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Daniela KAPOSZTASOVA[1]
Zuzana VRANAYOVA[2]
Martina RYSULOVA[3]
Gabriel MARKOVIC[4]

WATER MANAGEMENT OPTIONS – PORTFOLIOS FOR SAFE WATER UTILIZATION IN BUILDINGS

„There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people - and the environment - suffer badly" This was presented in the World Water Vision Report from 2015 at it leads us to think about sustainble management options. The main aim of this article is to introduce a concept of water management portofolios to give as much as possible information to customer to change his thinking to sustainable water solution even when they are not so cost effective, while building or reconstructing his house.

Keywords: water types, water portfolios, savings, water use, sustainability

1. Introduction

The aim of the European Commission's policy review is to introduce "a water-saving culture" in Europe and create "a drought-resilient society" in the context of climate change. The policy paper will focus on increasing water savings in all areas, improving water retention by making changes to land use and management. Other areas where efficiency gains are expected include water supply infrastructures and buildings [1]. IWAs "Cities of the Future" are moving towards sustainable urban water use. The major goal of the Strategic Research Agenda (SRA) was to develop the long term vision of WssTP [2] for the water sector and to identify the research priorities by six pilot programmes. More than 50% of the world population lives in urban areas. Urban areas, especially large

[1] Corresponding author: Daniela Kaposztasova, Faculty of Civil Engineering, Institute of Architectural Engineering, TUKE, Slovakia, e-mail: daniela.kaposztasova@tuke.sk
[2] Zuzana Vranayova, TUKE, Slovakia, e-mail: zuzana.vranayova@tuke.sk
[3] Martina Rysulova, TUKE, Slovakia, e-mail: martina.rysulova@tuke.sk
[4] Gabriel Markovic, TUKE, Slovakia, e-mail: gabriel.markovic@tuke.sk

or densely inhabited ones, raise specific issues with regard to water management.

1.1. Background and water demand

It is increasingly obvious that the current use, development and management of the planet's water resources, and the services they provide, is unsustainable. At the United Nations Conference on Sustainable Development in 2012 (Rio+20), governments recognized that water is "at the core of sustainable development as it is closely linked to a number of key global challenges" [3]. While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50%. This population growth - coupled with industrialization and urbanization - will result in an increasing demand for water and will have serious consequences on the environment (Fig. 1) [4]. The total volume of water in the world remains constant. What changes is its quality and availability. Water is constantly being recycled, a well known phenomenon as the water or hydrological cycle [5]. In Slovakia the average consumption is around 145 l/per person/day. According to the Population and Housing census results 2011 there was an increase of built houses around 3,2%.

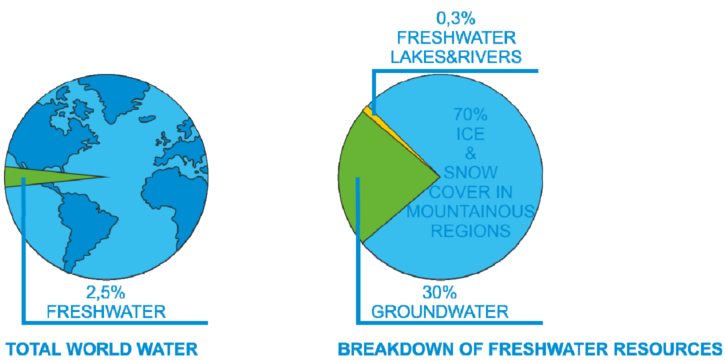


Fig. 1. Total world water (based on [4])

From the 2011 census results with an average of six inhabitants per household average water use per household per day in Slovakia was 843 343 200 l/day. And therefore only households are yearly consuming around 308 000 000 m^3/year of potable water. It shows that about 55% of drinking water may be replaced by alternative water source as rain water, grey water or water from well…etc. Potable water consumption of the Slovak households isn't above average at all but we use it in inappropriate ways. Questionnaire on Water, as one of data collection methods gave us a closer look at water habits of households.

The result is that most of our citizens are pro water saving oriented and open to new water ideas as closed in-building water cycle. In Slovakia this area hasn't been so developed yet. It is necessary to define regulation and set standards for designing hybrid systems for example according to foreign national standards and performed experiments in Slovak conditions.

2. Water portfolios for savings

Many researchers confirmed that the importance of water savings is rising every day. The fresh water is our riches. 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 such purposes as irrigation, toilet flushing…etc. Grey water reuse is in our condition still rare. 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) [6].

Most of the water management options would reduce demand on the potable water system. These reduced demands could result in cost savings for the potable water system in terms of smaller infrastructure needs and lower operating costs. These water management options (Fig. 2) could be directly implemented by customers (described in [7]).

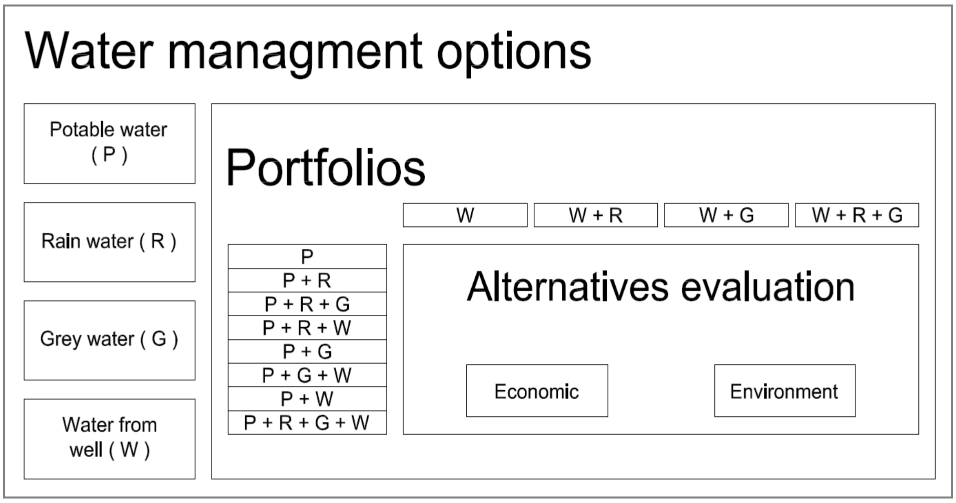


Fig. 2. Water management option vision at the building level

2.1. Portfolios 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 Fig. 3.

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

Portfolio1. Base Case – Potable water, Well water (potable 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 [8].

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 between 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 to obtain 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- 600 l/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 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 [7].

2.2. Water consumption in Slovakia

We use large amounts of water each day, as water serves many different purposes, which we can divide to potable and non-potable water needs. Water with potable water quality parameters is used to personal hygiene drinking, cooking, showering, bathing and dishwashing (Fig. 3). Water that does not require such quality parameters is suitable for toilet flushing, irrigation, laundry, car wash and others (Fig. 4).

According the presented 9 purposes all possible combinations with 4 or 3 sources were calculated.

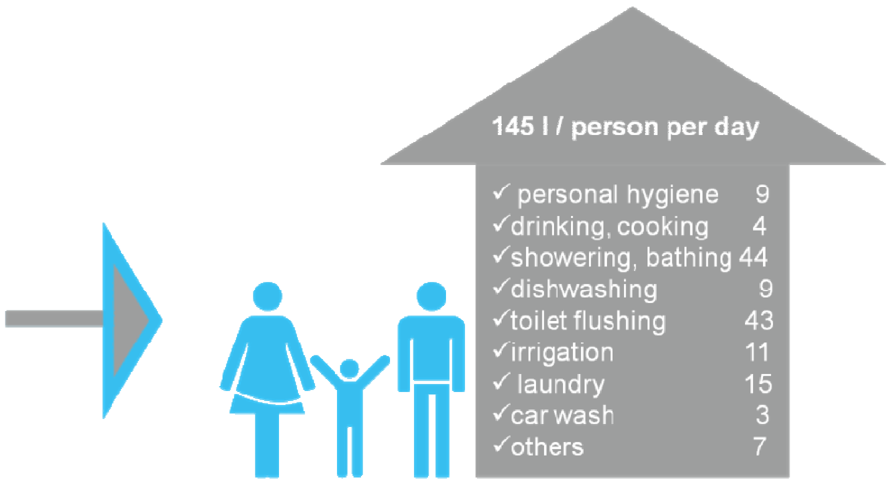


Fig. 3. Average water consumption in Slovak household [l/person per day] (based on [7])

3. Possible combinations of all portfolios

To define all possible combinations of water management options referred to water management portfolios for both alternatives the classical combinatorial task of combinations number determining was used.

If we have e.g. 4 different water sources and define them by 9 end use purposes, then if we want to find the number of all the possibilities of application to a given source of water we need to use a classical combinatorial task approach of all tetrads of nine elements without repetition. This number is expressed in mathematics standard combinatorial numbers in the form $\binom{n}{k}$ where n is the number of elements where the k number of k-tuples. The calculation of the number of the combination is given by the formula (1):

$$\binom{n}{k} = \frac{n!}{(n-k)!n!} \tag{1}$$

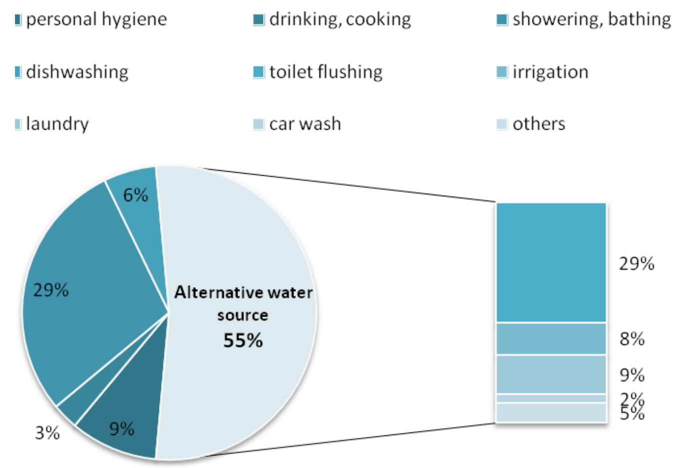


Fig. 4. Different purposes for non-potable use in household

When trying to find the best solution it is, however, important to know all of these options and then choose the one best suited to each particular case. It is preferable to use commonly used software products, such as Visual Basic on Microsoft Excel and so get the desired solution directly in the environment of Excel spreadsheets. Counting combinations is difficult from a programming standpoint, since it does not order the elements concerned, which is somewhat contrary to the strict deterministic approach to reigning in creating algorithms. From the perspective of a programmer is thus an easier to handle (even though mathematically seemingly extensive) process based on the calculation with variations without repetition, which in contrast to the combination depends on the order, after eliminating same solutions. The process started by identification of all permutations considered for 9 end purpose. Permutations in this context are a special case of variations without repetition, where ***n*** **=** ***k*** is the calculation of the simple relation as ***n*!** (*n* - factorial). There was need to eliminate the same solutions, after re-compile all of four variations in Excel tables. The important boundary conditions were set like daily capacity of the water resources, sanitary restrictions, etc. The calculation resulted in **996** options which are from the practical point of view not applicable. By specifying boundary conditions related mainly to the removal of some "irrational" clusters of activities in terms of connection to a water source. Final results have obtained an acceptable number of options, which are of the order of large number of different cases. We decided to choose most suitable ones. By setting up the boundary conditions for alternative 1 and 2 (Fig. 5) the results are as follows: in alternative 1 - four sources were used, in alternative 2 - 3 water sources were used.

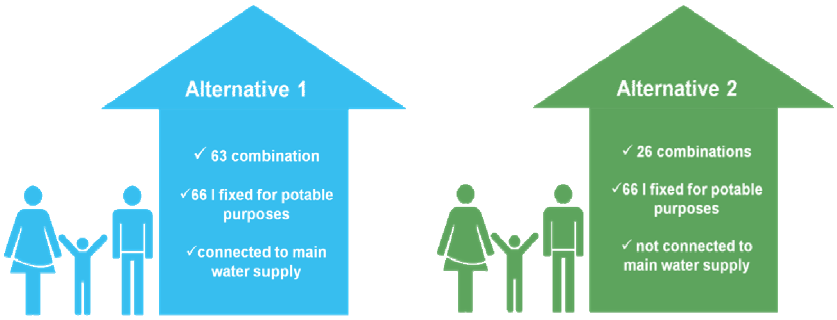


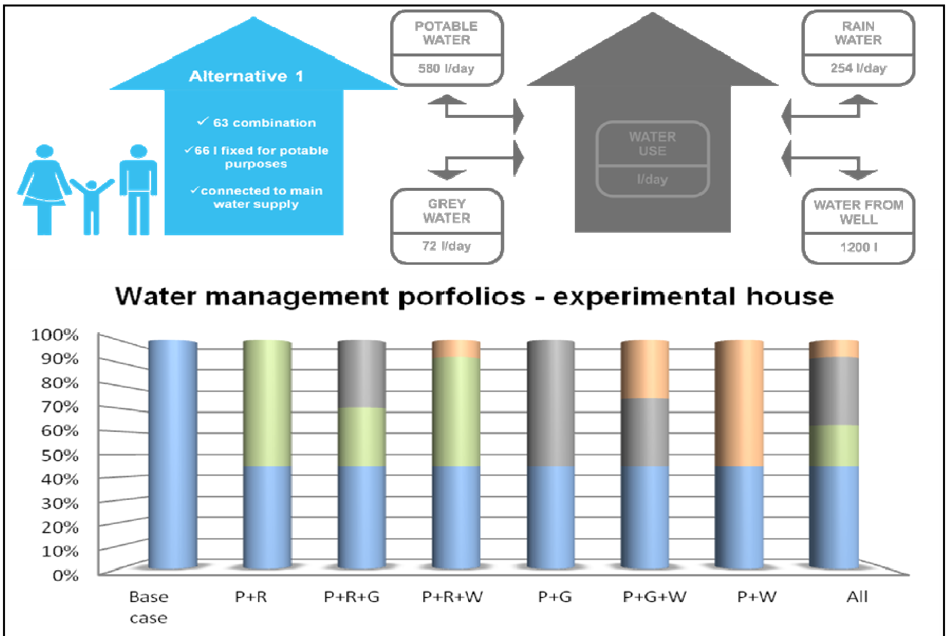
Fig. 5. Possible combination for both alternatives

According to the study eight portfolios are prepared for the house owner when connected to the main water supply and four without the connection (Figs. 6 and 7). We can apply also the economic and environmental approach to discussed subsystem used in the house. To demonstrate the best solution to investor according his preferences it is inventible to consider hypothetical economic or environmental approaches. It can be done by AHP - Analytical Hierarchy Process. This method we deeply described in article [7].

4. Discussion and results

Supported by mathematical methods the comprehensive evaluation on water use was established to find the pattern of water user in Slovakia. The classic pattern consists of potable use for all purposes and when it is possible to have a well the water is used for irrigation. The results were supported also by the questionnaire and can be used as a tool in water audits. It is inevitable to inform our public about the possibilities of water savings not only when building a new 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 as independent set on the boundary conditions (Figs. 6 and 7). The economic and environmental evaluation approach can be presented to support investor's decision and interests. The main aim is to give as much as possible information to investor to change his thinking to sustainable solution even when they are not so cost effective.

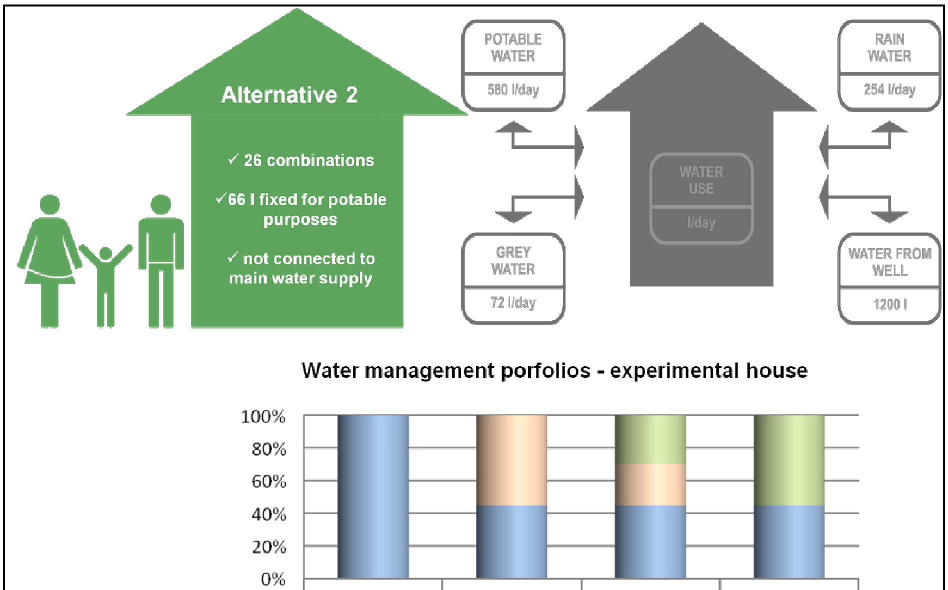


	Base case	P+R	P+R+G	P+R+W	P+G	P+G+W	P+W	All
Water from well	0%	0%	0%	8%	0%	26%	55%	8%
Grey water	0%	0%	30%	0%	55%	30%	0%	30%
Rain water	0%	55%	26%	48%	0%	0%	0%	18%
Potable water	100%	45%	45%	45%	45%	45%	45%	45%

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

5. Conclusion

Massive use of reused water for non-potable purposes in buildings also promotes the conservation of natural resources, water, and thus the overall sustainability in water management. Potable water consumption in the Slovak households isn't above average at all but we use it in inappropriate ways. We need to change the thinking of the society to be in the balance with the nature. Small steps as changing a family house to a „blue" family house can lead to a bigger changes in our lifestyle and our attitude toward water use. Proposed methodology can help the customer 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 can be presented to support customers's decision and interests. The main aim was to give as much as possible information to customer to change his thinking to sustainable solution even when they are not so cost effective.



	W	W+R	W+R+G	W+G
Grey water	0%	0%	30%	55%
Rain water	0%	55%	26%	0%
Potable water	100%	45%	45%	45%

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

Acknowledgements

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S u m m a r y

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