Water conservation at the building level

Daniela Kaposztasova, Martina Rysulova, Gabriel Markovic, Pavol Purcz

***Abstract*—**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. This article does not seek to recommend or discredit any particular system, rather to provide general guidance on the issues and information to support decisions on alternative water use at the building level and make it more attractive to public. The aim is to calculate 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.

***Keywords*—**water sources, water production, saving potential, water strategies, grey water, potable water, well water, rainwater

I. Introduction

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 [2].

This work was supported by projects VEGA n. 1/0202/15: Sustainable and Safe Water Management in Buildings of the 3rd Millennium.

This work was supported by The APVV - SK-CZ-2013-0188 Lets Talk about the Water – An Essential Dimension of Sustainable Society of the 21. Century.

D. Kaposztasova, Technical University of Kosice, Faculty of Civil Engineering (e-mail: daniela.ocipova@tuke.sk).

M. Rysulova, Technical University of Kosice, Faculty of Civil Engineering (e-mail: martina.rysulova@tuke.sk).

G. Markovic, Technical University of Kosice, Faculty of Civil Engineering (e-mail: gabriel.markovic@tuke.sk).

P. Purcz, Technical University of Kosice, Faculty of Civil Engineering (e-mail: pavol.purcz@tuke.sk).

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 [2].

The main topic of this article is to describe, how we can treat with this source of water, and demonstrate its potential utilization, which means saving particular source of potable water and in parallel to water savings, bring financial savings.

II. Description of water sources

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 [3]. 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% [4]. Focusing on household water consumption, and in particular the use of water efficient devices, offers significant potential for water savings [5].

A. 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.

B. 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 [6]. Grey water reuse is in our condition still rare.

C. 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 [7].

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 [8].The potential of rainwater harvesting depends on location and weather. Precipitation monitoring is a very a common process all around the world

III. Water management portfolios

In the world a lot of authors have discussed the water issue from the different views [15,16,17,18,19,12]. This part defines and evaluates combinations of water management options, referred to as water management portfolios. The costs and benefits of the portfolios are described in the next chapter. 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

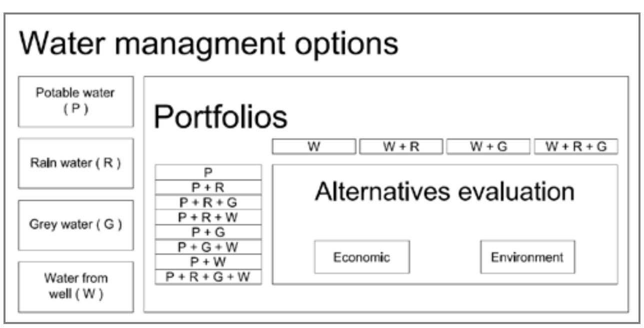


Fig. 1 Water management option vision at the building level

The 11 Case portfolios were prepared in two alternatives (Figure 1).

A. 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 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].

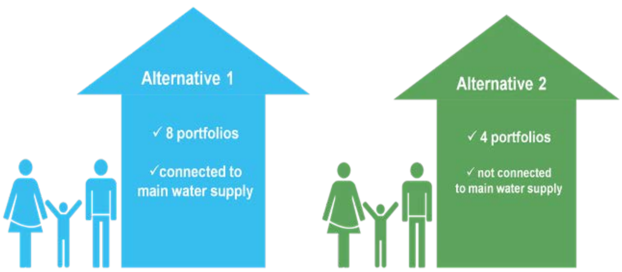


Fig. 2 Two alternatives of portfolios

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

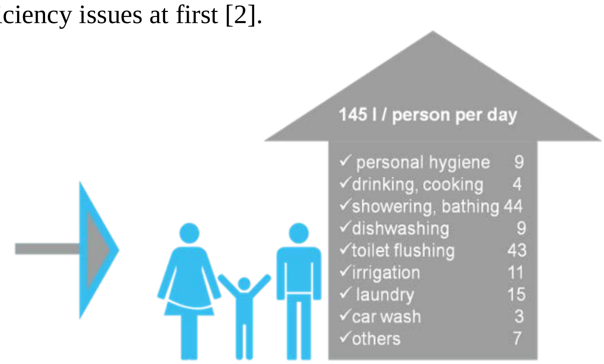


Fig. 3 Average water consumption in Slovak household [l/person per day)

B. Water use

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. Water that does not require such quality parameters is suitable for toilet flushing, irrigation, laundry, car wash and others (Fig. 3).

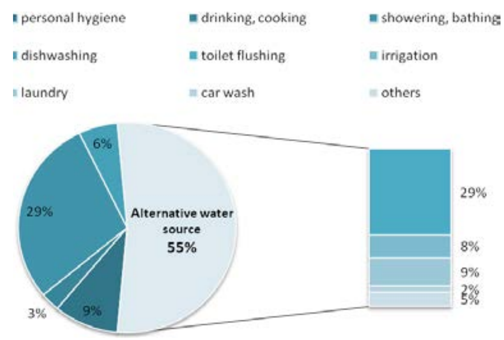


Fig. 4 purposes for non-potable use in household

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

IV. Possible combinations of all portfolios – Mathematical approach

A. Combinatorial task

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

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

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 and 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 water sources were used in 63 combinations, in alternative 2 - 26 combinations of 3 sources.

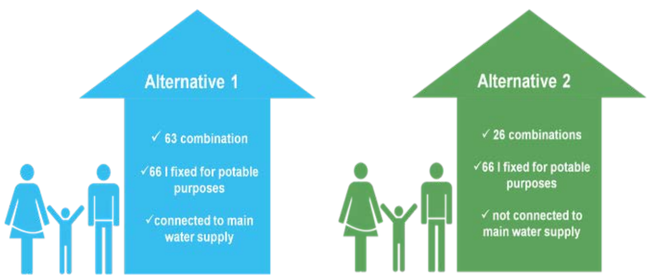
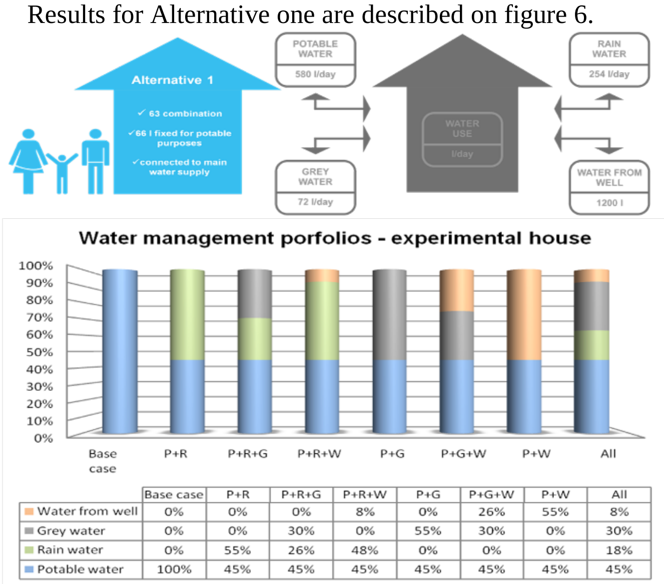


Fig. 5 Possible combination for both alternatives

B. 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. 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.

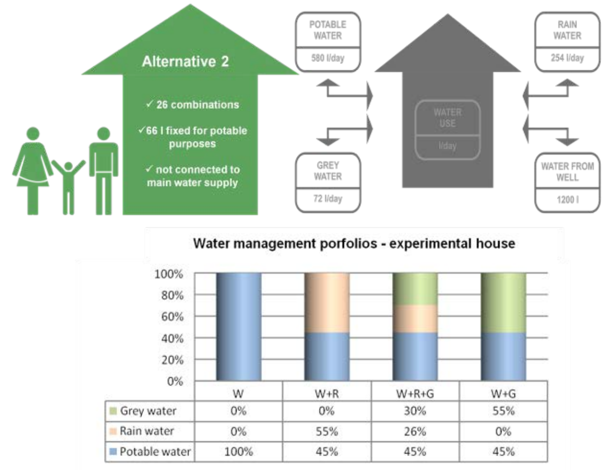
Results for Alternative one are described on figure 6.



	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

Results for Alternative two are described on figure 7.



	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

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
- ✓ it is the only possibility of runoff disposal
- ✓ user wishes to support the sustainability and environment

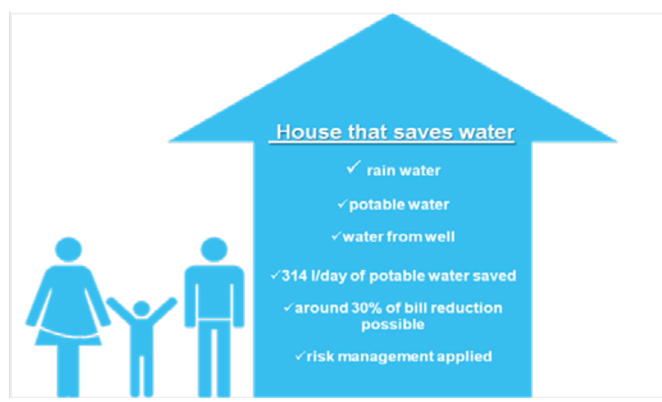


Fig. 8 Portfolio 4 – experimental family house

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).

ISBN: 978-1-61804-324-5

V. Conclusion

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. The provision of safe water and sanitation has been more effective than any other intervention in reducing infectious disease and increasing public health. The public expects to have safe water and sanitation; therefore, when recycling water, it is essential to protect public health and the environment.

References

[1] N. F. Gray, 2010, Water technology, third edition. London: IWA Publishing, 747 p. ISBN 978-1843393030.

[2] D.J. Leggett et. al. (2001): Project report 80: Building that Save Water: [online].[cit.2014-03-15]. http://web.stanford.edu/group/narratives/classes/08-09/CEE215/Projects/greendorm/water/GraywaterCD/greywater/pr80.pdf

[3] Euroactiv 2015- [online]. [cit. 2014-03-15]. Available: www.euroactiv.com

[4] A. Silva-Afonso, C. Rodrigues. (2008). "Water efficiency of products and buildings: The implementation of certification and labelling measures in Portugal". In: Proceedings – CIB W062 2008 – 34th International Symposium of Water Supply and Drainage for Buildings. Hong-Kong: HKPU.

[5] D. Kelly (2013): „The European Water Label: An analysis and review" In: CIB W062 39th International Symposium on Water Supply and Drainage for Buildings, At Nagano, Japan.

[6] British Standard BS 8528-1:2010. Geywater systems - Part 1: Code of practice. UK: BSI, (2010).

[7] H. Kinkade-Levario, 2007, Design for Water. Gabriola Island: New society Publisher, 240 p. ISBN 978-0-86571-580-6.

[8] B. Lancaster2012. Rainwater Harvesting for Drylands and Beyond.

[9] Srážkové a šedé vody aneb "colors of water". Conference proceedings.2013. www.asio.sk

[10] Ceny vodného a stočného. [online]. [cit.2014-12-26]. Available on the internet: http://www.lvsas.sk/ceny-vodneho-a-stocneho

[11] Zelenakova M. et al.:Assessment of low flows occurrence in chosen river stations in Slovakia In: WSEAS Transactions on Environment and Development Vol. 10, no. 1 (2014), p. 417-422 ISSN: 1790-5079

[12] D. Kaposztasova .et cal. (2014): Grey water as a part of in-building water cycle, IN: Proceedings of 40th International Symposium CIB W062 on Water Supply and Drainage for Buildings, Sao Paolo.

[13] G. Markovič, M. Zeleňáková, Measurements of quality and quantity of rainwater runoff from roof in experimental conditions - 2014. In: ICITSEM 2014 : International conference on innovative trends in science, engineering and managment 2014 : 12th and 13th February 2014, Dubaj, UAE. - [Bangalore]: Mudranik Technologies, 2014 P. 145-151. - ISBN 978-93-83303-19-9

[14] Nonpotable gray water systems. [online].[cit.2015-03-03]. Available on the internet: http://courses.washington.edu/cejordan/GW-Sept.-11.pdf http://www.sciencedirect.com/science/article/pii/S0011916404001924

[15] N. Jasminska: Measurement of Energy Flows and CO 2 Emissions Balance of the Low-Potential Heat Source in Combination with a Cogeneration Unit, In: Aspects of Computational Intelligence: Theory and Applications Topics in Intelligent Engineering and Informatics, 2013, Volume 2, Part 1, 63-82, DOI: 10.1007/978-3-642-30668-6_5 L. Madarász et al. (Eds.): Aspects of Computational Intelligence, TIEI 2, pp.

[16] J. Vrána, et. al.:Preparation a new Czech Standard ČSN 75 6780 Reuse of greywater and rainwater in buildings and adjoining grounds, príspevok na konferencii CLIMA 2013 - 11th REHVA World Congress and the 8th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings. STP. Praha. 2013. ISBN: 978-80-260-4001-9.

[17] Z. Vranayova, D. Kosicanova,: Evaluation of feasibility and benefits of a storm water systems for housing supply in slovak conditions, In: International Journal for Housing and Its Applications, vol. 29, 2005, no. 1, p. 33-44.

[18] T.A Kiov, et. al.:DHW design flow rates in educational, office buildings and shopping centers In: WSEAS Transactions on Environment and Development Vol. 9, no. 2 (2013), p. 153-162 ISSN: 1790-5079

[19] D. Halmova,, et al. Uncertainties in runoff components modelling and frequency analysis In: WSEAS Transactions on Environment and Development Vol. 10, no. 10 (2014), p. 374-381 ISSN: 1790-5079

Daniela Kaposztasova is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. She is specialized in Water supply and drainage systems. Recently she has been concentrated on the field of rainwater use and grey water reuse. She is a vice dean for education

Martina Rysulova is a PhD. student at the Faculty of Civil Engineering, Technical University of Kosice. She is specialized in water supply and drainage systems. Recently she has been concentrated on the field of grey water reuse.

Gabriel Markovic is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. He is specialized in Water supply and drainage systems. Recently he has been concentrated on the field of rainwater infiltration systems.

Pavol Purcz is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. He is specialized at mathematical and statistical approaches.