

# Rainwater harvesting and greywater recycling as alternative water resources: a survey of public opinion

Agnieszka Stec<sup>1,\*</sup>

<sup>1</sup>Department of Infrastructure and Water Management, Rzeszow University of Technology, al. Powstańców Warszawy 6, 35-959 Rzeszów

**Abstract.** This paper reports results from a survey of households in Poland concerning the use of alternative sources of water. Research showed that respondents were not too inclined to replace water from the water supply with greywater and rainwater. They would be afraid of using both greywater (79%) and rainwater (60%) in their household. The biggest concern was the use of alternative sources of water for doing laundry - more than 50% of respondents identified this issue in both cases. Only 43% of respondents would like to install a greywater recycling system and much more -78% a rainwater harvesting system. For the vast majority of respondents (80%) a subsidy would be an incentive for using these systems in their household.

## 1 Introduction

Water is the basic natural resource for social and economic development in the world. Therefore, water management should be implemented in a sustainable way, and the actions taken should result in its protection not only in terms of quality but also quantity, which was recorded as one of the Millennium Development Goals [1].

Over the past few decades the global demand for water has risen dramatically, and it is forecasted to continue to rise to 55% by 2050 [2]. The unequal distribution of the world's water resources, and their over-exploitation in many regions, generate the problem of access to safe drinking water. It is estimated that this problem affects more than one billion people globally. Water resources are also affected by climate changes and the intensification of the urbanization process, which also causes significant hydrological changes in catchment areas and hydraulic changes in sewage systems [3-8].

Taking into consideration the fact that cities consume almost 70% of the world's resources, including water resources, a modern economy that is based on sustainable consumption and the use of alternative sources of water such as rainwater and greywater [9-12] is needed. In recent years there has been an increase in the ecological awareness of the public, which has resulted in more and more buildings with a reduced demand for water and energy [13-17].

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\* Corresponding author: [stec\\_aga@prz.edu.pl](mailto:stec_aga@prz.edu.pl)

Due to the low degree of pollution and the ease with which it can be obtained, the most attractive source is rainwater. Taking into account hygiene considerations, it is also the most socially acceptable source [18-19]. Harvested rainwater, depending on the system applied, can be used as potable water as well as non-potable water [20-22]. In developing countries, rainwater harvesting systems (RWHS) are primarily used to solve drinking water shortages and for other uses; and in developed countries, as a complement to the traditional water supply system used for toilet flushing, irrigation and the washing of clothes [ 23-25].

The second alternative water source in a building may be greywater which, according to European standards [26], is defined as sewage free of faeces and urine. Greywater recycling systems are mainly used to replace potable water intended for toilet flushing and garden irrigation [27], sometimes including rainwater [28].

In Poland, despite the fact that the quality of potable water is one of the poorest in Europe, rainwater and greywater as an alternative source of water is still being used to a limited extent. Considering this, it was decided that a survey be carried out to determine the causes of such a situation. The results of these studies were intended to answer two main questions: (1) Does the environment have a low ecological awareness or (2) Do hygiene or financial considerations prevent the use of unconventional water supply systems in buildings?

## 2 Methodology

A questionnaire consisting of 13 questions: 4 concerning general information about the respondents and 9 on water conservation issues, as well as the possibilities of using alternative sources of water were developed for the purpose of conducting the research. The survey was conducted in 200 households located in Podkarpackie Province which is located in the south-eastern part of Poland. Because of the topic of the questionnaire, statistical units were selected in a targeted manner. The target selection was based on the informed decision of the researcher in selecting the elements of the population.

Statistical Package for Social Sciences (SPSS), which is a widely used statistical analysis tool in both the social and technical sciences, was used to develop the survey.

Since the results of the questionnaire allowed the determination of mainly non-measurable (qualitative) statistics, the significance of the differences between the qualitative (nominal) variables was checked using the Chi-squared independence test. The formula (1) was used to calculate its value.

$$\chi^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

where:  $O_i$  – observed value,  $E_i$  – expected value.

In the statistical analyses, the significance level of  $p < 0,05$  was assumed.

## 3 Result and discussion

### 3.1. An analysis of the research group

200 respondents were surveyed, of whom nearly 60% were women; the proportion of men was less than 41%. 9% of respondents were between 18 and 24 years old, 38% of respondents were aged 24 to 34 years old, 30% were aged 35 to 44 years old, 20% were aged 45 to 54 years the remaining respondents were over the age of 55 years old (5%).

The majority of respondents had a higher education (63%), 35% had a secondary education, and the lowest percentage were persons with a primary education (3%). More than half of the respondents (58%) lived in the city, while the remainder lived in the country (42%).

### 3.2. The possibilities of using alternative water sources in a building

The second part of the questionnaire, which covered 9 questions, allowed determining the level of knowledge of those surveyed about Poland's natural water resources and the possibilities of their protection by using alternative sources of water. Only 48% of respondents believed that there was a problem of potable water shortage in Poland. The majority of respondents (45%) who so claimed were over 45 years of age (71%). The Chi-squared test showed that the differences were statistically significant ( $p < 0,001$ ). Table 1 presents the results of this study.

**Table 1.** Problem of potable water shortage - distribution of responses– age division.

		Age			
		Under 35 years of age	From 35 to 45 years of age	Over 45 years of age	
Do you think there is a problem of potable water shortage in Poland?	Yes	Population% of Age	33	28	35
			35,9%	47,5%	71,4%
	No	Population% of Age	59	31	14
			64,1%	52,5%	28,6%
Chi-squared test		$\chi^2 = 16,21; p < 0,001$			

The respondents also answered questions about the reasons for their conserving water. They could indicate their willingness to reduce water fees, their need to protect water resources, or both. The main reasons for conserving water are the willingness to reduce costs (60%), slightly less frequent were those who indicated the protection of water resources (58%). Chi-squared analysis revealed that urban dwellers (67%) were more likely to report economic reasons than the rural population (49%) ( $p = 0,012$ ). The results of these studies are summarized in table 2.

**Table 2.** Reasons of saving water.

		Place of living				Chi-squared test	
		Village		City			
		n	%	n	%	$\chi^2$	p
Water resources protection	% indications	51	60,0%	64	55,7%	0,38	0,539
Reduction of fees for water	% indications	42	49,4%	77	67,0%	6,24	0,012

The vast majority of respondents claimed that their households were conserving water (87%). The most common manifestations were: turning off the tap while brushing teeth (67%), running the washing machine only when it was full (63%), taking a shower instead of bathing in a tub (57%) and maintaining the taps (57%). Less time was spent washing dishes in the dishwasher (45%) and running the dishwasher only when it was full (39%). More often, the dishwasher was used by people aged 35-45 years (68%) than younger

(33%) or older (45%) users. The difference between the age groups was statistically significant ( $p = 0,001$ ).

The average Pole consumes 120 liters of water per day. Nearly 60% of respondents knew that nearly half of this amount could be replaced by lower quality water: rainwater or greywater.

The most important questions in the survey, which would indicate the reasons for a low interest in alternative water supply systems in Poland, were formulated as follows:

1. Would you be concerned about the use of greywater in your household for the following purposes: to flush the toilet, to do the laundry, to water the garden, to clean, to wash the car?
2. Would you like to use a greywater system in your household? If NO, please indicate the reasons (hygienic considerations, high capital expenditure).
3. Would you be concerned about the use of rainwater in your household for the following purposes: to flush the toilet, to do the laundry, to water the garden, to clean, to wash the car?
4. Would you like to use a rainwater system in your household? If NO, please indicate the reasons (hygienic considerations, high capital expenditure).

Most respondents were concerned about the use of greywater in their households (79%). Women were more worried (84%) than men (72%). The difference between them in the response distribution is statistically significant ( $p = 0,034$ ) (Table 3). The biggest concern was the use of clean greywater for washing (57%), cleaning work (49%), garden watering (38%), car wash (28%) or toilet flushing (27%).

**Table 3.** The use of greywater - distribution of responses – gender division.

			Gender of respondent	
			Female	Male
Would you be afraid to use greywater in your household?	Yes	Population %	100	58
		% of Sex	84,0%	71,6%
	No	Population % of Sex	19	23
			16,8%	29,6%
Chi-squared test			$\chi^2 = 4,49; p = 0,034$	

60% of respondents would be afraid of using rainwater in their households. Women were more concerned (66%) than men (51%). The difference is statistically significant ( $p = 0.025$ ) (Table 4). The greatest concern was the use of rainwater for washing (51%), less for cleaning work (33%). The least concern was the use of rainwater to clean the toilet bowl (19%), car wash (14%), or to water a garden (11%).

43% of respondents would like to use the system of using greywater in their household. Most were respondents from 35 to 45 years of age (56%), less often in those over 45 years of age (41%), and the least in those under 36% (36%). The distribution of responses in this area is summarized in Table 5. The main reasons why respondents would not like to use the greywater system in their household are hygiene (50,5%) and investment outlays (14%).

**Table 4.** The use of greywater - distribution of responses – gender division.

			Gender of respondent	
			Female	Male
Would you be afraid to use rainwater in your household?	Yes	Population% of Sex	79 66,4%	41 50,6%
	No	Population% of Sex	40 33,6%	40 49,4%
Chi-squared test			$\chi^2 = 4,99; p = 0,025$	

**Table 5.** A possibility of greywater system application – distribution of responses – age division.

			Age		
			Under 35 years of age	From 35 to 45 years of age	Over 45 years of age
Would you like to use a greywater system in your household?	Yes	Population% of Age	33 35,9%	33 55,9%	20 40,8%
	No	Population% of Age	59 64,1%	26 44,1%	29 59,2%
Chi-squared test			$\chi^2 = 6,03; p = 0,049$		

Nearly 78% of respondents would like to use a rainwater system in their household. Table 6 shows a detailed distribution of the answers to this question. No statistically significant differences were found.

The respondents who did not want to use such a system mentioned higher investment outlays (12%) and hygiene (12%) as a cause.

Taking into account the actions of many countries supporting the use of alternative sources of water, respondents were also asked whether subsidies would encourage them to use a rainwater recycling system and recycle greywater in their households. The vast majority of respondents answered affirmatively (80%).

**Table 6.** The possibility of rainwater system application – distribution of responses – age division.

			Age		
			Under 35 years of age	From 35 to 45 years of age	Over 45 years of age
Would you like to use a rainwater system in your household?	Yes	Population% of Age	67 72,8%	44 74,6%	44 89,8%
	No	Population % of Age	25 27,2%	15 25,4%	5 10,2%
Chi-squared test			$\chi^2 = 5,69; p = 0,058$		

## 4 Conclusions

Rainwater harvesting systems have been used for decades in the developing world as well as in developed countries. On the other hand, greywater recycling systems have gained popularity over time with the development of technology for their recycling. The reasons for using these systems as an alternative water source vary. In the vast majority of cases this is the answer to the water deficit or the desire to save tap water. However, in Poland, although water quality is one of the poorest among the countries of Europe, alternative sources of water in the form of rainwater and greywater are rarely used. Taking into account the surveys, the purpose was to determine the causes of such a situation.

The obtained results demonstrated that in all probability the main reason for installing a small number of analyzed systems in Poland is the low awareness in society about its small water resources and the possibility of partial replacement with alternative water sources. More than 50% of respondents claimed that in Poland the problem of a shortage of potable water was did not exist. However, it is worth noting that most respondents (87%) conserve water in their households through daily activities such as turning off the tap while brushing their teeth (67%), running the washing machine only when full (63%), taking a shower instead of bathing in the tub (57%) and washing dishes in the dishwasher (45%).

Most respondents would be concerned about the use of greywater (79%) and rainwater (60%) in their household. The biggest concern was the use of alternative sources of water for washing - more than 50% of respondents identified this issue in both cases. The respondents were more inclined to use rainwater than greywater. This trend was noticeable for each of the analyzed objectives. For example, 89% of the respondents would in fact water the garden with rainwater, yet only 62% with purified greywater, 67% would use rainwater for cleaning purposes and 51% would use greywater.

43% of respondents would like to use a recycling system for greywater in their households. More than half of those who did not install such a system in their home indicated the reasons as hygiene. Much better is the situation with respect to rainwater harvesting systems. Nearly 78% of respondents would like to use this solution in their households.

In Poland there is the public's conviction deeming the installation of unconventional water supply systems as unprofitable. This was also confirmed in the results of the survey, where 80% of respondents indicated that subsidies would provide them with a large incentive to implement these systems. This belief is mainly due to the lack of social campaigns promoting alternative sources of water as well as information about the financial and environmental benefits of using them. The fact that the use of rainwater harvesting systems and greywater recycling systems is also financially viable in Polish conditions has been confirmed in studies by Słyś and Stec [23, 29]. An increase in interest in these systems in Poland could also be attributed to a change in law, the governmental and non-governmental funding for the installation of these systems and the introduction of lower taxes for those who would apply such solutions in their buildings.

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