Sustainable Water Management in Buildings

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Contents

Abstract A significant number of building sustainability assessment methods and tools have been developed over the past two decades. Sustainability assessment of buildings means an evaluation of environmental, social and economic aspects and indicators respecting technical and functional characteristics of buildings to design and construction of sustainable buildings. There are many tools for sustainability assessment of buildings used over the world such as LEED, BREEAM, Green Globes, SBTool, CASBEE, etc. This chapter is aimed at introducing the building environmental assessment system (BEAS) which has been developed at the Technical University of Košice. The Slovak system was developed on the base of existing systems and methods used in many countries. The BEAS includes a number of environmental, social and cultural factors. The indicators were proposed according to the analysis of building performance as well as on the base of experimental experiences. The primary fields are building site and project planning, building construction, indoor environment, energy performance, water management and waste management. Water management in buildings is presented here as a critical issue for achieving the sustainable buildings. Indicators of water management are reduction and regulation of water flow in water systems with the weight of 42.3%, surface water run-off with the weight of 12.2%,

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drinking water supply with the weight of 22.7% and using filtration of grey water (GW) with the weight of 22.7%.

Keywords Building, Sustainability assessment, Water management

1 Introduction

Currently, European cities and cities around the world are concerned with sustainable development, as well as its evolution. Countries seek a way to adapt to contemporary changes, to meet the required needs and ensure the population's well-being. Considering this, the new sustainability assessment tools are being developed to be used to guide and help cities and urban areas to become more sustainable. Assessment tools such as Building Research Establishment's Environmental Assessment Method (BREEAM), Sustainable Building Tool (SBTool) and Leadership in Energy and Environmental Design (LEED) constitute the basis for the other approaches used throughout the world. These and other tools are focused on rating the buildings respecting environmental, social and economic perspectives [1]. For example, sustainability assessment tool SBTool^{PT} was developed as a version for assessing the sustainability of the built environment for conditions in Portugal. This conceptual change in mentioned sustainability assessment tool boosts its application and improves the sustainability of the built environment. It leads to guide and help designers, engineers, architects, urban planners and politicians to develop urban regeneration plans as well as to define sustainability principles or indicators allowing the comparison of different measures. The scope of this assessment system methodology is to assess the sustainability of the built environment, including projects for urban planning and urban regeneration, specifically in the Portuguese context [2]. The buildings' sustainability and evaluation models, which consider the ecological, economic and social aspects of sustainability, are solved in the study [3]. This study presents the structure of the buildings' sustainability and two evaluation models, which consider all the three aspects. The first one is a global model, where a building is scored, fulfilling some requirements. The second one is a specific model, based on a simple formula, which takes into account numerical values. These evaluation models were applied on three residential buildings of different structural solutions: concrete framed structure, ceramic masonry structure and wooden structure. Each aspect has its specific requirements that characterize a building through its life cycle and contributes, in a different amount, to the overall evaluation. By applying the global and specific model to evaluate the three buildings, similar results were obtained. According to both evaluation models, the most sustainable solution was the wooden structure, followed by the concrete framed structure and at least, the less sustainable, the ceramic masonry structure. Berardi [4] shows that building energy performance is considered as the most important criterion in sustainability rating systems and the least achieved one in sustainability assessments. In contrast, other performance ratings of the building, such as water efficiency or indoor air quality, are achieved with a high rate of success in sustainability assessments. First assessment systems considered the building as a manufactured product and evaluated it almost in isolation. However, the importance given to the surrounding site is greatly increasing. Energy requirements have also become stronger in the latest versions of other assessment systems. This can certainly be motivated by the more rigid requests of energy regulations worldwide but also by the greater attention being given to energy saving in buildings. Results of certified buildings have shown that energy performances are well below the optimal ones even in sustainable buildings. Reasons for this are often the high cost of energy-saving measures and the low preparedness of construction actors. In a study [5], an approach allowing comparisons between the embodied energy and emissions of the building materials as well as the energy consumption and GHG emissions at the use stage is introduced. The results show that embodied energy can represent more than 30% of the primary energy requirement during the life cycle of a single house of 222 m^2 with a garage for one car. This study highlights that if the house does not include a parking area, the contribution of the building materials decreases. It can be explained by increasing the heated surface percentage. Further the heating and building materials in a residential building have the significant share in energy consumption. In addition the building materials represent more than 60% of the heating consumption. Citherlet and Defaux [6] compare three variants of a family house from environmental impacts for their entire life cycle. The first variant was chosen to correspond with the standard in force in Switzerland. The second alternative was selected to meet the requirements of a quality control label for houses with low energy consumption. And finally, the third variant was selected to be a very low energy consumption building. These variants have the same architectural aspect but different insulation thicknesses and types, different energy production systems and the use of different renewable energies. The environmental impacts were determined using life cycle analysis including the impact related to the energy consumption during the occupancy stage as well as the material manufacture, transport, replacement and elimination at the end of the building lifetime. Results of this study indicate that good insulation provides a significant reduction of direct environmental impacts (energy consumption during the occupancy phase). The environmental and resource impacts of wooden single-family residences designed to meet the conventional Norwegian Building Code from 2010 and the Norwegian passive house standard NS 3700 are compared using life cycle assessment which is presented in the study [7]. Four different heating systems were evaluated for the two building designs: (1) electric (resistance heating), (2) electric and wood, (3) electric and a solar heat collector and (4) electric and an air-water heat pump system. The goal of the research was to evaluate the different ways of lowering the total environmental burden of a building's life cycle. Evaluation of impacts due to implementation of renewable heating systems in comparison to standard Norwegian systems largely based on electricity was considered. According to the life cycle analysis, the wood-framed single-family residence complying the passive house standard provides a consistent and clear reduction of cumulative energy demand of 24–38% in comparison to the conventional building standard TEK10 with electric panel heating. In combination with efficient heating systems, a passive house building envelope with a heat pump system provides almost 40% savings of compared to a conventional house with electric heating. The reduction in GHG emissions of the cleanest design compared to the standard alternative is almost 30%. Solar heated water also provides substantial environmental gains for the passive house. On the other hand, a standard building envelope with a heat pump system reduces impacts to a level comparable to that of a passive house building with only electric heating. Another study [8] demonstrates the importance of criteria and sub-criteria in developing a new potential building assessment method for Saudi Arabia. The various aspects influence the criteria and sub-criteria of assessment tools such as environment, economic, social and cultural to mention. The study provides an investigation of the most popular and globally used assessment systems, BREEAM, LEED, Green Star, CASBEE and Estidama, in order to identify the effectiveness of the different aspects of the assessment criteria and the impacts of these criteria on the assessment results. These will provide a solid foundation to develop an effective sustainable assessment method for buildings in Saudi Arabia. It can be stated that all the above-mentioned tools have common issues such as energy, water and materials for increasing the knowledge about the built environment while reducing the impacts of the construction on its users and the environment. Results suggest that it is more appropriate to develop assessment method applicable in the given country and thus achieve desired results focusing on the environmental, economic, social and cultural conditions.

2 Sustainability Assessment of Buildings

Sustainability assessment of buildings is a way on how to build high-performance green buildings. It requires the integrated design of buildings towards the reduction of resource depletion like energy, water and raw materials, prevents environmental degradation caused by facilities and infrastructure throughout their life cycle as well as creates safe and productive built environments [9]. Methods and systems for integrated evaluation of buildings are used for predesign, design, construction, operation, maintenance and end of life of buildings [10]. According to ISO 15392:2008, construction sustainability includes considering sustainable development in terms of its three primary aspects (economic, environmental and social), while meeting the requirements for technical and functional performance [11, 12]. Criteria of sustainability are included in integrated assessment methods, systems and tools for evaluating environmental, social and economic perspectives of buildings. The study [13] emphasizes that although the sustainable building is considered as multidimensional concept, it often gives an attention to the environmental indicators and ignores the substantial importance of social, economic and cultural indicators. Building sustainability involves interdependencies between natural, built and social systems and therefore comprises a complex of different priorities that require consideration at each stage of a building's life cycle. The study of Ding [14] states that the comprehensive assessment of buildings is very important in achieving sustainable development. Building environmental assessment aimed at providing a sustainable building design, construction, operation, maintenance and deconstruction thus requires cooperation between architects; structural engineers; designers of heating, ventilation and air-conditioning (HVAC) systems; environmentalists; developers; builders; and users. Sustainable buildings take into account environmental quality, functional quality, social and cultural factors, economic factors as well as future values during the entire life cycle of buildings [14]. The building construction industry consumes a lot of resources and energy, owing to current global population growth trends. Therefore the climate change became a priority issue on the agenda of the energy and environmental policy of the European Union. With regard to climate change, the energy efficiency and renewable energy are the main pillars [15]. Buildings consume approximately 40% of total global energy, during the construction phase in the form of embodied energy and during the operation phase as operating energy [16–20], and 36% of total CO_2 emissions of the EU Member States [18, 21]. In recent years worldwide commitments in reducing carbon dioxide and other greenhouse gases are recognized from the anthropogenic carbon dioxide's impact on climate change [22]. The development of assessment methods and tools is a challenge for the academic working and also practice. The primary importance is managing the flows of information and knowledge between the various experts. An important constraint to the sustainability methods is that the specific definition of "sustainable building" or "high-performance building" is complex since different actors in the building's life cycle have different interests and requirements [23]. For instance, promoters will give more attention to economic issues, whereas the end users are more interested in health and comfort issues [9]. The study [24] points out that in assessing the performance of buildings, the scope of the sustainability assessment is widening, marking an evolution from a single criterion consideration, like the social performance of buildings, towards a full integration of all aspects emerging during the lifetime of a building. Therefore we can consider the "sustainable buildings" as a broad, multi-criteria subject related to three basic interlinked aspects: environmental, economic and social. Other studies [25–27] show that modern buildings and their heating, ventilation and air-conditioning (HVAC) systems are required not only to be more energy efficient while adhering to an ever-increasing demand for better performance from comfort but equally in respect to financial and environmental issues. Many methodologies have been developed to establish the degree of accomplishment of sustainability goals, guiding the planning and design processes. In the earlier stages of the design process, planners can make decisions to improve building performance at very little cost, following the recommendations of the decision-making tool. The development of building environmental assessment is enhanced for the last 20 years worldwide. The first of such tools was in 1990, the Building Research Establishment's Environmental Assessment Method (BREEAM) [28]. After that, many methodologies have been developed and are currently widely applied such as:

- The Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan

- The Building and Environmental Performance Assessment Criteria (BEPAC) from Canada
- The Building Environmental Assessment Method (BEAM) from Hong Kong
- The Green Building Rating System (SABA) from Jordan
- The Estidama from Emirate
- The Sustainable Building Assessment Tool (SBAT) from South Africa
- Deutsche the Gesellschaft für Nachhaltiges Bauen (DGNB) from Germany
- The Leadership in Energy and Environmental Design (LEED) from the United States.

Very comprehensive inventories of available tools for environmental assessment methods can be found in Ding [14], Seo et al. [29], the Whole Building Design Guide [30] and the World Green Building Council [31]. The comprehensive study of Alyami and Rezgui [32] states that the most reliable and commonly used schemes in the global context are BREEAM, LEED, SBTool and CASBEE. These tools have been highlighted in the terminal objective of implementing the principles of sustainability. There are a growing number of environmental assessment systems and tools being developed for the building sector. BREEAM and LEED are the leading systems designed for very well-known organizations (BRE and USGBC), which have made a significant contribution to sustainable development. BREEAM had a profound impact on almost all of the environmental impact assessment methods. BREEAM was also used as a design template to many other systems around the world such as Green Star, Basix Australia, BEPAC Canada, Hong Kong [14, 33]. Studies [13, 33] state that some sustainability methods were modified, for example: BREEAM for Lithuanian recreational buildings assessment and SBTool for Portuguese exist, new and renovated residential buildings. The amount of information and tools are available to assist designers and builders in incorporating sustainable technologies and design strategies in their projects. In relation to existing tools, many reports [34] present a description of the evaluation tool characteristics used for building as a whole as well as building materials and constructions, nationally and internationally. Building environmental assessment systems focus on considering the three aspects of building sustainability: environmental issues related mainly to greenhouse gas emissions and energy consumption, economic aspects such as life cycle cost and social requirements such as accessibility and quality of spaces. The most common feature of building environmental assessment systems is that they are multi-criteria systems. Multi-criteria systems are based on the evaluation of criteria measured by parameters and compare real performances with reference ones. Each criterion has a certain number of available points over total assessment. The overall evaluation of sustainability is obtained by summing the results of assessed criteria [11].

This work presents proposal of building environmental assessment system BEAS for the condition of the Slovak Republic. Percentage weight of proposed indicators' significance is determined according to methods of multi-criteria decision analysis (MCDA). The results of the presented BEAS are validated on selected residential buildings.

3 Building Environmental Assessment System in Slovakia

Slovak building environmental assessment system (BEAS) has been developed at the Technical University of Košice on the basis of existing systems used in many countries. It includes a number of environmental, social and cultural aspects and indicators. They were proposed according to the analysis of the technical, functional, environmental, social and economic performance of buildings. After the proposal of main fields and indicators, they were weighted using the AHP method. The methodology of the derivation of the field in BEAS has been performed according to study [27]. A field list has been derived by a three-step process. To establish a comprehensive set of fields of the BEAS, a review of a combination of existing environmental assessment methods used worldwide, Slovak standards and regulations and academic research papers has been conducted. A three-step process has been carried out. The first step was collecting and reviewing the existing building environmental assessment methods and tools. Sufficient information and tools are available to assist designers and builders in incorporating sustainable technologies and design strategies in their projects. In relation to existing tools, many reports [21, 28] present a description of the characteristics of a number of evaluation tools which are used for building and materials, nationally and internationally. The second step was based on a selection of a field list based on the in-depth analysis. Final main assessment fields in BEAS are the following: (A) site selection and project planning, (B) building construction, (C) indoor environment, (D) energy performance, (E) water management and (F) waste management. As a result, a final list of fields has been proposed. The multi-criteria framework incorporates the consideration of environmental and social issues in the development of BEAS. To ensure that the proposed indicators are applicable, it is necessary to validate and revise them through relevant reviews and consultation with experts and stakeholders. This series of verification processes is repeated until a refined set of indicators is obtained and sufficient to measure the sustainability performance of buildings [29].

A final list of proposed indicators for building environmental assessment system for conditions of Slovak Republic is as follows:

- *A – Site Selection and Project Planning*

  A1 Site selection: Use of land with previously high ecological sensitivity or value, land vulnerable to flooding, land close to water endangered contamination, distance to commercial and cultural facilities, distance to public green space and distance to road-traffic infrastructure

  A2 Site development: Development of density, possibility of change of building purpose, impact of the design on existing streetscapes, compatibility of urban design with local cultural values, policies governing use of private vehicles, guarantee of sufficient public green space and provision of trees with shading potential

- *B – Building Construction*

B1 Materials: Degree of reuse of suitable existing structures where available, use of materials that are locally produced, material efficiency of structural and building envelope components, radioactivity of building materials, ease of disassembly, reuse or recycling

B2 LCA: Primary energy embodied in building materials, GWP and AP

- *C – Indoor Environment*

C1 Thermal comfort
C2 Humidity
C3 Acoustic
C4 Daylighting
C5 Total volatile organic compounds (TVOC)
C6 Indoor air quality
C7 Radon
C8 Nitrogen oxides (NOx)
C9 Particulate matters for fraction of 10 micrometres (PM10)
C10 Microbe

- *D – Energy Performance*

D1 Operational energy: Energy consumption for heating, energy consumption for domestic hot water, energy consumption for mechanical ventilation, energy consumption for cooling, energy consumption for lighting and energy consumption for appliances

D2 Active systems using renewable energy sources: Solar system, heat pump, photovoltaic technology and heat recuperation

D3 Energy management: Energy management system, operation and maintenance, degree of local control of lighting systems and degree of personal control of technical systems by occupants

- *E – Water Management*

E1 Reduction and regulation of water flow
E2 Surface water run-off
E3 Drinking water supply
E4 Using filtration of grey water

- *F – Waste Management*

F1 Measures to minimize waste resulting from building operation
F2 Measures to minimize emission resulting from building construction, operations and demolition
F3 Risk of hazardous waste resulting from facility operations

In step 3, a questionnaire survey has been conducted to get the suggestions from the group of participating experts to refine the draft fields. A questionnaire survey aimed at weighing the final fields in BEAS. The task of experts was the determination of significance intensity of main fields according to nine-point scale of relative importance [30]. For the determination of criterion significance, weighting the median absolute deviation (MAD) method was used. MAD is a well-known statistical method that is mostly used in the problem of decision between many independent opinions. According to Lee et al. [31], credit-weighting is the heart of all assessment schemes. It can be said that this way dominates the overall performance score of the assessed building. This system has 52 indicators in six main fields. Each field has several indicators which have the intent of assessment and the scale of assessment. This scale is from negative (−1 point), acceptable practice (0 points), good practice (3 points) and best practice (5 points). The result of each indicator is obtained by multiplying the point with a weight of indicator.

4 Water Management

Sustainable water management can contribute to the preservation and protection of wetlands because it maintains high water quality and quantity conditions, fulfils the present and future water demands and minimizes potential environmental impacts. Applications of water management plans in Europe have a history of approximately 50 years, and this has played a significant role in the improved water conditions encountered in most European countries nowadays [35]. The study [36] mentions that controlling the environmental problems with technical solutions is considered to be the strong engineering tradition in water resource management. The management of risks relied on the ability to predict extremes and limit their impact with technical means such as dikes, dams and reservoirs [36]. Grey water (GW) is the water collected separately from sewage flow that originates from clothe washers, bathtubs, showers and sinks but does not include wastewater from kitchen sinks, dishwashers or toilets. Dish, shower, sink and laundry water comprise 40–50% of residential wastewater. GW is used in groundwater recharge, landscaping and plant growth [37].

Reducing building water consumption and rethinking the wastewater strategy employed for the built environment can dramatically extend the available supply of water, improve human health and reduce threats to ecological systems. In addition to these benefits, the Rocky Mountain Institute (RMI) suggests that water efficiency can have these other tangible and calculable benefits [38]:

- Energy savings
- Reduced wastewater production
- Lower facility service investments
- Industrial processes
- Higher worker productivity
- Reduced financial risk
- Environmental benefits
- Public relations value

The water management field aimed at reducing drinking water consumption, reusing grey water for irrigation or flushing toilets, preserving site watersheds and groundwater aquifers and reducing off-site treatment of wastewater. It is known that two of the more significant problems of the modern society are the water shortage and the degradation of the environment [39]. The increasing demand for sustainable development has a serious impact on urban infrastructures. Even today, there is a lack of knowledge of how sustainable development should be achieved. Next we often do not know how sustainability of various technical systems should be assessed. So a set of sustainability criteria covering health and hygiene, social and cultural aspects, environmental aspects, economy and technical considerations are defined. To promote the practical use of a set of sustainability criteria, it must be related to quantifiable indicators that are easily measured [40].

Water management in Slovak system BEAS has a percentage weight of 8.88%. Water management field includes four indicators: reduction and regulation of water flow in water systems with the weight of 42.3%, surface water run-off with the weight of 12.2%, drinking water supply with the weight of 22.7% and an indicator that addresses using filtration of grey water with the weight of 22.7%.

The indicators related to the field of water management and method for determining the significance weight of this field in BEAS are presented. In water management field of significant environmental assessment systems, the percentage weights vary from 2 to 27.7%. The lowest significant weight of 2% is in Japanese system CASBEE. Significant weights of 6%, 6.67%, 7%, 8.5% and the highest of 27.7% are in BREEAM (UK method), NABERS (Australian system), LEED (US system), Green Globes (Canadian system) and SABA (Jordan system), respectively. All those weights of significance reflect national specificities.

5 Family House Assessment from Water Management

Five family houses were chosen for their evaluation from water management point of view. Family houses are located in the northwest part of the town of Kosice in the Slovak Republic. According to urban zoning plan of Kosice, the built-up areas are localities intended to low-rise residential areas. The location of the houses is not in the floodplain town of Kosice [41]. According to environmental regionalization of Slovakia, the territory where family houses are situated is soft disturbed environment [42].

Family house 1 is situated in a slightly sloping terrain. Family house 2 is located in an area which was initially used for gardening purposes, near the forest in a slightly sloping terrain. Family house 3 is located in a slightly sloping terrain in a dense built-up area with cramped conditions for further construction, and family houses 4 and 5 are located in a sloping terrain in the slightly built-up area.

Table 1 Way of the assessment of water management

E	Water management	8.88%	
E1	Reduction and regulation of water flow in water systems	42.3%	
Purpose	To reduce water consumption using equipment for reduction and regulation water flow in plumbing fixtures and WC stop in the toilet	Point	Weight
Indicator	Consumption of potable water		2.115
Negative practice	According to drawing documentation, there are no facilities designed to reduce and control the flow of water fittings and toilet flushing		−1
Acceptable practice	According to drawing documentation, there are facilities designed to reduce and control the flow of water fittings		0
Good practice	According to drawing documentation, there are facilities designed to reduce and control the flow of water fittings and toilet flushing		3
Good practice Best practice	According to drawing documentation, there are high-quality facilities designed to reduce and control the flow of water fittings and toilet flushing		5
E2	Surface water run-off	12.2%	
Purpose	To ensure that surface water is managed within site boundaries and is reinjected into the aquifer	Point	Weight
Indicator	The quality of a surface water management plan		0.61
Negative practice	A general plan has not been developed for the management of surface water		1
Acceptable practice	A general plan has been developed for the main agreement of surface water and its percolation into the ground within site boundaries, including at least 80% of natural surface water courses, paved and landscaped areas		0
Good practice	A detailed plan has been developed for the management of surface water and its percolation into the ground within site boundaries, including at least 90% of natural surface water courses, paved and landscaped areas		3
Best practice	A detailed plan has been developed for the management of surface water and its percolation into the ground within site boundaries, covering 100% of areas		5
E3	Drinking water supply	22.7%	
Purpose	To ensure the quality of drinking water in buildings which are not supplied by water with water supply	Point	Weight
		5	1.135
Indicator	The quality of drinking water		
Negative practice	The building is supplied with not enough drinking water		−1
Acceptable practice	The building is supplied with enough drinking water		0
Good practice	The building is supplied with enough drinking water of good quality		3
Best practice	The building is supplied with enough drinking water of high quality		5
E4	Using filtration of grey water	22.7%	
Purpose	To ensure using "grey water" for flushing of the toilet	Point	Weight
			1.135

(continued)

Table 1 (continued)

E	Water management	8.88%
Indicator	Design of "grey water" system in drawing documentation	
Negative practice	According to drawing documentation, the building has not designed a "grey water" system	−1
Acceptable practice	According to drawing documentation, the building has designed a "grey water" system for irrigation	0
Good practice	According to drawing documentation, the building has designed a "grey water" system for irrigation and flushing of the toilet	3
Best practice	According to drawing documentation, the building has designed a "grey water" system for irrigation and flushing of the toilet, and the building has separate metering of water consumption	5

Table 2 Characteristics of the groundwater aquifers in the Nile Delta and its fringes [12]

Photo	Subfield: score – evaluation
	**E1: 0** – Equipment designed to reduce and control the water flow in the armature **E2: −1** – Surface water is not stored and used for irrigation **E3: 5** – Sufficient amount of fresh water with high quality **E4: −1** – Split potable and grey water systems are not used
	**E1: 0 –** Equipment designed to reduce and control the water flow in the armature **E2: 5** – Collected in storage tank and is used for irrigation **E3: 3** – Sufficient amount of fresh water with high quality **E4: −1** – Split potable and grey water systems are not used
	**E1: 3 –** Equipment designed to reduce and control the water flow in the armature and flush toilet **E2: 5** – Water of surface run-off is collected in vegetation roof **E3: 5** – Sufficient amount of fresh water with high quality **E4: −1** – Split potable and grey water systems are not used
	**E1: 3 –** Equipment designed to reduce and control the water flow in the armature and flush toilet **E2: 5** – Water of surface run-off is collected in storage tank and is used for irrigation **E3: 5** – Sufficient amount of fresh water with high quality **E4: −1** – Split potable and grey water systems are not used
	**E1: 3 –** Equipment designed to reduce and control the water flow in the armature and flush toilet **E2: 5** – Water of surface run-off is collected in vegetation roof **E3: 5** – Sufficient amount of fresh water with high quality **E4: −1** – Split potable and grey water systems are not used

The highest score of 5 was assigned to the indicator drinking water supply for all family houses and water management of surface run-off for four family houses. All buildings are supplied with sufficient amount of fresh water with high quality. Only family house 1 did not collect the water from surface run-off in the storage tank and used for irrigation. Score 3 was assigned to the indicator reduction and regulation of water flow in water systems for family houses 3, 4 and 5. Family houses have designed equipment to reduce and control the water flow in the armature and flush toilet. Score 0 was assigned to the indicators reduction and regulation of water flow in water systems for family houses 1 and 2. Score -1 was assigned for the indicator system of grey water for all family houses. Buildings do not use split potable and grey water system.

Based on the evaluation, it can be said that family house 1 obtained a rating of 1.0, family house 2 obtained 1.906 points, and the best rating of 3.106 was assigned to family houses 3, 4 and 5.

6 Conclusion and Recommendations

The integrated assessment of buildings is critical in achieving sustainable development. The aim of sustainability assessment of buildings is to provide a sustainable building design, construction, operation, maintenance and renovation. Sustainable buildings involve taking the entire life cycle of buildings, environmental quality, technical and functional quality, social and cultural factors, economic factors as well as future values all into account.

The developed building environmental assessment system applicable in Slovak conditions consists of 6 primary fields and 52 relevant indicators. The basis of assessment development consists of systems and methods used in many countries. The main fields are building site and project planning, building constructions, indoor environment, energy performance, water management and waste management.

Main features of the system include the following:

- BEAS as the multi-criteria system includes environmental, social and cultural aspects.
- Indicators respect European and Slovak standards, rules, studies and experiments.
- This system allows to establish indicator weights that reflect their varying importance in the region.
- Designers can specify targets of building performance in terms of various aspects.
- Assessors can accept the assessment made by designers.

The theoretical level of the present knowledge of building environmental assessment is wholly analysed and applied making it necessary to implement this knowledge in construction practice. For the purpose of system verification, a statistically significant set of buildings needs to be evaluated, the outcome of which will be a modification of the fields and indicators weighting.

Future research work will be aimed at evaluation of a statistically significant set of buildings in the field of water management. According to the results, it will be necessary to perform the modification of indicators and their significant weight.

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