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RAINWATER HARVESTING SYSTEM AND RISK MANAGEMENT APPLICATION

ZASTOSOWANIE SYSTEMU ZARZĄDZANIA RYZYKIEM PRZY WYKORZYSTANIU WODY OPADOWEJ

A b s t r a c t

Submitted paper presents risk assessment using risk analysis of the rainwater harvesting system. The aim of this article is to present selected approach in risk factors identification within proposed RWH system evaluation for an experimental family house. In our case, we were able to collect helpful information from questionnaires that later facilitated the risk identification as well as risk assessment phase along with the aid of brainstorming activities within a team of experts. The results from the risk analysis were verified by the AHP and empirical multilevel comprehensive evaluation, which was also found to be useful.

Keywords: *rainwater harvesting*, *risk analysis*, *risk assessment*, *questionnaire*

S t r e s z c z e n i e

W artykule przedstawiono zastosowanie metody oceny ryzyka w odniesieniu do sytemu gromadzenia wody opadowej. Celem artykułu jest identyfikacja czynników ryzyka w proponowanym dla eksperymentalnego domu systemie RWH. W naszym przypadku udało się zebrać przydatne informacje z ankiet, które później ułatwiły identyfikację oraz ocenę ryzyka. Równolegle korzystano też z burzy mózgów. Rezultaty analizy ryzyka były weryfikowane przez AHP i doświadczalną wielopoziomową ewaluację, która okazała się także użyteczna.

Słowa kluczowe: *wykorzystanie wody opadowej*, *analiza ryzyka*, *ocena ryzyka*, *ankieta*

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1. Introduction

Rainwater harvesting system, although well-known all around the world, is still not well established in our conditions of Slovak Republic. In the past, there had been no need to look for new alternative water sources for domestic or commercial use because of the availability of good water sources in Slovak Republic. Furthermore, there are still voices that support the claim that it still is unnecessary in our conditions. However, overloaded sewerage systems and water treatment plants, cases of urban floods or water scarcity make us consider the sustainable usage of water sources all around the world and about proper water quality usage for different purposes [1]. That is the reason why we are interested in this topic and why we would like to increase awareness of this topic in our conditions as well. Relevant information on the developments in the field were obtained for the purpose of this article from the following reading materials listed in the reference section of this paper: [10–15]. As with all human activities this system could potentially be risky in some cases, as well. Risk management has its place in science and our everyday life [8]. Water management in general comprises a wide range of problems – especially in recent years when we started seeing an increasing need to manager ain water in a decentralized way. This entails the use of different infiltration or percolation systems or yet other ways of reusing this water. Generally, it is called rainwater harvesting, or RWH.

Indisputably, rainwater harvesting systems bring many benefits but, as with other areas, some events can be categorized as risky according to risk management.

Risk management programs generally cover five main components:
Context – What is at risk and why?
Risk identification – What and where are the risks?
Risk analysis – What is known about them?
Risk evaluation – How important are they?
Risk treatment – What should be done about them? [2].

Effective risk management requires identification of potential risks or hazards as described in methodology below. This methodology has been designed step-by-step in accordance with Water Safety Plan and WSP Manual and comprises the following stages:

1. Formation of a team of experts.
2. Description of an RWH system.
3. Risk identification.
4. Risk assessment.
5. Determination and evaluation of control measures [2].

RWH systems and other sustainable urban drainage systems undeniably offer many benefits, but as in others areas, some events can be categorized as risky from the perspective of risk management. The objective of risk analysis is to detect these potential risks, summarize them, determine their importance and find out the solution for how to prevent or eliminate them.

1.1. Questionnaire as a tool for risk analysis

The questionnaire was completed by designers and construction companies in Slovakia and it should provide many ideas, opinions and experiences related to the design process as well as to the construction and operation of such systems. Hopefully the questionnaire will help identify and assess risks.

The questionnaire was completed by 63 respondents. Not all of the respondents, however, felt knowledgeable enough to answer all of the questions. The last part of the questionnaire focused on the risks in RWH, as described below, and was assessed by 20 respondents. At the beginning of the questionnaire there were a few basic questions about the respondents pertaining to their experience, position and opinion about RWH. The second group of questions focused on practical experiences, such as for example: when did you produce your first design?, what problems did you face during the design process?, have you seen an increased demand for RWH in recent years?, what standards or manuals do you use for your designs?, etc. Finally, the target of the last group of questions was to obtain information about the risks involved in RWH.

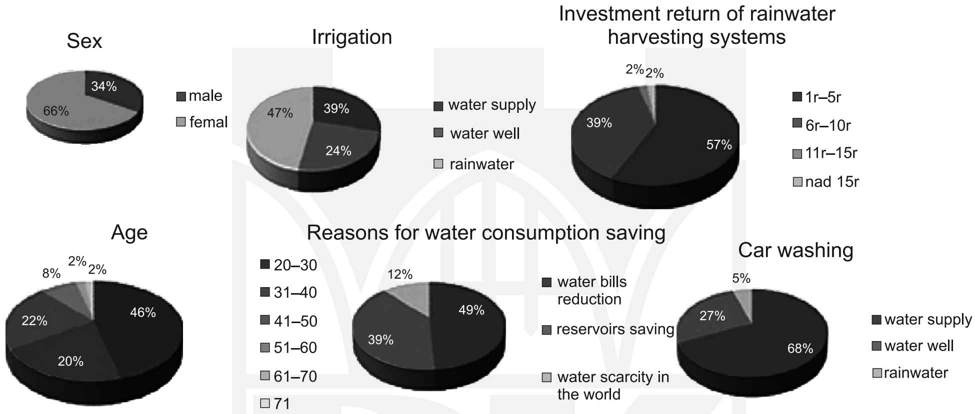

Fig. 1. Sample of results obtained from the questionnaire – according to [7]

This part is strongly subjective as it is based on a respondent's experiences and opinions. In this section we will introduce a few results obtained through the last group of questions in the questionnaire where respondents were asked to assign values ranging from 1 to 10 (1 referring to the lowest risk, 10 having the highest risk) to the main parts of the system (as shown in Fig. 2) contingent on the significance of the risk. The results show that the riskiest parts of the system according to questionnaire responses are: the pump, the filter, and the tank. Accordingly, we can say that the greatest attention should be paid to the design, installation and maintenance of these three parts of the system. Approximately half of the respondents think that there is a lack of information about system maintenance and water usage by users which pins our attention also to this kind of risk. We can say that the questionnaire is a good example of how to obtain relevant practical information about the design process, experiences and opinions on the risk analysis steps such as risk identification and risk assessment.

2. Risk analysis –aims and methods

The aim was to prepare a general risk analysis methodology for rainwater harvesting systems. This methodology can especially be applied to small scale projects such as family houses. In our case, it was applied to a newly constructed family house with a RWH system (see Fig. 1). The installed system is brand new and supplied with a 4 m^3 underground water tank. Rainwater is used for flushing toilets, irrigation, property maintenance, and potentially for washing machine usage as well.

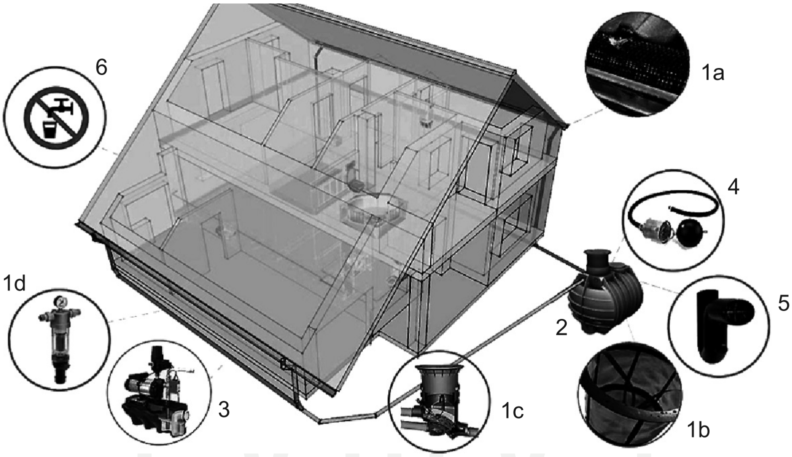

Fig. 2. Experimental family house and RWH system (1a – gutters, 1c, 1b – filters 1d water level sensors, 2 – tank, 3 – pumps, 4 – floating suction assembly, 5 – safety overflow, 6 – label –non-potable water)

One of the aims of this risk analysis is to prepare a check-list for this type of user. The check list should serve as a tool for standard system checks which can eliminate various types of events and also inform the user about the system. The methodology was designed in accordance with Water Safety protocols mentioned in section 1.

Quantitative or qualitative methods can be used for the risk evaluation. A semi--quantitative methodology was selected for the RWH evaluation of our experimental system. The semi-quantitative risk assessment is a method for differentiating risks, focusing on the big issues, and managing the entire risk portfolio better. The scoring system is inherently imperfect, but so is any other risk evaluation system [3].

By using the semi-quantitative risk assessment method, the team of experts who is performing the evaluation can calculate a priority score for each identified hazard. The objective of the prioritisation matrix is to rank hazardous events to provide a focus on the most significant hazards. The likelihood and severity of these events can be derived from the team's technical knowledge and expertise, historical data and relevant guidelines [2].

For the purposes of risk identification and assessment, the RWH system was divided into 4 parts according to Fig. 3. These four parts have thus subdivided our system into 4 main evaluation folders. Each part was then divided into sub-systems. A sub-system en compasses main system components where all sorts of potential hazards – ranging from minor ones to those most important – can be identified. These potential hazards constitute a list which constitutes the last level of our evaluation hierarchy. This final list is not presented in this article.

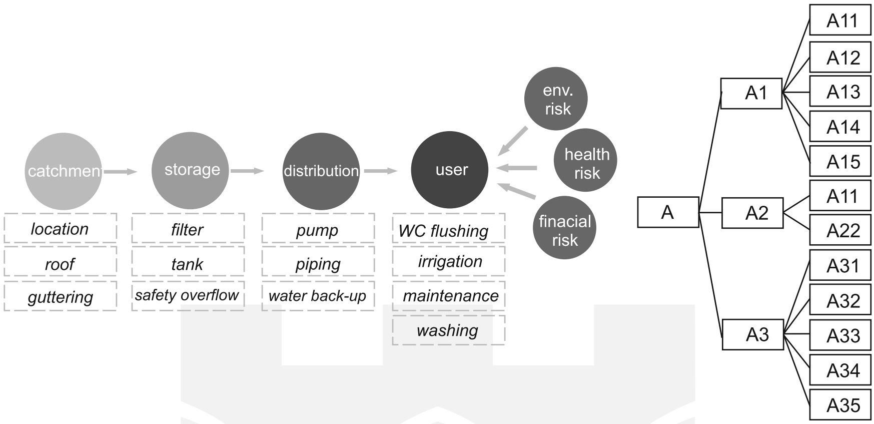

Fig. 3. Flow diagram: A – catchment, B – storage, C – distribution, D – user-each part was divided into subsections (A1, A2, A3, B1, etc.) and the last level of our system contains potential hazards (A11, A12, A13, A21, A31)

The objective of our work was to prepare risk analysis methodology for small scale RWH projects in particular. The methodology was applied on an experimental family house with an RWH system where rainwater will be used for flushing toilets, irrigation and potentially for washing machine usage as well.

The risk score consistent with semi-quantitative methodology is determined in accordance with this formula [4]:

Risk = likelihood of occurrence x severity of consequence

The risk is determined by multiplying these two values. This approach allows us to distinguish serious risks from minor ones and to determine priorities both for their prevention and their elimination.

Table 1

Table of risk scores resulting from the semi-quantitative risk matrix

risk score	1–3	4–6	8–10	12–16	20–25
risk rating	very low	low	medium	high	very high

All potential hazards with a risk score of 9 or higher were taken into further consideration. The risk score value of 9 constitutes our point of division. This value was chosen by the team of experts based on their knowledge; it is a noticeably subjective value.

The team can choose whatever point of division or can consider all of the potential hazards. However, we have chosen this value and have taken into further consideration and evaluation only those potential hazards with the risk score of 9 or higher. These potential hazards can be found in Table 2.

Table 2

Identified potential hazards with the risk score of 9 or higher

sub-system	**potential hazards**
location	microbiological contamination
	dustiness
	drought
guttering	modificationand maintenance
filters	upgrade and maintenance
tank	under sizing
	over sizing
	microbiological contamination
	upgradeand maintenance
pump	clogging
WC flushing	toilet lid closing
	joint bathroom and toilet
	inhalation of dangerous microbes

We have observed that the risk level of the system is not high at all. What is the most important aspect of this RWH system evaluation are thorough and regular system upgrades and maintenance and good knowledge of the system function by its users.

The results of this semi-quantitative risk analysis were verified by other mathematical methods and a questionnaire. The questionnaire facilitated the identification and assessment of risks. According to the respondents (who included construction companies' staff and other professionals) the parts of the RWH system most risk-prone include the pump, filters and the tank. We can find these parts mentioned in the results section of our risk analysis as well.

The mathematical method was also useful in this process. The most objective and appropriate method amidst mathematical methods is the AHP (which stands for Analytic Hierarchy Process). The highest significance as indicated by this method was attributed to location, pump, filter and tank. These verification methods show that the results obtained through the semi-quantitative method can be considered valid. Based on that, easy-to-use control measures for the RWH systems can be designed in order to reduce potential hazards to minimum or eliminate them even if the system is considered non-risky.

3. Discussion and conclusion

What must be indicated is that even if we focus our attention only on some parts of the system, its other component parts are equally essential due to the interconnectedness of the system. Failure to maintain one part the system can lead to potential risks in its other parts. Good knowledge of the system being used is equally imperative [5].

It must also be mentioned that even if we work with numbers and methods which are considered objective, the interpretation of given evaluations and evaluation input is subjective and based on the knowledge of a team of experts. In this kind of evaluation it is impossible to exclude a level of subjectivity [6].

The risk assessment provides a checklist for users of RWH systems, enabling them to use this list of questions to perform regular system checks, to be informed about their system and serving also as a prevention tool [7].

3.1. Conclusion

Systems using rainwater are well-known, although they are not widespread enough in our country yet. The use of this alternative water resource, as well as other resources, definitely offers many benefits, however, the risks should not be ignored. The risks are associated with any activity we do in our everyday life. Early risk identification allows us to prevent potential hazardous events, which is crucial for proper system functioning and user satisfaction. In conclusion, it can be stated that most risk event-prone parts of RWH include the pump, filter, tank and the location itself. The goal is to design an easy-to-use risk management approach in order to prevent potential hazardous events, especially for small-scale RWH projects consistent with this experimental one.

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