present (Phillips, 2010a). The environment is a function of physical-chemical and biological-ecological components, thus $E = \sum PC + \sum BE$. Yet both clusters have their own capacity in terms of hydrosphere, atmosphere, lithosphere and biosphere, with their maxima, determining a particular capacity per each (Eq. 5.7).

Reading Tab. 5.4 and Tab. 5.5, the overall size of ecological system is $EB = \sum H + \sum B + \sum A + \sum L = 6{,}090$ at a performance of $E_{EB} = 0.75$. Then, $E_{EB} > E$. After substitution into (Eq. 5.7) and conserving a same level of human needs at $H_{NI} = 0.42$, it is clear that $E_{EB} > H_{NI}$ and thus $S_{EB} = E_{EB} – H_{NI} = 0.33$. Hence $S_{EB} > 0$, the project of the Sliač Spa is ecologically sustainable, however, at a weak level according to a classification by (Phillips, 2010a).

5.5.2 Nature of sustainability

Whether it is an ecological (S_{EB}) or environmental (S_E) sustainability, it is always a function of positive capacity of the environment or component, compared to negative impact of human needs, as a difference between a capacity and actual SC or EO status. It is, especially for a case where $S_{EB} \approx S_E$ is not valid, useful to map partial sustainability performance of key components or aspects.

To help imaging what the environmental performance or consumption of environment is, we plotted polar charts (Fig. 5.11) for each of component group. At each, a radius determines environmental performance (ES/384) for every aspect ranging 0 – 100 %. The red line is a boundary between positive and negative impact regions. For PC and BE components, the more is the circle filled, the higher is the environmental performance of a project to the environment, and, thus, the higher capacity is still available in the environment. At charts for SC and EO, the more is the fill, the less is the human needs count, as the better societal wealth status is already reached, limiting needs in essence. Thus, the deeper below a red line region the SC and EO are, the higher are human needs.

Aspects per each of components are clustered into groups (Tab. 5.2) representing net parts of the natural and human environment. If the $\sum X/X_{max}$ is the performance of PC and BE aspects or wealth status of humans (SC, EO), then a net performance of physical-chemical components of environment (0.66) is the highest amongst, followed by a social-cultural wealth related to existence and activity of the Spa (0.64). The lowest is the economical performance 0.52 (Fig. 5.12), approaching almost negative score (Tab. 5.8).

According to (Eq. 5.8), particular sustainability may be considered per each of component or a group. Similarly to previous, PC component is of highest environmental sustainability level; $S_{E-PC} = 0.24$ (Tab. 5.8). It means, that there is a most of capacity in the PC components available to vary with some development of the Spa, preserving sustainable behaviour. Indeed, highest scores are calculated for quality and quantity of the resource ($S_{E-PC} = 0.32$), and ecology ($S_{E-BEC} = 0.34$). In a contrast, cultural and operational subcomponents yield lowest scores ($S_{E-X} \leq 0.05$).

A microanalysis on a nature of sustainability executed on ecological subsystems shows that the hydrosphere performs as of highest ecological sustainability $S_{EB-H} = 0.38$. Biota and lithosphere, both at a level of 0.14 suffer from groundwater disposal and land management.

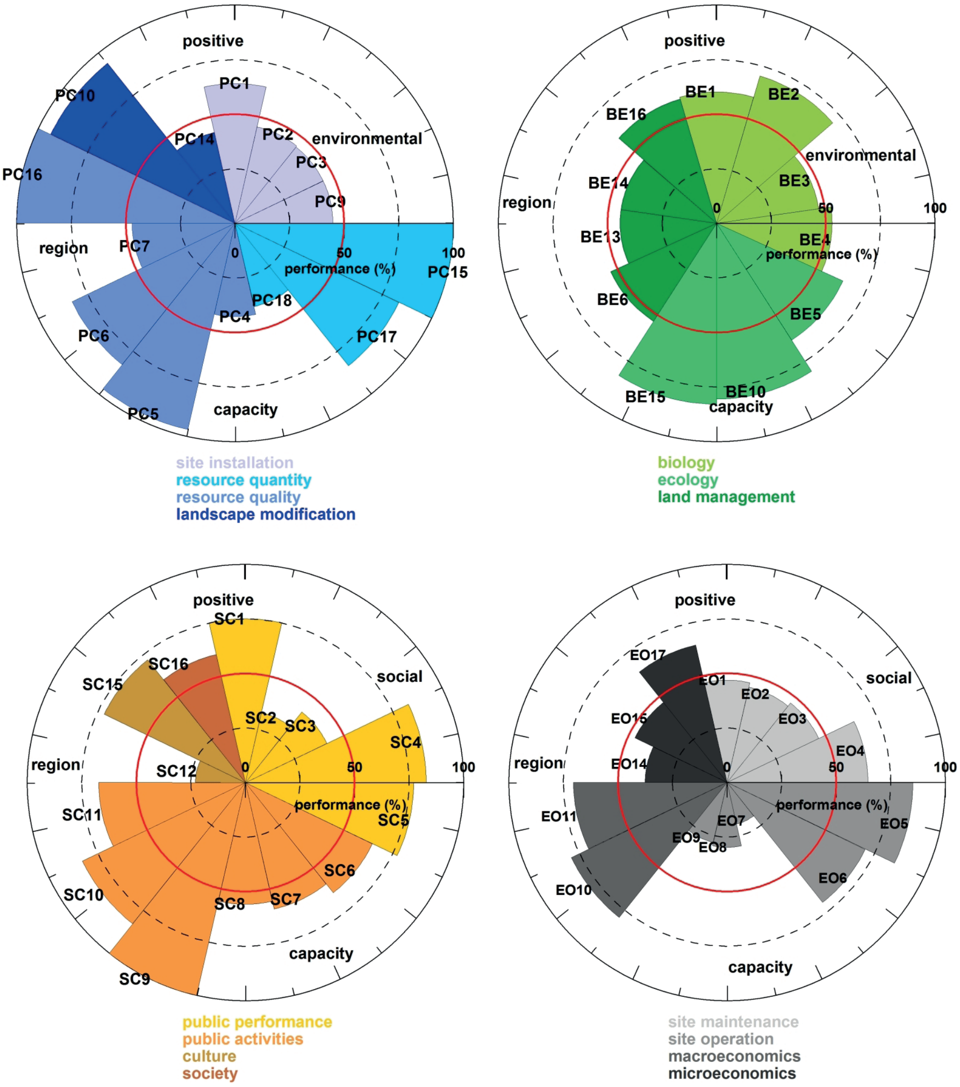

Fig. 5.11 Environmental and social capacity comparison for sustainable development components at the Sliač Spa. See Tabs. 5.4 – 5.7 for acronyms

Tab. 5.8 Environmental and social capacity comparison for sustainable development components at the Sliač Spa

Subcomponent	Code	S_E	S_E level
PC total	PC	0.24	very weak
Site installation	PCA	0.08	very weak
Resource quantity	PCB	0.32	weak
Resource quality	PCC	0.32	weak
Landscape issues	PCD	0.26	weak
BE total	BE	0.18	very weak
Biology	BEA	0.16	very weak
Ecology	BEB	0.34	weak
Land management	BEC	0.08	very weak
SC total	SC	0.22	very weak
Public performance	SCA	0.2	very weak
Public activities	SCB	0.3	weak
Society	SCC	0.05	very weak
Culture	SCD	0.18	very weak
EO total	EO	0.1	very weak
Site maintenance	EOA	0.09	very weak
Site operation	EOB	0.04	very weak
Macroeconomics	EOC	0.33	weak
Microeconomics	EOD	0.08	very weak

5.6 Discussion

The Rapid Impact Assessment Matrix (RIAM) and sustainable development model, either on environmental S_E or ecological scale S_{EB}, are executed at a site of the Sliač Spa.

According to results, the $S_{EB} > S_E$, hence the $S_{EB} = 0.33$ and $S_E = 0.21$, define weak and very weak level of sustainability respectively. A level of sustainability and performance of the Spa (as a complex) with the environment is, in fact, unusual, hence the Spa and its close region come under specific provision on land use, management or public activities; and fall within a protective zone for mineral, medical or thermal springs (groundwater resources).

Reading Tabs. 5.4 to 5.7, there is relatively close score on areal impact of evaluated aspects, with sum of 31 for positive and 22 for negative performance. Negative impact controls an areal and its close vicinity, whilst there is a general positive performance to the regional and national interests of the Spa (Fig. 5.13).

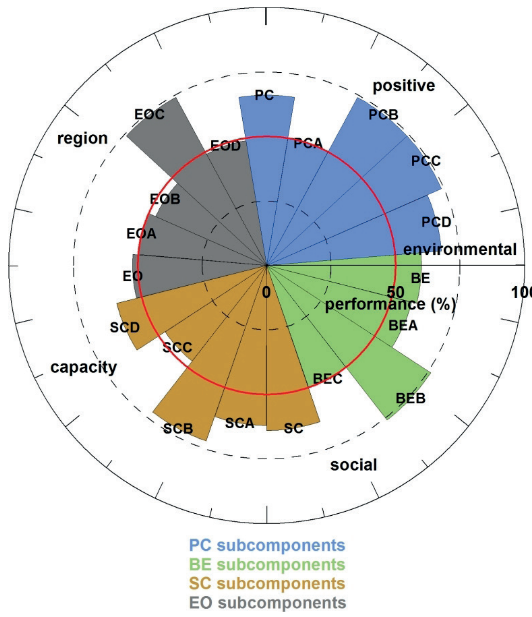

Fig. 5.12 Environmental performance for environmental and human needs subcomponents. See Tab. 5.8 for acronyms

Hence generally sustainable development yielded, the rate of impact is definitely higher for positive aspects (+75) compared to those evaluated as negative (-29). Even importance controls the environmental score in major (Fig. 5.13), there is definitely some impact of performance variations in commutativity and susceptibility of the environment to the impact.

5.6.1 Impact analysis

Two principal components control the overall performance of the Sliač Spa: resource quality/resource quantity and current technical condition of bathhouses. These are, however, not performing separately. To analyze real impact on total performance, we constructed alternative hierarchy chart to identify commutativity of the aspect with other components, keeping original aspects according to Tabs 5.4 – 5.7.

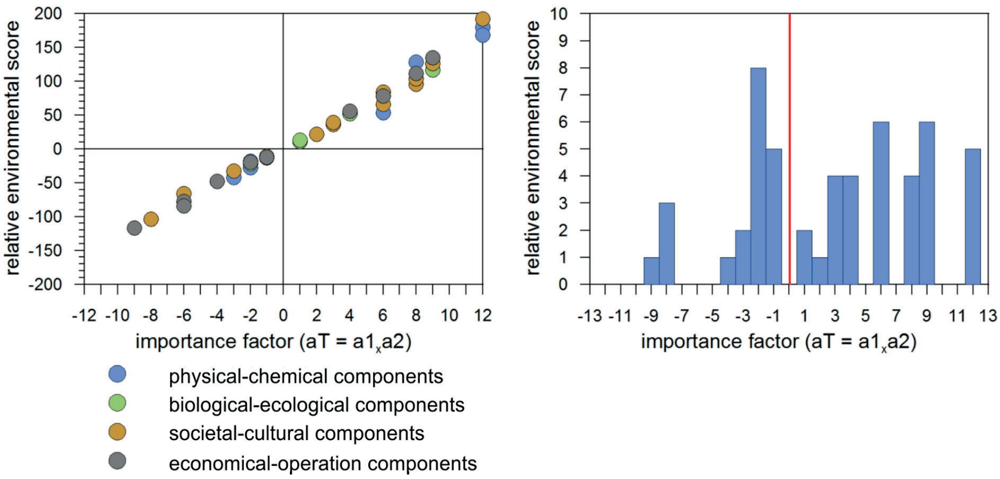

Fig. 5.13 Environmental score (left) and importance factor (right) analysis

5.6.1.1 Resource sensitivity (negative scenario)

Yield allowances control production of mineral waters. Recently, the amount of groundwater abstraction approaches towards 75 % of the given capacity (see 5.4.1.2). Let us consider a situation the amount of produced groundwater exceeds allowance level over 25 %. Even if the mineral water structure is open, overexploitation may turn springs to cease. If deliverability drops, a project lifetime may not be prolonged too much. Investments into pumping drive then health costs high.

The resource is sensitive to changes in chemistry, controlled by effective filtration velocity, groundwater-rock interaction duration, temperature, etc. Given a fact that the structure is operated in depletive manner (pessimistic assumption) the quality may drop on a recordable scale. At such, chemistry may vary, restraining positive medical effects on a public, affecting acceptability, services and therapeutics on secondary. Hence the resource is disposed into a near channel; increased yields come with destructive effect on aquatic biota.

Depletion scenario, as simulated by changing performance evaluation (Tab. 5.9) would had have devastating impact on PC components at performance ($\sum PC/PC_{max}$ = 0.37) and sustainability decline (S_{E-PC} = -0.17). Limitation of groundwater use results in multiple drawns in social ($\sum SC/SC_{max}$ = 0.46;

Tab. 5.9 Component performance variation setup: resource sensitivity

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
PC5	groundwater quality	4	-2	4	3	4	4	-8	15	-120	-D
PC4	surface water quality	2	-3	4	2	3	3	-6	12	-72	-C
PC10	springs manifestations	4	-2	4	3	4	4	-8	15	-120	-D
PC15	deliverability	4	-3	4	3	4	4	-12	15	-180	-D
PC16	geochemical stability	4	-2	4	4	4	4	-8	16	-128	-D
PC17	production stability	4	-2	4	3	4	4	-8	15	-120	-D
BE3	aquatic fauna	1	-2	4	2	3	2	-2	11	-22	A
SC1	public services	4	-2	4	2	4	4	-8	14	-112	-D
SC2	public acceptability	3	-2	4	3	3	3	-6	13	-78	-C
SC5	public health	4	1	4	2	4	3	4	13	52	B
SC6	region promotion	4	-2	4	3	4	4	-8	15	-120	-D
SC8	recreation	1	-1	3	3	4	2	-1	12	-12	-A
SC9	therapeutics	4	-2	4	4	4	4	-8	16	-128	-D
SC11	climatic adaptability	3	-1	4	3	4	2	-3	13	-39	-B
EO2	project lifetime	2	-2	4	4	4	2	-4	14	-56	-C
EO10	health costs	4	1	4	2	4	2	4	12	48	B
EO11	employment	3	-2	4	3	4	3	-6	14	-84	-C
EO14	economic self-sufficiency	4	-1	2	3	4	3	-4	12	-48	-B
EO15	local pricing	1	-3	3	3	3	3	-3	12	-36	-B

S_{E-SC} = -0.08) and EO aspects (∑EO/EO_{max} = 0.47; S_{E-EO} = -0.06), as decline in public wealth causes human needs to increase, H_{NI} = 0.47.

At current situation, only biological-ecological components preserve environmental performance (∑BE/BE_{max} = 0.6) with drop in chemistry of groundwater by depletive reservoir management. This is because the only interaction occurs along groundwater disposal, negative in impact either now. Drop in environmental sustainability of BE components (S_{E-PC} = 0.06) compared to actual situation responses to an increase in human needs.

Potential combination of decline in environmental performance predicted for almost each of components and sustainable interaction of the Spa with them may result in $S_E < H_{NI}$ thus $S_E < 0$, or $S_E = E – H_{NI} = -0.07$, describing unsustainable project operation and development.

5.6.1.2 Publics and societal sensitivity (positive scenario)

In above, we set a notion on high H_{NI} (5.5.1-5.5.2). A reason is (Tabs. 5.4 to 5.7) in, say, alarming condition of 7 abandoned bathhouses (3 of which are declared cultural heritage) posing a substantial risk on soil quality, limiting public acceptability or services and adaptability, increasing energy losses and negatively affecting built-up area efficiency. In study on sensitivity of such a project, let us consider a case where investments are put to reconstruct resort objects. Besides positive effects on social needs and regional promotion, creation of tourist opportunities or benefits on preservation of cultural heritage, the action may reduce energy losses, and drive up the efficiency of occupied area usage. However, increasing the number of visitors and active objects comes with increase in noise and light pollution, temporary traffic and transport, and will, as expected, increase not only a property value, but local pricings as well as a consequence of reaching a payback soon (Tab. 5.10).

Managing artificial objects has a straight (positive) impact on public and social wealth. Consequently, initial human needs H_{NI} = 0.42 decrease to 0.36. It is a paradox that reconstruction of buildings plays a negative effect on PC components of the environment, somewhat compensated by reducing negative impact on soil quality and landscape issues. BE performance remains, perhaps, at an initial level, however, sustainability in use of BE part of environment increases S_{E-BE} = 0.24 as H_{NI} declines. Preservation of PC and increase in S_{E-BE} may then be understood as a consumption of environment necessary to satisfy wealth creation. Meanwhile, reconstruction plays positive impact not only on reduction of human needs, but increases a social and economic performance of the Spa in general (Tab. 5.10).

Combination of all, performance and H_{NI} reduction effects of increase in condition of residential objects results in increase in environmental, ES = 0.28, and ecological sustainability E_{EB} = 0.44. Thus, after reconstruction, the sustainability level shall increase to weak, creating more confidence into the development in case of uncertainties accounting.

5.6.2 Limitations

Together 69 aspects related to current situation and interaction between the Sliač Spa, environment and public were identified and evaluated subjectively. Still, the environment is a dynamic system. It is a must then to take obtained scores as an actual fingerprint, variable at various intensities, as mostly SC and EO components are the most instable. Even under a best endeavour to create an evaluation background as objective as possible, construction of a finite matrix criteria for spas shall become mandatory in

Tab. 5.10 Component performance variation setup: publics and societal sensitivity

Code	Description	a1	a2	b1	b2	b3	b4	aT	bT	ES	ES
PC3	noise	2	-2	4	4	3	2	-4	13	-52	-B
PC7	soil quality	1	1	3	2	3	2	1	10	10	A
PC9	light pollution	2	-1	4	4	3	2	-2	13	-26	-A
PC14	landscape modification	2	1	4	2	2	4	2	12	24	A
SC1	public services	4	2	4	2	4	3	8	13	104	D
SC2	public acceptability	3	1	3	2	2	3	3	10	30	A
SC3	public adaptability	3	2	3	2	2	3	6	10	60	C
SC6	region promotion	4	2	4	2	4	4	8	14	112	D
SC12	cultural heritage	4	2	4	2	4	3	8	13	104	D
EO2	project lifetime	2	1	3	2	3	2	2	10	20	A
EO3	energy losses	1	2	3	3	4	4	2	14	28	A
EO5	traffic and transport	3	-1	2	2	4	4	-3	12	-36	-B
EO6	infrastructure buildup	2	2	3	3	3	3	4	12	48	B
EO7	tech.condition-buildings	3	2	3	3	4	3	6	13	78	C
EO8	tech.condition-equipment	3	1	3	3	4	3	3	13	39	A
EO14	economic self-sufficiency	4	1	3	2	4	3	4	12	48	B
EO15	local pricing	1	-2	4	3	4	3	-2	14	-28	-A
EO17	property value impact	2	-2	4	3	4	3	-4	14	-56	-B

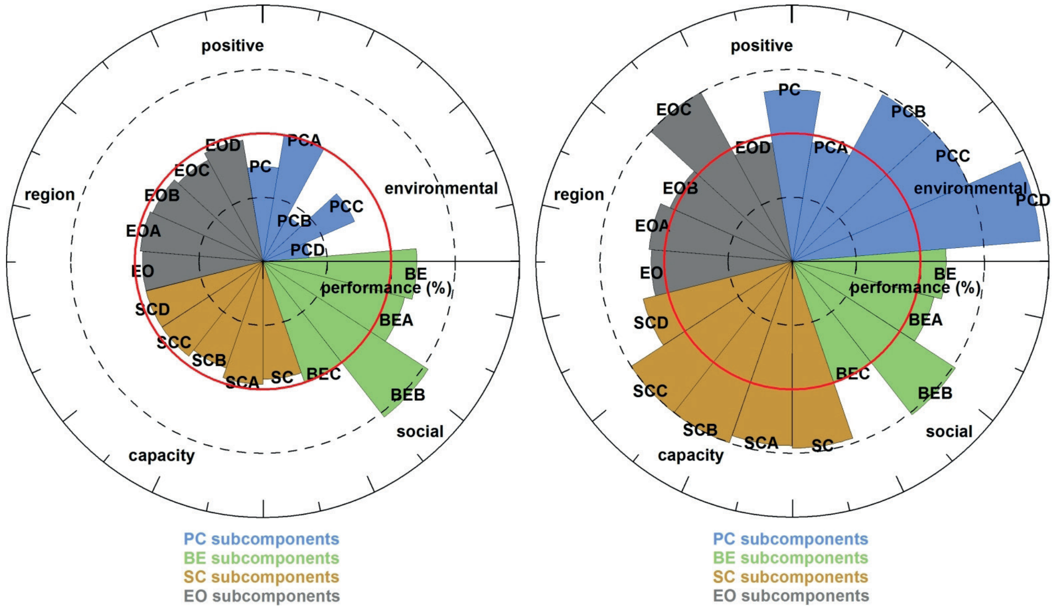

Fig. 5.14 Sensitivity analysis for positive and negative scenarios

Fig. 5.15 Kúpeľný prameň spring – production installation.

such a case, providing comparative background between case studies on not only a national but international scale.

5.7 Conclusions

The Directive of the Ministry of Health of the Slovak Republic No. 89/2000 Coll. On Healing springs and natural resources of mineral table waters declared mineral waters of the Sliač Spa as healing springs. Later, an Action No. 10389-44/2009 by Inspectorate of Spas and Springs set allowances on a use of the Kúpeľný prameň spring to 5 l . s^{-1}. Delineation of protective zones of the Ist and IInd order (Bondarenková et al., 1986) for mineral waters was modified to reflect a current need for protection of the environment (Masiar, 2004). Allowances on production of the Kúpeľný prameň spring are limited to 4.85 l . s^{-1}. Total allowances for mineral groundwater at the Sliač area reach 5.011 l . s^{-1} (Dzúrik, 2012).

The Rapid Impact Assessment Matrix (Pastakia, 1998; Ijäs et al., 2008) and sustainable development model (Phillips, 2010a) have been constructed for the Sliač Spa. At selection phase of the procedure, 69 aspects of environmental and social interaction of the project with a nature and society were identified, playing a positive to negative impact on environment. The environment E (Eq. 5.5) represents a capacity of a nature to provide resources for development (PC + BE), with a critical limit of E = 0.5, meaning that "consumption" of resources in a present conserves the same amount for a future.

At current situation, the E = 0.65. For social-economic aspects (SC, EO), the higher is the wealth status, the less are the human needs (Eq. 5.6), actually yielding a score of 0.42. Then, an environmental sustainability equals $S_E = E - H_{NI} = 0.65\text{-}0.42 = 0.23$, defining actually a project sustainable at a very weak level. To compare, ecological sustainability S_{EB} (Eq. 5.7) scores $S_{EB} = 0.33$. A fact that $S_{EB} > S_E$ means that biotic components of the nature are less sensitive to the potential nature "consumption" (project activity) than the rest in the environment, however the PC components record a highest capacity amongst. Current lows in sustainable development score are, most probably, a consequence of frequently weak importance of positive impacts and variable timeline performance to the environment in combination with high level of human needs given by an objection to reconstruct residential objects, synergistically affecting other social, economic and operation aspects of the Spa.

Executed sensitivity analysis for pessimistic scenario (groundwater depletion) and optimistic scenario (residential objects reconstruction) gives a strong evidence on dependency of the project rather on environment than a rate of human wealth. While groundwater depletion affects BE, SC and EO components, the reconstruction plays a minor role on PC, modifying SC and EO in major only. Indeed, depletion of groundwater (use of resources at 25 % above actual allowances (thus above ≈ 7.5 l . s^{-1}) may result, after some time, in devastation of healing character and initial chemistry of groundwater on which SC and EO components are clearly dependent. Drop in environment capacity (performance) to E = 0.53 with increasing human needs (consequent to reduction of public services and local economics) to H_{NI} = 0.47 gives E < H_{NI}, so that E_S = -0.07, contravening a sustainable development. This is a drop by a magnitude of almost 1.5.

By a contrast, reconstruction of residential objects in spas may increase a general wealth, represented by decline in human needs to H_{NI} = 0.36. Meanwhile, there is a need to account on, at least temporary, negative impact on environment from increased traffic, light pollution and noise (not only during a reconstruction works but from increased number of residents and online residential objects), somewhat balanced by reduction of potential degradation of soil quality and negative land use efficiency. Thus, the performance of the environment may approach E = 0.64. Consequently, E > H_{NI} , yielding S_E = 0.28 (increase by 33 %) and S_{EB} = 0.43 (30 % increase).

Interaction of the Spa with environment is, at least to some extension, limited along specific provisions (restricted land use, public activities, resource mining, etc.) and delineation of protective zones (yield allowances, groundwater chemistry preservation etc.). Conflicts of interests and reduction of third-parties' access to groundwater resources in the area is definitely balanced by positive impact of the Spa on environment and society.

There is a growing pressure on implementation of principles of sustainable development into all spheres of human interaction with the environment. By definition of the sustainable development (e.g. Chichilniski, 1997; Schellnhuber, 1998; Nel-Cooper, 2009; Phillips, 2010a), defining sustainability in use of natural resources cannot avoid analysis of human actions and impacts on environment. An example for the Sliač Spa shows that limitation of sustainability studies on resource deliverability (in this case a groundwater production), which is a well-established praxis, is simply not enough, and there must be a complex picture, accounting on all aspects of repeatedly accented human – nature interaction.

With no doubt left, existence of the Sliač Spa contributes to sustainability and sustainable development on, at least local to regional scale. Restrictions in resource accessibility are evidently balanced by positive impact on a nature and wealth. Good environmental and ecological performance ensures that the risk to the nature is locally low. Continuous studies on groundwater production allowances and periodical groundwater monitoring shall, thus, be mandatory to predict unexpected changes in status-quo, forming a base for societal wealth conservation or increase. At such conditions, strengthening of the sustainable performance is a case of investments to preservation of local residential objects and cultural heritages, and shall be an objective for the close future.

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