Integrated building water management options

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Abstract: Using alternative water sources is the way how to ensure the sustainable water management and treat with potable water carefully. How we can treat water carefully? If we focus on buildings water management, there are several ways, how we can preserve wasting of potable water, what is the usual event in building water treatment. The decision to collect and use alternative water sources may be influenced by a range of factors. It reflects the adaptability of water uses to the changes of environment, and the ability to make long-term development strategy of possible water use in building to the characteristic and various regulations of building cycle and water sources. According to raising charges for water and sewerage, we can expect that using grey water systems become more popular and more attractive not just for user but also for investors. The aim is to show all combination of portfolios of proposed water strategies and to describe how we can treat with this source of water, and demonstrate its potential utilization at the building level.

Key-Words:, user habits, saving potential, water portfolios, grey water, potable water, well water, rainwater, AHP.

1 Introduction

The quantity of water used by European households has increased significantly over the past 30 years and now represents approximately 70% of the total water use in buildings. A report by the Office of Community and Economic Development (2002) estimates that 35-40% of household water consumption is used for personal hygiene (shower and bath), 20-30% for toilet flushing, and 10-20% for laundry. The research has shown that replacing high water-using devices with water efficient alternatives can reduce annual water consumption by 32-50% [1, 3, 6]. Focusing on household water consumption, and in particular the use of water efficient devices, offers significant potential for water savings [4].To achieve sustainability of water resources the approaches taken must be economically, environmentally and socially acceptable and avoid negative impacts on future generation. The decision to collect and use alternative water sources may be influenced by a range of factors. Energy efficiency and sustainability are key drivers of water reuse, which is why water reuse is so integral to sustainable water management [3]. The total volume of water in the world remains constant. What changes is its quality and availability [1]. Many researchers confirmed that the importance of water savings is rising every day. The fresh water is our gold. Common household uses consume a lot of water. There is a need to manage its end use as sustainable as our conditions allow us. In EU it is common to use well and rain water source for purposes as irrigation, toilet flushing…etc. There are three main approaches to reduce water in household:

- water saving by good housekeeping and efficient water use in buildings
- alternative water supplies (rainwater…etc)
- recycling and reuse of water (grey water…etc)

The project titled "Building that Save Water" presented a decision tree approach to assessing options available for reducing mains water use [2]. The ability of different water types to meet the water demanded for various end uses within the building is significantly improved where less water in total is required. Consumers must be clear on how to operate water-using appliances correctly, and be aware of the implications of their water consumption [4]. The article is divided in to three main parts. Firstly we would discuss the water sources, than propose the evaluation of water habits and management options. Finally we discuss the results and set the future vision for the research.

2 Water sources description

Focusing on household water consumption, and in particular the use of water efficient devices, offers significant potential for water savings [6].

Potable water

Potable water could be supplied from several possible sources.

- Municipal water supply
- Water wells – driven, dug, drilled

Tap water (running water, city water, municipal water, etc.) is water supplied to a tap (valve). Other typical uses include washing, toilets and irrigation. Indoor tap water is distributed through "indoor plumbing", which has existed since antiquity but was available to very few people until the second half of the 19th century. Water used for abstraction of drinking water is now covered by Water Framework Directive - WFD.

Water from well is s water supplied from groundwater sources. It could be used for potable or non-potable purposes according to its quality. About 14% of the Slovak population is individually supplied from well water. 80-85% of water resources for individual supply do not meet the hygiene requirements and are permanent risk to health or the water has poor sensory properties. The most common case of overflow values of indicators is faecal pollution, nitrate and iron. Water quality in individual water resources is adversely affected by poor technical condition of wells, lack of depth and poor disposal of sewage in their neighborhood. High risk of infectious diseases, especially in times of flood and case of failures drains.

Grey water

Grey water system can be described as system which is oriented on capturing waste water before its discharging from building. If we want to apply this system, the waste water has to be separated on grey water and black water. There are a lot of descriptions, what grey water means, for example according to British Standard, we can consider grey water as domestic wastewater excluding faecal matter and urine [7]. Grey water reuse is in our condition still rare.

Rainwater

Rain, a form of precipitation is the first form of water in the natural hydrological cycle. It is a primary source of water that feeds rivers, lakes, and groundwater aquifers and they became the secondary source of water [8].

Rainwater may be collected from any hard surface, such as stone or concrete patios, and asphalts parking lots. However, once the rain hits the ground it is no longer referred as rain, but as the storm water. Landscape can also be contoured to retain the storm water runoff. Rainwater harvesting captures precipitations and uses it as close as possible to where it falls [9, 10].The potential of rainwater harvesting depends on location and weather. Precipitation monitoring is a very a common process all around the world.

Discussing the water is used in a good or bad (waste) way and the pressure of the climatic changes and draughts led us to discuss if we are using water in the sustainable way.

3 Evaluation of water habits

The intent of the integrated water management is to consider water management options that were identified by the expert group that might be useful in enhancing the water sustainability and reliability. When considering water – energy nexus it is necessary to know the users water habits and set the boundary conditions of used systems. The first evaluation is described in this article. Water is commonly described either in terms of its nature, usage, or origin. To put it simply four main water types (potable, grey, storm and well water) are used in this evaluation. The suitability and availability of water is creating the behavior of the system (Fig. 1).

Fig. 1 Average water consumption in Slovak household (l/person per day)

The opinions and habits of four groups (of 10 persons) were collected.

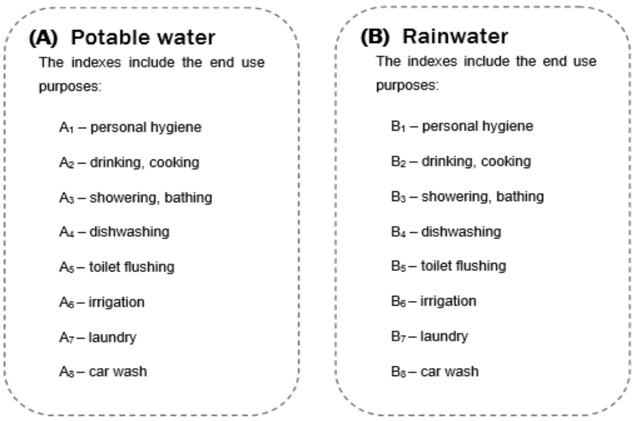

Fig. 2 Indexes for suitability purposes of water use evaluation

They expressed their opinion and water use habits. The first group consisted of classic users – users without scientific background on water use. The second group was represented by foreign experts, the third one by Slovak experts and the last group was represented by companies that are installing and selling these systems. The evaluation was made by sophisticated decision analysis based on Saaty methodology. The results were compared to the ideal case of water use. The first step in Analytical hierarchy process (AHP) procedure is to decompose the decision problem into a hierarchy that consists of the most important elements of the decision problem. In developing the hierarchy, the top level is ultimate goal of the decision at hand. The hierarchy then descends from the general goal to the more specific elements of the problem until a level of attributes is reached. Although the hierarchical structure typically consists of goal, objectives, attributes and alternatives, a variety of elements relevant to a particular decision problem and a different combination of these elements can be used to represent the problem [5].Chosen method as an algorithm was successfully implemented on the platform Excel using the programming tools of the Visual Basic. Evaluation of water use was done by establishing index system of water end use: 40 experts (10 classic users, 10 foreign experts, 10 Slovak experts, 10 companies) from different spheres were asked to make judgment according to water use habits, according to the circumstance and related data together with various indexes, corresponding to concourse of comment. The four group evaluation was prepared (Fig. 2). Concourse of comment power coefficient matrix F= (9, 7, 5, 3, 1)$_T$. Comment is qualitative description on suitable or less suitable of evaluation object. It becomes nonfigurative data to evaluation language that people know well. Concourse of comment is consistent to each layer index. Evaluation matrix is fuzzy matrix result from fuzzy mapping. It means a comprehensive result that experts investigate. If there is m index and n grade, then R is m line, n row matrix, namely R= {rij}. Proceeding to multilevel fuzzy comprehensive evaluation beginning from the top level, proceeding to comprehensive evaluation to each layer every kind of index,

$$E_i=W_i*R_i \qquad (1)$$

Calculating comprehensive evaluation worth

$$X=E*F \qquad (2)$$

If X ≥ 9, then the purpose of use is very suitable;
If 7 ≤ X ≤ 9, then the purpose of use is between suitable and very suitable;
If 5 ≤ X ≤ 7, then the purpose of use is between general and suitable;
If 3 ≤ X ≤ 5, then the purpose of use is between less suitable and general;
If 1 ≤ X ≤ 3, then the purpose of use is between less suitable and unsuitable;
If X ≤ 1, the purpose of use is unsuitable.

P= {very suitable, suitable, general, less suitable, unsuitable} (3)

The AHP is used to get the weight for each of the factors. The calculation results for GROUP 1,2,3,4 (G1) are as follows by evaluation matrix R1:

$$\left\{\begin{matrix} 1 & 0 & 0 & 0 & 0 \\ 0,8 & 0,2 & 0 & 0 & 0 \\ 0,7 & 0,2 & 0 & 0 & 0 \\ 0,5 & 0,5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0,5 & 0,5 \\ 0 & 0 & 0 & 0,3 & 0,7 \\ 0 & 0,4 & 0,4 & 0,2 & 0 \\ 0 & 0 & 0 & 0,4 & 0,6 \end{matrix}\right\}$$

Fig. 3 Example of evaluation matrix

Because of Concourse of comment power coefficient matrix is F= (9, 7, 5, 3, 1)$_T$, comprehensive evaluation worth is: *X=B*F*

The calculation result is x (G1) = 5, 841244202

Simple analysis

because of 5 ≤ X= 5,841≤ 7 (4)

according to concourse of comment power coefficient matrix is F= (9, 7, 5, 3, 1)T and corresponding to concourse of comment P= {very suitable, suitable, general, less suitable, unsuitable}. Water use is between general and suitable - into middle level according to the result of evaluation by group 1 – classic users. This method was used for 3 another groups in the same order.

The calculation result is x = (5)

(G2) = 6,139903869 because of 5 ≤ G2 ≤ 7

(G3) = 4,424796468 because of 3 ≤ G3 ≤ 5

(G4) = 7,856748 because of 7 ≤ G1 ≤ 9

(G_{ideal})= 8,201481691 because of 7 ≤ G1 ≤ 9

The advantage of chosen method we see in possibility of use as the global tool for creating a hierarchical model of the spatial decision problem, analyzing the whole process and evaluating each alternative. The disadvantages are limited to expectation of the ideal case – subjective evaluation. The whole mathematical process is deeply described in [21].

4 Water management options

In the world a lot of authors have discussed the water issue from the different views [11,12, 13,14,15,16,17,18,19, 20,22,23]. This part defines and evaluates combinations of water management options, referred to as water management portfolios. The water management portfolios are scored and compared based on screening criteria presented in this section. We can divide them to two alternatives using the proposed portfolios.

1. House is connected to main water supply – Alternative 1
2. House is not connected to main water supply- Alternative 2

The 11 Case portfolios were prepared in two alternatives (Figure 4).

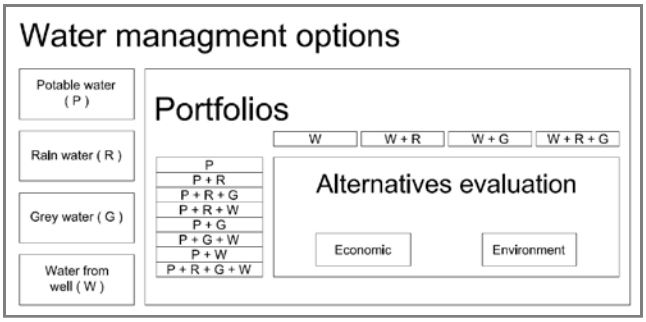

Fig. 4 Water management option vision at the building level

4.1 Portfolio description

First alternative gives us 8 portfolios how we can manage water consumption and demand. In this case all possible use purposes of four water sources are described for end use in Figure 2.

- Potable water (P)
- Rain water (R)
- Grey water (G)
- Water from well (W)

Portfolio1. Base Case – Potable water, Well water (water quality as drinking). It is represented by main water supply that reaches the highest water quality. Portfolio assumes that none of the other water management options presented here would be implemented. In case there is not possible connection to water supply only Well water that reaches quality requirements will be used.

Portfolio 2. P + R - this portfolio consists of the adding just the rain water use option to the base case portfolio. In some cases, this option is a must,

- if it is not possible to connect to the main sewage (overloading sewerage), this is happening often in the cities, while building a new house
- sewage system is not built (downtown areas, villages)
- subsoil is not suitable for infiltration.

In this case we cannot calculate the initial costs for the payback period because we have to invest in the system.

Each town has its own regulations to deal with the floods and problems of overloading sewers.

Portfolio 3. P+R+G - this portfolio consists of the adding the recycled water option to the P+R case portfolio. It means that the water according to its quality and availability will be divided for other purposes. For example grey water for flushing the toilets and rainwater for garden irrigation and laundry. It is also possible to build also a hybrid system.

Portfolio 4. P+R+W - this portfolio consists of the replacing the recycled water option by well water and works in the same way. The water from well is in this time the cheapest way how to have a good quality water, but it should be controlled at least 1 time per year.

Portfolio 5. P+R this portfolio is similar to the portfolio 2, the grey water is used for non-potable purposes. It becomes cost effective where water consumption is more than 500- 600I/ day.

Portfolio 6. P+ R + W - this portfolio is combination of potable water, well water and rain water. Wells can recharge themselves, and can provide a constant, steady supply of water that is not easily impacted by dry weather conditions, so it is always a good idea.

Portfolio 7. P+W – the often used combination in our conditions. Potable water is used for all indoor activities and well water for the irrigation. The purposes of use are based on the quality of water.

Portfolio 8. P+R+G+W – the last portfolio is combination of all sources. The all options portfolio includes incorporating all of the water management option. It should be evaluated by case by case approach.
The same approach is used in alternative 2 but potable water is replaced by water from well. In this case we have four portfolios: Well water, W+R, W+R+G, W+G.The water audit equates the volume of water that goes into building to where it is used and where it ends up. A final decision on whether to proceed with a rainwater, well water or grey water system should take into account all changes in water use and viability assessed having addressed water efficiency issues at first [2].

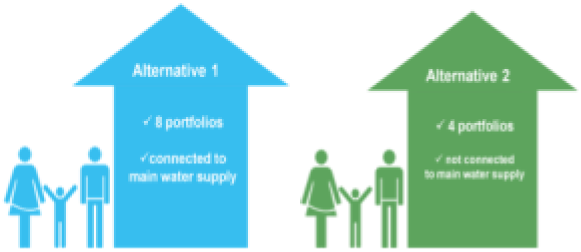

Fig. 5 Two alternatives of portfolios

The water audit equates the volume of water that goes into building to where it is used and where it ends up [2].

5 Discussion and Results

The intent of the integrated water management is to consider water management options that were identified by the expert group that might be useful in enhancing the water sustainability and reliability.

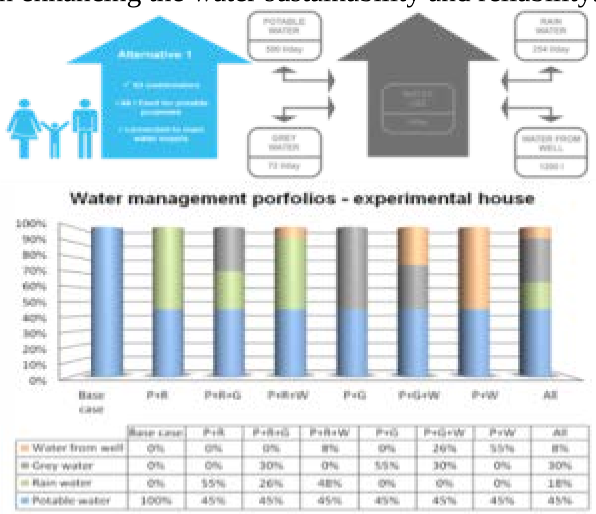

Fig. 6 Alternative 1 – 8 portfolios for experimental family house

To sum up evaluation of water use according to the results of G1, G2 is at in the middle level, so we see a lot of possibilities how to raise the people awareness and change their water habits.
The companies G4 that work with the water saving systems (water reuse, rainwater harvesting systems…etc) are very close to ideal pattern of usage. The worst pattern came out from our Slovak experts, the result is between less suitable and unsuitable water use, so there is still a great gap in water habits in Slovakia.
Results for Alternative one are described on figure 6. Described water management options that are considered at the building level were implemented on experimental house. According to the study eight portfolios are prepared for the house owner when connected to the main water supply and four without the connection.
Results for Alternative two are described on figure 7.

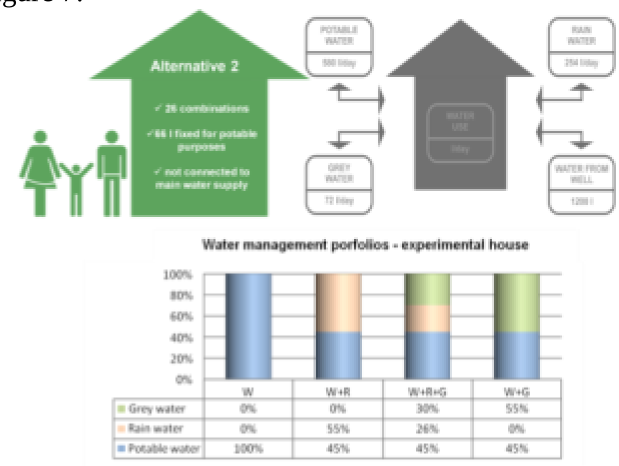

Fig. 7 Alternative 2 – 4 portfolios for experimental family house

Proposed eleven portfolios offer a plan how to deal with the water scarcity. The calculations of all combinations were set. It can help the investor to see all possibilities of water management strategies directly aimed at his case. Each case should be evaluated independent set on the boundary conditions. The economic and environmental evaluation approach will support investor's decision and interests. The main aim was to give as much as possible information to investor to change his thinking to sustainable solution even when they are not so cost effective.
Rain water and grey water can contribute to sustainability at the building level, particularly where:

- ✓ problems with water sources occur
- ✓ the cost of water mains is high

- ✓ user wishes to reduce the water consumption
- ✓ user wishes to be independent of water mains
- ✓ user wishes to support the sustainability and environment
- ✓ it is the only possibility of runoff disposal[2].

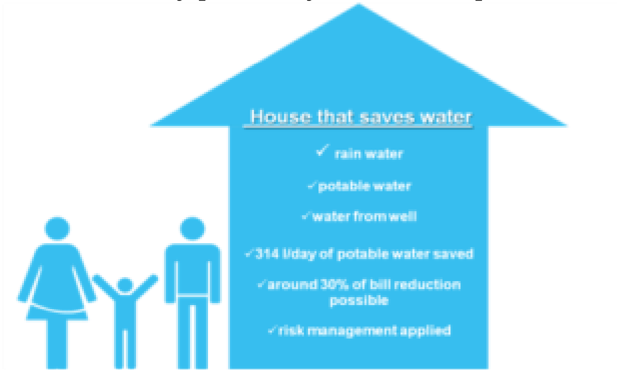

Fig. 8 Portfolio 4 – experimental family house

The change of a classic family house to a BLUE house by implementing the portfolio four led to reduction of water bills. The saved costs for water in the year 2016 will be around 160 € (Fig. 8). The topics for ***future research*** should include calculation of savings for hybrid systems and evolving an application (for smart phones) for a BLUE HOUSE to raise people awareness about water systems.

6 Conclusion

The water topic covers a lot of interesting issues that can be discovered to help the environment and to save the water for the next generations. To achieve sustainability of water resources the approaches taken must be economically, environmentally and socially acceptable and avoid negative impacts on future generation. Now the systems are more viable where the consumption is above average and for rainwater systems if there is sufficient rainfall. As grey water systems become more popular, there is a need for standardization to protect the public and to ensure that reliable systems are designed, installed and maintained. A modern decentralised water infrastructure can include site-collected rainwater, grey water, storm water, and black water systems. These alternative water sources may never totally replace centralized system. They do help manage and store water and treat it to various levels of quality for use in buildings and the sites upon which they stand. The designers should complete the site and building as the one system – where water is conserved, energy saved and the costs are reduced. New technologies and better understanding of the in building water cycle allow us to reduce our water footprint. In this article we would like to support decisions on alternative water use at the building level. Following the hypothesis that a small change in thinking of the society – by changing a house to blue house could lead to a blue world.

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