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Modelling Possible Household Uses of Grey Water in Poland using Property Fitting Analysis

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Abstract: One of the most important methods of optimising water consumption is grey water recycling. From a technological point of view, the treatment of grey water guarantees that it can be reused for domestic or corporate purposes, but it raises the issue of the social acceptance of the use of such water. This study aimed to assess the possibility of using grey water in households in Poland. The originality of this research study lies in the application of the PROFIT method for the separate construction of models of the benefits of grey water according to user groups. Four groups were identified, differentiated by gender and age; age and possession of an irretrievable water meter; gender and place of residence; place of residence and possession of an irretrievable water meter. To answer the formulated research questions, a diagnostic survey method was used, in which 807 randomly selected respondents from all over Poland were surveyed. The results of the survey indicate that homeowners perceive the potential use of grey water as beneficial, pointing most often to the following factors: rebuilding groundwater levels, reduced extraction of drinking water from rivers and other water bodies, and increased vegetation growth. On the other hand, they are concerned about the need to reconstruct the existing water and sewerage systems in order to produce drinking water from grey water as well as about the high cost and parameter stability of drinking water produced from grey water. Furthermore, men and older people attribute less importance to measures related to the introduction of good practices based on the reuse of recycled water in water management. Women, on the other hand, appreciate almost all opportunities to use grey water to a greater extent than men.

Keywords: water; grey wastewater; water recycling; water conservation; water treatment; water resources

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1. Introduction

Water is an essential element for the life and development of living organisms, including humans. Water is particularly important for the proper functioning of humans, as it represents approximately 60% of the total body weight of an adult. The Earth's water resources are limited and the amount of water in its various states of aggregation is fixed, so it is particularly important to minimise its use efficiently. Almost a quarter of the world's population does not have access to potable water [1]. Fresh water accounts for only 2% of the world's resources [2]. Built areas have large paved surfaces, making rainwater storage and use essential for sustainable water management [3]. The water environment is vulnerable to pollution and the impact of human activities [4]. Increasingly, restrictions on tap water use for plant watering purposes are being introduced on warm days [5]. Much of this water can be saved and reused [6]. In Poland, the average water consumption per day is approximately 110 L, with showering taking up 50 L and bathing between 50 and 100 L [7].

The Water Framework Directive aims to improve the quality of surface- and groundwater, maintaining a sustainable balance between natural phenomena and human activities, in accordance with the principle of sustainable development. The quality of microbiological water can change rapidly and over a wide range of areas [8]. All standards for the microbiological, organoleptic, physicochemical, and radiological requirements that drinking water must meet are defined by relevant regulations [9].

Water deficits are becoming an increasingly serious challenge as a result of increasing population and low growth in gross domestic product [10,11]. The latter factor significantly limits opportunities to invest in the rational use of arable land and water resources [12]. Furthermore, the world's water resources are unevenly distributed across the world and across regions, and most rivers are transboundary in nature [13,14]. Transporting drinking water over long distances is not cheap [15]. By 2030, water shortages are projected to affect 40% of the population. This problem affects many countries, both highly developed and underdeveloped [16].

The availability of water and the amount of its resources is also an important topic in Poland. The greatest interest in this issue can be seen during summer, when water supply difficulties arise in various parts of the country [17]. In 2019, in up to 300 municipalities, the authorities appealed to residents to reduce their water consumption. Limited water availability and the appearance of droughts are increasingly influenced by climate change [18]. Forecasts indicate that the problem will intensify. Rising temperatures and especially increasingly frequent summer heat waves contribute to water loss through evaporation [19]. A major problem in Poland is the unfavourable hydrological situation due to relatively small water resources. There are also many concerns about the management of water and sewerage services and the outdated and highly failing infrastructure [20]. The average water resources in Poland are approximately 60 billion m^3, and in dry seasons, this level decreases to 40 billion m3. The largest water resources in Europe are held by Norway, Sweden, France, and Germany [21].

The simplest way to save water is to reduce water abstraction [22]. Optimising the use of limited water resources is being addressed by new technologies, including grey and rainwater recycling [23]. An important solution in the area of water treatment is the recycling of grey water, called grey wastewater. This method is increasingly popular in highly developed and developing countries [24]. Grey water is used for non-food purposes, but for reasons of hygiene, aesthetics, usability, and sanitary safety, it is necessary to treat it beforehand [25]. Increasing public awareness contributes to improving methods, tools, and materials in the construction of increasingly sophisticated water and wastewater infrastructure while minimising expenditures and managing risks associated with socioeconomic and climate change impacts [26].

Changing the approach to water recovery and recirculation is a major challenge in the transformation of economies around the world [27–29]. Today, several technologies can be used for water conservation and purification, including but not limited to aerators in tap faucets or autonomous buildings designed to function regardless of external infrastructure [30]. In houses and flats, dual grey water treatment installations can be used to reduce water consumption [31]. A prerequisite for the use of dual systems is that grey water adequately covers water demand and that the technical solution introduced is economically viable [32]. The use of dual water and wastewater systems for the recovery of water from domestic wastewater should be characterised by appropriately selected technology. These new technologies are increasingly being used by large companies and entrepreneurs who want to operate according to the concept of zero-energy buildings [33–36].

From a technological point of view, the treatment of grey water guarantees that it can be reused for domestic or corporate purposes, but this raises the issue of the social and sanitary acceptance of the use of such water and the requirements of the Minister of Health. Studies available in the literature deal with water recycling research and only address technical issues, focussing on engineering details. What is lacking is a holistic approach that also takes into account the public opinion on the issue of water recycling.

Unfortunately, without social acceptance, it will be difficult to implement technologically innovative installations using treated grey water. To fill the above-identified gap, the authors conducted a survey to assess the possibility of using grey water in households in Poland. An additional novelty and originality of the analysis we carried out was the separate construction of models of the benefits of grey water use according to user groups. Four different groups were identified, differentiated by the following characteristics: gender and age; age and possession of an irretrievable water meter; gender and place of residence; place of residence and possession of an irretrievable water meter. In doing so, it was assumed that answers to the following eight research questions (Q1–Q8) would be verified: (Q1) What benefits of using grey water are the most recognised in households?; (Q2) What are residents most concerned about when using recycled drinking water?; (Q3) Does gender and/or age influence the assessment of the importance of introducing good practices based on the reuse of recycled water in water management?; (Q4) Does the assessment of grey water use differ between men and women?; (Q5) Does the age of residents make a difference in their assessment of their ability to use grey water?; (Q6) Does residents' ownership of an irretrievable water meter differentiate their assessment of their ability to use grey water?; (Q7) Do house and flat dwellers differ in their assessment of grey water use options?; (Q8) What benefits have the potential to convince residents to use recycled water, taking into account their different situations in terms of gender, age, place of residence, and/or having an irretrievable water meter?

The next section of this manuscript presents a literature analysis to briefly characterise the issue of grey water management. The third section presents the research methods and tools used during this study and discusses the research sample. The fourth section presents the overall results of this study with a discussion and builds models of the benefits of grey water use in different user groups. The final section summarises the results obtained and presents possibilities for practical applications and future research in this area.

2. Theoretical Background

In households, two types of wastewater are generated: black wastewater and grey wastewater, which falls into the category of urban wastewater. Black sewage is generated by flushing the toilet and grey sewage is generated by the use of water for other purposes, such as showering, bathing, and dishwashing [37]. Grey water, according to EN 12056-1 [38], is dirty but faeces-free water and can include non-industrial wastewater generated during domestic processes such as showering, bathing, or washing dishes [6,39]. Some definitions separate wastewater into light grey wastewater, which comes from sinks, baths, and showers, and heavily polluted dark grey wastewater, which comes from washing machines and kitchen sinks. This view excludes wastewater from kitchen sinks and washing machines from grey wastewater [40].

In households, around 50–80% of the generated wastewater is grey water. It differs from black sewage in terms of quantity, chemistry, and bacteria. Grey sewage comprises wastewater from buildings intended for human habitation, i.e., residential areas and service areas, and results from the human metabolism and the operation of households [41]. It is determined by parameters such as suspended solids, turbidity, COD5, total nitrogen and phosphorus content, and level of bacteriological contamination, expressed in terms of total faecal coliform bacteria [42].

The physicochemical and biological composition of grey wastewater varies depending on its source [7]. The concentration of individual pollutants in grey wastewater is determined by its place of origin [43]. Grey wastewater contains organic pollutants that decompose rapidly compared to black wastewater. Grey water is characterised by a poor mineral content and contains 10% total nitrogen. The amount of phosphorus depends on the phosphate content of the washing and cleaning agents.

Grey wastewater is less prone to bacteriological contamination than black wastewater, and the source of bacteria is often secondary contamination due to the presence of microorganisms on the walls of drain pipes [42,44]. Sink and bath wastewater has lower concentrations of physicochemical pollutants but is more microbiologically contaminated compared to other types of grey wastewater. Grey wastewater contains rapidly decomposing organic pollutants [7].

The use of technology for the reuse of grey wastewater is very beneficial in economic and environmental terms [45]. Today, grey water reuse installations are mostly found in buildings with high water consumption, where the investment pays off very quickly.

Grey water can be used to clean, flush the toilet, wash cars, water gardens, and for irrigation in agriculture [26]. According to estimates, the per capita consumption of grey water can be 55 L per day, so by using it, the consumption of drinking water can be reduced, and the amount of wastewater generated can be reduced. The use of retreated grey wastewater has the following benefits:

- reducing the abstraction of drinking water from its intakes;
- reduced environmental impact due to the lack of need for sewage networks and treatment plants;
- soil fertilisation;
- lower energy and chemical consumption compared to traditional water treatment;
- improving environmental conditions for vegetation, contributing to better growth;
- recovery of groundwater levels;
- recovery of fertilising components that would be diverted to the treatment plant in a traditional system [46].

Undoubtedly, for households, the most important benefit is the reduction in the costs of water abstraction and wastewater disposal [47]. Therefore, the use of rainwater and grey water is mainly supported by economic and environmental considerations [48]. If water and wastewater prices are maintained at a level that is acceptable to residents, i.e., a 4% share of household disposable income, changes in this respect are unlikely to occur very quickly in Poland. Increases in consumer costs prompt new pro-ecological solutions to reduce expenditure [49]. The use of high-quality water for all human living purposes is, in principle, an unjustified waste [50]. However, it should be noted that this is due to the legal regulations that water must comply with. Therefore, it becomes necessary for sanitary services to make legislative changes regarding the approval of the household use of grey water of a certain parameter, as this is not yet fully regulated.

The circular economy is a model for the functioning of the global economy that aims to make the economic growth of individual countries and regions independent of the availability, price, and quality of resources, particularly water [51]. The main assumption of this model is that the materials used in production are designed to be reused or safely reintroduced into the biosphere and that the technologies used in production cycles are environmentally benign [52]. As part of a closed-circuit economy, recycling processes should be implemented to recover waste and energy as much as possible [53]. The closed loop also refers to households in the context of their water use. As part of a closed loop, water use should be reduced, and pollutants should be reduced [52]. Such a concept implies minimising the human impact on the environment and should be implemented by both households and businesses.

3. Materials and Methods

3.1. Research Tool

This study was carried out using a diagnostic survey that used the authors' questionnaire, "Possibilities of using grey water in households". In constructing the survey questionnaire, the authors used the literature analysis method, interviews, and surveys (so far unpublished) conducted in 2020 on this issue by the Rybnik Water and Sewage Company, Poland (PWiK Rybnik Sp. z o.o.). The survey contained 16 closed questions. For most questions, respondents were asked to score their responses on a 5-point Likert scale. The issues indicated in the questions were mainly with regard to the problem of drought and water demand in Poland and the possibility of using grey water in households. The reliability of the aforementioned questionnaire was tested with Cronbach's alpha internal consistency coefficient, the result of which indicated a high level of reliability (alpha = 0.84).

Questionnaires were administered electronically via the on-line platform Interankiety.pl between 23 February 2023 and 31 May 2023. The eligibility criteria for the survey group were being over 18 years of age, being a homeowner (of a house or flat), and receiving water from the water supply on a daily basis. The respondents were informed that the survey was voluntary and anonymous and that there was the possibility of withdrawing at any stage.

3.2. Subject Matter and Methodology of Statistical Analysis

Sensitivity to the problem of water demand in Poland and the possibility of using grey water in households were the primary subjects of this statistical analysis. This study took into account both declarations concerning the existence of the problem of potable water in Poland and throughout the world and assessments of the scale of the problem of drought and water demand in Poland, assessments of the potential benefits of using grey water and the possibilities of its use, and concerns about the use of recycled drinking water. Our statistical analysis aimed to examine the level of awareness of the above-mentioned problems and opportunities among the surveyed residents, identify factors that differentiate the level of awareness, and identify the benefits of the use of grey water that could convince specific groups of people to do so.

The results of the survey were subjected to quantitative and descriptive analysis. Basic descriptive statistics were determined for all quantitative (measurable) parameters. Qualitative parameters were presented using counts (n) and percentages (%).

Statistical verification of the collected material consisted first of all of an analysis of the overall results of the survey, to find out the level of awareness of the surveyed people about the problem of water demand in Poland and the possibility of using grey water.

In the next step, using PROFIT analysis, models were developed for the benefits of grey water use in different groups according to factors such as gender, age, owning an irretrievable water meter, and place of residence.

The first stage of PROFIT analysis for the set of objects $A = \{A_1, \ldots, A_n\}$ and the dissimilarities δ_{ij} between A_i and A_j ($i, j = 1, \ldots, n$) consisted of creating, using multidimensional scaling methods, a perceptual map of objects in the r-dimensional space (r is usually equal to 2 or 3) so that:

$$d_{ij} = \hat{d}_{ij} = f(\delta_{ij})$$

where:

d_{ij}—reconstructed distance between points i and j;

δ_{ij}—distance between points i and j for the input data (observed distances);

$\hat{d}_{ij}$—regression function between d_{ij} and δ_{ij}.

The magnitudes of $\hat{d}_{ij}$ were determined to minimise the value of the STRESS (Standardised Residual Sum of Squares) fitting function. This was because the quality of the fit of the reconstructed data to the input data is measured by the above-mentioned STRESS function, and the smaller its value, the better the fit of the reconstructed distance matrix to the observed distance matrix. The STRESS function took the following form:

$$\phi = \sqrt{\frac{\sum\sum\left(d_{ij} - f(\delta_{ij})\right)^2}{\sum\sum d_{ij}^2}}$$

where:

d_{ij}—reconstructed distance between points i and j;

δ_{ij}—distance between points i and j for input data (observed distances);

$f(\delta_{ij})$—function of the input data.

As a result of the use of multidimensional scaling, in the case of a two-dimensional perceptual map, each object was described by two coordinates.

As a first step, a model of the benefits of grey water use was built in groups distinguished by gender and age. In this model, the following groups were analysed:

- Women up to 34 years of age (K/34);
- Women aged 35–44 years (K/35–44 years);
- Women aged 45–54 years (K/45–54 years);
- Women aged 55 and over (K/55);
- Men up to 34 years of age (M/34);
- Men aged 35–44 years (M/35–44 years);
- Men aged 45–54 years (M/45–54 years);
- Men aged 55 and over (M/55).

The individual benefits of grey water use were taken as variables (features) in the developed model and were defined as follows:

- Reduced abstraction of drinking water from rivers and other water bodies (C1);
- Lower environmental impact due to the lack of a sewage network and treatment plant (C2);
- Reduction in pressure on water and sewerage networks due to lower water abstraction and less wastewater (C3);
- Soil fertilisation (C4);
- Lower energy and chemical consumption compared to traditional water treatment (C5);
- Recovery of groundwater levels (C6);
- Increased vegetation growth (C7);
- Recovery of fertilising nutrients that would have been diverted to the treatment plant in the traditional system (C8).

To begin building a model of the benefits of grey water use in groups distinguished by gender and age, multidimensional scaling was performed to develop a graphical representation of the structure of similarity (or dissimilarity) between the objects analysed in relation to a selected set of variables (characteristics). The identical nature of the analysed characteristics (5-point Likert scale) as variables precluded the need to standardise them. Classical Euclidean distance was used for multidimensional scaling, and consequently, the three features describing the four objects were reduced to two dimensions. The STRESS coefficient for multidimensional scaling, including all features, was 0.00, indicating a high reliability of the results of the multidimensional scaling procedure.

The fit of the individual objects was then verified. For this purpose, a regression analysis was performed in which the explanatory variable was the ratings of the individual benefits of grey water use and the explanatory variables were the values of the two dimensions for each unit obtained by multidimensional scaling: DIM.1 and DIM.2. To recognise a given grey water use as a key benefit, it was assumed that it has a fit of $R^2 > 0.70$. The final stage of this part of the analysis was to develop, using PROFIT analysis, a model of the benefits of grey water use along each dimension in relation to gender and age.

In the next step, an analogous model was built, i.e., the benefits of grey water use in groups distinguished by age and the possession of an irretrievable water meter. In this case, the following groups were analysed:

- Persons up to 34 years of age who possess an irretrievable water meter (34/L);
- Persons up to 34 years of age who do not possess an irretrievable water meter (34/B);
- Persons aged 35–44 years who possess an irretrievable water meter (35–44/L);
- Persons aged 35–44 years who do not possess an irretrievable water meter (35–44/B);
- Persons aged 45–54 years who possess an irretrievable water meter (45–54/L);
- Persons aged 45–54 years who do not possess an irretrievable water meter (45–54/B);
- Persons 55 and over who possess an irretrievable water meter (55/L);
- Persons 55 and over who do not possess an irretrievable water meter (55/B).

The variables (characteristics) in this model overlapped with the previous model, i.e., they were the individual benefits of grey water use. As before, the construction of a model of the benefits of grey water use in groups distinguished by age and possession of an irretrievable water meter consisted, first of all, of performing multidimensional scaling in order to develop a graphical representation of the structure of similarity (or dissimilarity) between the analysed objects in relation to a selected set of variables (features). The STRESS coefficient obtained for multidimensional scaling, taking into account all characteristics, was 0.00, indicating a high reliability of the results of the multidimensional scaling procedure.

The next step consisted of verifying the fit of the individual sites by means of a regression analysis in which the explanatory variable was the ratings of the individual benefits of grey water use, and the explanatory variables were the values of the two dimensions for each unit obtained by multidimensional scaling: DIM.1 and DIM.2. Finally, a model of the use of the benefits of grey water in each dimension in relation to age and owning an irretrievable water meter was developed using PROFIT analysis.

Further analyses consisted of building an analogous model, that is, the benefits of grey water use in groups distinguished by gender and place of residence. In this model, the following groups were analysed:

- Women who live in a house (K/D);
- Women who live in a flat (K/M);
- Men who live in a house (M/D);
- Men who live in a flat (M/M);

The variables (characteristics) in this model overlapped with the previous ones, i.e., they were the individual benefits of grey water use. At the beginning of the construction of the model of the benefits resulting from the use of grey water in groups distinguished by gender and place of residence, analogously as before, multidimensional scaling was performed in order to develop a graphical representation of the structure of similarity (or dissimilarity) between the analysed objects in relation to a selected set of variables (features). The STRESS coefficient obtained for multidimensional scaling, taking into account all characteristics, was 0.00, indicating a high reliability of the results of the multidimensional scaling procedure.

The fit of the individual sites was then checked using a regression analysis in which the explanatory variable was the ratings of the individual benefits of grey water use, and the explanatory variables were the values of the two dimensions for each unit obtained by multidimensional scaling: DIM.1 and DIM.2. As a final step, a model of the benefits of grey water use was developed across dimensions in relation to gender and place of residence using PROFIT analysis.

Finally, an analogous model was built, i.e., the benefits of grey water use in groups distinguished by place of residence and possession of an irretrievable water meter. The objects analysed in this model were the following groups:

- People who live in a house and possess an irretrievable water meter (D/L);
- People who live in a house and do not possess an irretrievable water meter (D/B);
- People who live in a flat and possess an irretrievable water meter (M/L);
- People who live in a flat and do not possess an irretrievable water meter (M/B).

Also in this model, the variables (characteristics) overlapped with the previous ones, i.e., they were the individual benefits of grey water use. As part of the efforts to build a model of the benefits of grey water use in groups distinguished by place of residence and possession of an irretrievable water meter, multidimensional scaling was performed—as before—to develop a graphical representation of the structure of similarity (or dissimilarity) between the analysed objects in relation to a selected set of variables (characteristics). The STRESS coefficient obtained for the multidimensional scaling, taking into account all features, was 0.00, which unequivocally indicated a high reliability of the results of the multidimensional scaling procedure.

In the next step, the fit of the individual sites was examined by means of a regression analysis in which the explanatory variable was the ratings of the individual benefits of grey water use and the explanatory variables were the values of the two dimensions for each unit obtained by multidimensional scaling: DIM.1 and DIM.2. A model of the benefits of grey water use along each dimension in relation to residence and ownership of an irretrievable water meter was then developed using PROFIT analysis.

Statistical analyses were performed using Statistica v.13.3 PL from StatSoft Polska, Cracow, Poland. A 5% inference error and an associated significance level of $p < 0.05$ were adopted to indicate the existence of statistically significant differences or correlations.

3.3. Characteristics of the Research Sample

The sociodemographic characteristics of the respondents are shown in Table 1. In Poland, it is possible to have separate water meters depending on the use of the water. A main water meter assumes the consumption of water and its discharge to wastewater. Then, the water consumed and the wastewater discharged are charged for, respectively. A second, optional "irretrievable water meter" means that water does not return to the sewerage system as wastewater because it is used, for example, to water the garden, water flowers at home, or fill swimming pools.

Table 1. Sociodemographic characteristics of the respondents.

		n	%
Gender	Women	350	43.37%
	Men	448	55.51%
	Other	9	1.12%
Age	Up to 24 years	28	3.47%
	25–34 years	88	10.90%
	35–44 years	200	24.78%
	45–54 years	224	27.76%
	55 and over	267	33.09%
Education	Basic	5	0.62%
	Basic vocational	64	7.93%
	Secondary	251	31.10%
	Higher	487	60.35%
Owning an irretrievable water meter	Yes	350	43.37%
	No	457	56.63%
Place of residence	House	683	84.63%
	Flat	124	15.37%

The formula for qualitative characteristics with a finite sample was used to estimate the minimum sample size [54]. The size of the estimated fraction was assumed on the basis of data from the Central Statistical Office on the working-age population (18–59 for women and 18–64 for men) and the post-working age population (60 and older for women and 65 and over for men), which, in 2022, constituted 58.70% and 22.90% of the total population, respectively, amounting to 37,766.30. On this basis, the size of the working age population was estimated at 22,168.82 and the post-working age population at 8648.48. The total size of the estimated fraction was 30,817.30 people [55], of whom 50.00% were assumed to receive water from the water supply system. Furthermore, it was assumed with 95% probability that the result obtained in this study would not deviate from the actual population value in the population by more than 5%. The minimum sample size estimated in this way was 384. Therefore, the sample size (N = 807) exceeded its minimum level by more than double.

4. Results and Discussion

4.1. Analysis of Overall Performance

To begin with, the general results of the survey were evaluated. Respondents were overwhelmingly aware of the problem of drinking water shortages in Poland (78.07%), and even more were aware of the problem worldwide (92.32%).

The respondents rated the degree of the prolongation of drought periods and the disappearance of water sources in Poland on a scale of 1 to 5, with a mean (M) = 3.28 and standard deviation (SD) = 1.02. The degree of increased water demand in Poland was slightly higher among respondents (M = 3.62; SD = 0.98), and the degree of importance of finding new technologies to obtain drinking water from non-traditional sources was higher, respectively (M = 4.31; SD = 1.07). Half of the respondents rated the degree of the above phenomena and the needs at a minimum of 3, 4, and 5, respectively (Table 2).

Table 2. Respondents' awareness of the problem of drought and the need for water in Poland.

	Descriptive Statistics					
	Mean ± Standard Deviation	Median (Q25–Q75)	Min.–Max.	Confidence Interval		Stand Error.
				−95.00%	+95.00%	
Evaluation of the extent to which drought periods are increasing and water sources are disappearing in Poland	3.28 ± 1.02	3 (3–4)	1–5	3.21	3.35	0.04
Assessment of the extent to which water demand is increasing in Poland	3.62 ± 0.98	4 (3–4)	1–5	3.56	3.69	0.03
Assessment of the degree of importance of exploring new technologies for obtaining drinking water from non-traditional sources	4.31 ± 1.07	5 (4–5)	1–5	4.23	4.38	0.04

The main benefits of using grey water, according to the respondents, were the restoration of groundwater levels, reduced abstraction of drinking water from rivers and other water bodies, and increased vegetation growth. They placed slightly less importance on benefits such as the recovery of fertilisation nutrients that would have been diverted to the treatment plant in the traditional system and reduced energy and chemical use compared to traditional water treatment. This was followed by the benefits of soil fertilisation and less environmental impact due to the lack of having to build a sewer network and treatment plant. In addition, the least rated benefit of using grey water was a reduction in pressure on the water supply and sewerage network due to a lower level of water abstraction and less wastewater (Table 3).

Table 3. Potential benefits of using grey water as rated by the respondents.

	Descriptive Statistics					
	Mean ± Standard Deviation	Median (Q25–Q75)	Min.–Max.	Confidence Interval		Stand Error.
				−95.00%	+95.00%	
Reduced abstraction of drinking water from rivers and other water bodies	3.53 ± 1.23	4 (3–5)	1–5	3.45	3.62	0.04
Reduced environmental impact	3.17 ± 1.3	3 (2–4)	1–5	3.08	3.26	0.05
Reducing pressure on the water supply and sewerage network	2.99 ± 1.27	3 (2–4)	1–5	2.91	3.08	0.04
Soil fertilisation	3.26 ± 1.32	3 (2–4)	1–5	3.17	3.35	0.05
Reduced energy and chemical consumption	3.32 ± 1.27	3 (3–4)	1–5	3.24	3.41	0.04
Groundwater level recovery	3.57 ± 1.24	4 (3–5)	1–5	3.48	3.65	0.04
Increased vegetation growth	3.47 ± 1.26	4 (3–5)	1–5	3.38	3.56	0.04
Recovery of fertiliser components	3.33 ± 1.25	3 (3–4)	1–5	3.24	3.42	0.04

The respondents believed treated grey water could primarily be used for industrial purposes (M = 4.18; SD = 1.1) and soil irrigation (M = 4.09; SD = 1.14). The respondents were open to the possibility of using treated grey water as a source of drinking water to a much smaller extent (M = 2.13; SD = 1.24).

When comparing the results obtained with those of similar studies, some similarities and differences can be observed. A study conducted in Istanbul indicated that participants would be the most willing to use grey water to flush toilets (79%). However, only 25% of the respondents were willing to use grey water for cooking [56]. In contrast, research conducted in Oman indicated that acceptable uses of treated grey water mainly included watering plants, washing floors, landscaping, and flushing toilets [57]. Other studies indicated that people would readily use treated grey water for purposes such as laundry, toilet flushing, car washing, and vegetable irrigation [58,59].

In relation to the use of recycled drinking water, respondents were more concerned about the need to reconfigure existing plumbing to produce drinking water from grey water. There was slightly less concern among the respondents about the high cost and the stability of the parameters of drinking water produced from grey water. Respondents were also significantly concerned about the quality of the technology for producing drinking water from grey water. In contrast, the respondents were the least concerned about the use of any form of recycled grey water.

The low scores for lack of concern about the use of grey water are indicative of the fact that the prospect of using recycled drinking water is problematic for respondents (Table 4).

Table 4. Degree of individual concerns about the use of recycled drinking water.

	Descriptive Statistics					
	Mean ± Standard Deviation	Median (Q25–Q75)	Min.–Max.	Confidence Interval −95.00%	Confidence Interval +95.00%	Stand Error.
I am concerned about any form of grey water use	2.56 ± 1.33	2 (1–4)	1–5	2.47	2.65	0.05
Concerns about the quality of technology to produce drinking water from grey water	3.1 ± 1.33	3 (2–4)	1–5	3.01	3.19	0.05
Concerns about the parameter stability of drinking water produced from grey water	3.24 ± 1.32	3 (2–4)	1–5	3.15	3.33	0.05
Concerned about the high cost of drinking water produced from grey water	3.29 ± 1.29	3 (2–4)	1–5	3.20	3.38	0.05
Concerns about the need to convert the existing water and sewer systems to produce potable water from grey water	3.39 ± 1.32	4 (2–5)	1–5	3.30	3.48	0.05
I have absolutely no concerns about the use of the grey water	2.26 ± 1.22	2 (1–3)	1–5	2.18	2.34	0.04

Comparing the results obtained with those of other studies, it can be seen that economic considerations were also important for Istanbul residents; in that study, 40% of the respondents were willing to pay for the installation of grey water systems, while 79% would be willing to accept such an installation, but under the condition that it would be free of charge [56]. This is also confirmed by other studies: in one study, nearly 80% of respondents would only be willing to invest in grey water systems in the event of significant subsidies or tax breaks [58]. In further studies, concerns about grey water use can be observed for religious and cultural reasons [57]. In contrast, surveys conducted in 12 countries indicate that hygiene concerns were the greatest concern related to the acceptance of grey water, especially in countries with significant water resources [58]. Other studies also indicate a very low acceptance of drinking treated grey water, mainly due to concerns about the quality of such water and health problems [59].

The importance of introducing good practices based on recycled water reuse in water management was moderately highly rated by the respondents. On a scale of 1 to 5, the average rating for these activities was 4.05 (SD = 1.08). Half of the respondents rated the importance of introducing the above-mentioned practices into water management at a minimum of 4 and one in four respondents at the highest possible level, that is, 5.

When assessing the degree of implementation of the principles of the circular economy model in the Polish economy, with reference to selected raw materials, the respondents gave the highest rating to metals (M = 3.3; SD = 1.16). The respondents rated the implementation of the principles mentioned above slightly lower in relation to paper (M = 3.18; SD = 1.23), glass (M = 3.11; SD = 1.24), and plastics (M = 3.08; SD = 1.28). On the scale of implementation of the principles in relation to water, the scores were the lowest among the respondents (M = 2.33; SD = 1.2).

The respondents gave a moderately poor assessment of the degree to which the Polish economy is keeping up with global trends in terms of implementing the sustainable development model and the closed-loop economy; on average, at a level of 2.43 (SD = 0.99) on a scale of 1 to 5. One in two respondents rated the above measures at a maximum of 2 points, and three-quarters of the respondents rated them at a maximum of 3 points.

4.2. Modelling Grey Water Benefits for Different Groups

The next stage of this analysis was to build models of the benefits of grey water use between different groups using PROFIT analysis (PROPERTy FITting). This research study aimed to identify the benefits that could potentially convince residents to use recycled water, taking into account their different situations in terms of gender, age, place of residence, and owning an irretrievable water meter.

4.2.1. Benefits of Grey Water Use in Groups Distinguished by Gender and Age

When developing the model, average scores of the potential benefits of grey water were used. These results are detailed in the following table (Table 5).

Table 5. Average scores of individual benefits of grey water use among groups distinguished by gender and age.

	C1	C2	C3	C4	C5	C6	C7	C8
Women/≤34 (K/34)	3.89	3.50	3.46	3.59	3.83	3.96	3.80	3.48
Women/35–44 (K/35–44)	3.67	3.48	3.20	3.47	3.57	3.69	3.62	3.50
Women/45–54 (K/45–54)	3.63	3.36	3.29	3.47	3.47	3.78	3.69	3.61
Women/≥55 (K/55)	3.45	3.13	2.97	3.22	3.31	3.50	3.55	3.35
Men/≤34 (M/34)	3.42	3.12	2.96	3.22	3.35	3.75	3.49	3.25
Men/35–44 (M/35–44)	3.47	3.13	2.94	3.11	3.17	3.43	3.25	3.22
Men/45–54 (M/45–54)	3.76	3.14	2.91	3.34	3.39	3.66	3.59	3.40
Men/≥55 (M/55)	3.24	2.90	2.70	3.02	2.99	3.26	3.15	3.07

Explanation of abbreviations: C1—reduced abstraction of potable water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage networks; C4—soil fertilisation; C5—reduced energy and chemical use; C6—recovery of groundwater level; C7—increased vegetation growth; C8—recovery of fertilising nutrients.

The developed multidimensional scaling map shows that the youngest age group of women and the oldest age group of men, respectively, diverged from each other and from the other groups in terms of their assessment of the benefits of grey water use. At the same time, the oldest age group of women and the youngest age group of men, respectively, were in the same place on the map, as were the groups of women aged 35–44 and 45–54 years. The other two groups, i.e., men aged 35–44 and men aged 45–54, deviated from the others, although they were located relatively close to each other and to the last four groups mentioned above.

The results of the regression analysis are presented in the table below (Table 6). They clearly indicate that all the evaluation dimensions tested were characterised by a very high impact on the differentiation of the units under study; the lowest fit was for less drinking water from rivers and other water bodies ($R^2 = 0.81$) and the highest fit was for soil fertilisation ($R^2 = 1.00$). Therefore, there was no need to reduce the number of traits tested in the model.

Table 6. Results of regression analysis between the individual benefits of grey water use and the derived dimensions of the surveyed units (applicable to groups distinguished by gender and age).

	Free Expression		**DIM.1**		**DIM.2**		R^2
	b0	***p***	**b**	***p***	**b**	***p***	
Reduced abstraction of drinking water from rivers and other water bodies (C1)	3.566	$p < 0.001$	0.194	$p < 0.01$	−0.029	$p = 0.772$	0.81
Reduced environmental impact (C2)	3.217	$p < 0.001$	0.204	$p < 0.001$	0.027	$p = 0.685$	0.92
Reducing pressure on the water supply and sewerage network (C3)	3.053	$p < 0.001$	0.235	$p < 0.001$	0.090	$p = 0.267$	0.92
Soil fertilisation (C4)	3.304	$p < 0.001$	0.200	$p < 0.001$	−0.001	$p = 0.917$	1.00
Reduced energy and chemical consumption (C5)	3.385	$p < 0.001$	0.248	$p < 0.001$	0.016	$p = 0.832$	0.93
Groundwater level recovery (C6)	3.631	$p < 0.001$	0.201	$p < 0.01$	−0.060	$p = 0.568$	0.82
Increased vegetation growth (C7)	3.517	$p < 0.001$	0.210	$p < 0.001$	−0.099	$p = 0.187$	0.92
Recovery of fertilising components (C8)	3.359	$p < 0.001$	0.165	$p < 0.01$	−0.100	$p = 0.132$	0.91

The final stage of this analysis was to develop, using PROFIT analysis, a model of the benefits of grey water use along each dimension in relation to gender and age, the result of which is shown below (Figure 1). As can be seen, all benefits were highly rated by 35–44- and 45–54-year-old women, with the closest being benefits related to reduced drinking water abstraction from rivers and other water bodies, soil fertilisation, and recovery of groundwater level. On the opposite side, in this respect, were men aged 35–44 and 55 years and over, who were particularly distant from any of the benefits (meaning these groups did not give particular importance to any benefit of grey water use). For women 55 and older and men aged up to 34 and 45–54 years, the most important benefits were increased vegetation growth and recovery of fertilising nutrients, while for women over 34 years, the reduction in the pressure on the water supply and sewerage network was the most important. At the same time, it should be noted that the shape of the developed model casts doubt on whether gender, in conjunction with age, is a factor that significantly determines the perception of individual benefits of grey water.

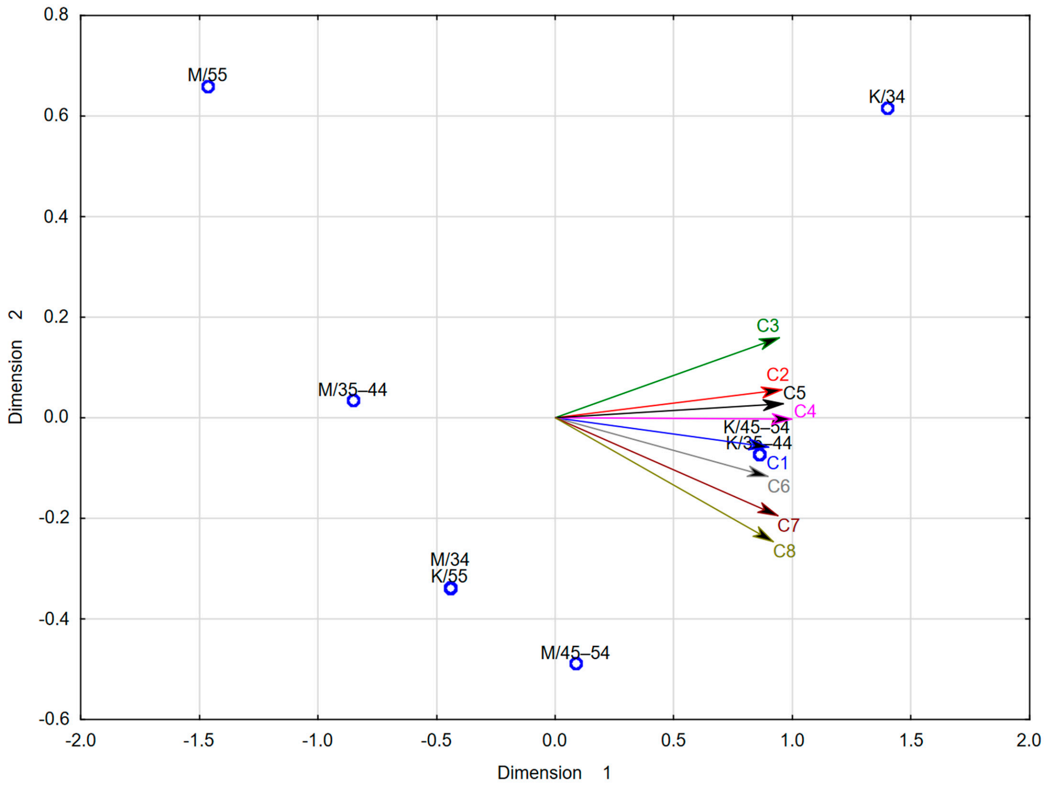

Figure 1. Biplot that incorporates the result of multidimensional scaling for individual subjects (groups distinguished by gender and age) based on individual benefits of grey water. Explanation of abbreviations: K/34—women aged up to 34 years; K/35–44—women aged 35–44 years; K/45–54—women aged 45–54 years; K/55—women aged 55 years and over; M/34—men aged up to 34 years; M/35–44—men aged 35–44 years; M/45–54—men aged 45–54 years; M/55—men aged 55 years and over; C1—reduced abstraction of drinking water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage network; C4—soil fertilisation; C5—reduced energy and chemical consumption; C6—groundwater level recovery; C7—increased vegetation growth; C8—recovery of fertilising components.

4.2.2. Benefits of Grey Water Use among Groups Differentiated by Age and Ownership of an Irretrievable Water Meter

Similarly to the previous model, the average scores of the potential benefits of using grey water mentioned above were used in the development of the model, and these results are presented in the table below (Table 7).

Table 7. Average ratings of individual grey water benefits among groups distinguished by age and ownership of an irretrievable water meter.

	C1	C2	C3	C4	C5	C6	C7	C8
≤34/owns an irretrievable water meter (≤34/L)	3.64	3.34	3.23	3.48	3.57	3.82	3.50	3.32
≤34/does not own an irretrievable water meter (≤34/B)	3.61	3.24	3.13	3.32	3.53	3.85	3.71	3.38
35–44/owns an irretrievable water meter (35–44/L)	3.66	3.34	3.22	3.40	3.41	3.72	3.52	3.48
35–44/does not own an irretrievable water meter (35–44/B)	3.50	3.27	2.96	3.20	3.33	3.44	3.36	3.26
45–54/owns an irretrievable water meter (45–54/L)	3.65	3.03	2.95	3.19	3.25	3.63	3.55	3.39
45–54/does not own an irretrievable water meter (45–54/B)	3.76	3.39	3.15	3.55	3.56	3.75	3.67	3.55
≥55/owns an irretrievable water meter (≥55/L)	3.31	2.82	2.82	3.00	3.07	3.28	3.31	3.13
≥55/does not own an irretrievable water meter (≥55/B)	3.33	3.12	2.80	3.16	3.16	3.40	3.31	3.21

Explanation of abbreviations: C1—reduced abstraction of potable water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage networks; C4—soil fertilisation; C5—reduced energy and chemical use; C6—recovery of groundwater level; C7—increased vegetation growth; C8—recovery of fertilising nutrients.

Those aged 45–54 years who did not own an irretrievable water meter differed the most from all other groups in their assessment of the benefits of grey water use; similarly, those up to 34 years who did not own an irretrievable water meter also stood out. Those under the age of 34 and those between 35 and 44 years of age and who owned an irretrievable water meter were in almost the same place on the map; relatively close to them was the group of those aged 45–54 who did not own an irretrievable water meter. The remaining groups (i.e., those aged 34–44 who did not own an irretrievable water meter and those aged 55 and over who did and did not own an irretrievable water meter) were distant from the above and relatively close to each other.

The results of the regression analysis are presented in the table below (Table 8). According to them, all the evaluation dimensions studied showed a very high influence on the variation of the units studied; the lowest fit was for the recovery of the fertilisation components (R^2 = 0.82) and the highest fit was for soil fertilisation (R^2 = 0.96).

Table 8. Results of regression analysis between individual benefits of grey water use and the resulting dimensions of the surveyed units (applies to groups distinguished by age and ownership of an irretrievable water meter).

	Free Expression		DIM.1		DIM.2		R^2
	b0	*p*	b	*p*	b	*p*	
Reduced abstraction of drinking water from rivers and other water bodies (C1)	3.557	$p < 0.001$	−0.148	$p < 0.001$	0.122	$p = 0.122$	0.93
Reduced environmental impact (C2)	3.192	$p < 0.001$	−0.161	$p < 0.01$	−0.228	$p = 0.104$	0.85
Reducing the pressure on the water supply and sewerage network (C3)	3.030	$p < 0.001$	−0.157	$p < 0.01$	−0.102	$p = 0.293$	0.90
Soil fertilisation (C4)	3.287	$p < 0.001$	−0.167	$p < 0.001$	−0.156	$p < 0.05$	0.96
Reduced energy and chemical consumption (C5)	3.359	$p < 0.001$	−0.176	$p < 0.001$	−0.067	$p = 0.473$	0.91
Groundwater level recovery (C6)	3.611	$p < 0.001$	−0.194	$p < 0.001$	0.108	$p = 0.303$	0.92
Increased vegetation growth (C7)	3.491	$p < 0.001$	−0.129	$p < 0.01$	0.207	$p < 0.05$	0.90
Recovery of fertilising components (C8)	3.339	$p < 0.001$	−0.119	$p < 0.01$	0.065	$p = 0.499$	0.82

Finally, a model of the benefits of using grey water was developed in each dimension in relation to age and possession of an irretrievable water meter using PROFIT analysis, the result of which is shown below (Figure 2). It shows that individual benefits were mainly recognised by four of the eight analysed groups. Those up to 34 years of age who did not own an irretrievable water meter were particularly attentive to benefits such as increased vegetation growth and reduced withdrawal of potable water from rivers and other water bodies, as well as, although somewhat less so, recovery of groundwater levels and recovery of fertilising nutrients. The benefit of reduced energy and chemical use was particularly important for those 45 to 54 years of age who did not own an irretrievable water meter; similarly, the benefit of reduced pressure on the water and sewer networks was equally important for those up to 34 and those aged 35–44 who owned an irretrievable water meter. For the latter two groups, the benefits of soil fertilisation and reduced environmental impact were particularly important. Those aged 45–54 who owned an irretrievable water meter paid much less attention to the individual benefits of grey water use, and the issue of increased vegetation growth was the most important to them. The remaining groups (i.e., those aged 34–44 who did not own an irretrievable water meter and those aged 55 and over who did and did not own an irretrievable water meter) were not associated with any of the benefits (they were on the opposite side to those aged under 34 who did not own an irretrievable water meter, which in practice means that the benefits relevant to this group were not in the focus of the other groups).

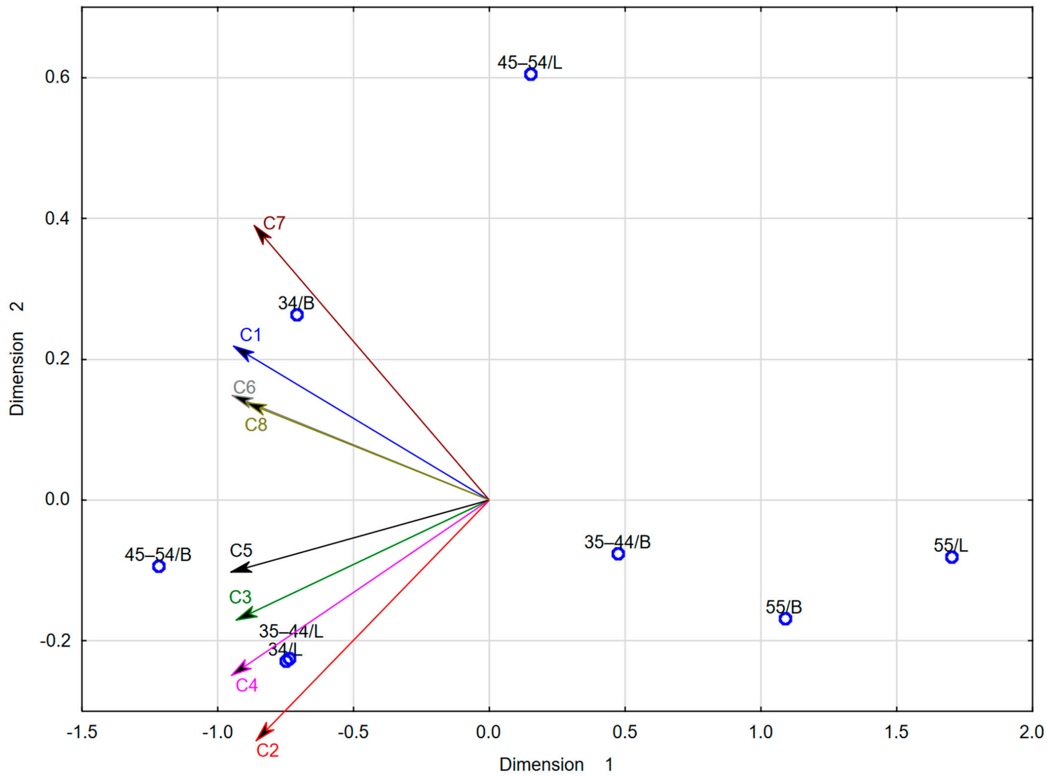

Figure 2. Biplot incorporating the result of multidimensional scaling for individual sites (groups distinguished by age and ownership of an irretrievable water meter) based on individual grey water benefits. Explanation of abbreviations: 34/L—those aged 34 and under who own an irretrievable water meter; 34/B—those aged 34 and under who do not own an irretrievable water meter; 35–44/L—those aged 35–44 who own an irretrievable water meter; 35–44/B—those aged 35–44 who do not own an irretrievable water meter; 45–54/L—those aged 45–54 who own an irretrievable water meter; 45–54/B—those aged 45–54 who do not own an irretrievable water meter; 55/L—those aged 55 and over who own an irretrievable water meter; 55/B—people aged 55 and over who do not own an irretrievable water meter; C1—reduced abstraction of drinking water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage network; C4—soil fertilisation; C5—reduced energy and chemical use; C6—groundwater level recovery; C7—increased vegetation growth; C8—recovery of fertilising nutrients.

4.2.3. Benefits of Grey Water Use in Groups Distinguished by Gender and Place of Residence

As before, the average scores of the potential benefits of grey water were used to develop the model. The results are presented in the table below (Table 9).

Table 9. Average scores of individual grey water benefits between groups distinguished by gender and place of residence.

	C1	C2	C3	C4	C5	C6	C7	C8
Women/House (K/D)	3.60	3.31	3.12	3.38	3.45	3.68	3.61	3.47
Women/Flat (K/M)	3.70	3.46	3.50	3.54	3.74	3.72	3.82	3.50
Men/House (M/D)	3.48	3.04	2.83	3.11	3.17	3.47	3.33	3.21
Men/Flat (M/M)	3.42	3.14	3.00	3.46	3.38	3.64	3.51	3.33

Explanation of abbreviations: C1—reduced abstraction of potable water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage networks; C4—soil fertilisation; C5—reduced energy and chemical use; C6—recovery of groundwater level; C7—increased vegetation growth; C8—recovery of fertilising nutrients.

Women who lived in flats and men who lived houses differed from each other and from all other groups in terms of their assessment of the benefits of grey water use. On the contrary, women living in houses and men living in flats were relatively close to each other on the map.

The following table shows the results of the regression analysis (Table 10). As can be read, all the assessment dimensions studied showed a very high impact on the variation of the units studied; the lowest fit was for less drinking water from rivers and other water bodies ($R^2 = 0.79$), and the highest fit was for the reduction in pressure on the water supply and sewerage network, less energy and chemical consumption, restored groundwater levels, and increased vegetation growth ($R^2 = 1.00$).

Table 10. Results of regression analysis between the individual benefits of grey water use and the derived dimensions of the surveyed individuals (applicable to groups distinguished by gender and place of residence).

	Free Expression		**DIM.1**		**DIM.2**		**R^2**
	b0	***p***	**b**	***p***	**b**	***p***	
Reduced abstraction of drinking water from rivers and other water bodies (C1)	3.551	$p < 0.01$	0.123	$p = 0.307$	−0.026	$p = 0.796$	0.79
Reduced environmental impact (C2)	3.238	$p < 0.01$	0.203	$p = 0.115$	0.045	$p = 0.499$	0.97
Reducing the pressure on the water supply and sewerage network (C3)	3.114	$p < 0.001$	0.320	$p < 0.01$	0.010	$p < 0.084$	1.00
Soil fertilisation (C4)	3.373	$p < 0.05$	0.167	$p = 0.288$	0.120	$p = 0.434$	0.85
Reduced energy and chemical consumption (C5)	3.435	$p < 0.01$	0.261	$p < 0.05$	0.040	$p = 0.29$	1.00
Groundwater level recovery (C6)	3.627	$p < 0.001$	0.104	$p < 0.05$	0.081	$p < 0.052$	1.00
Increased vegetation growth (C7)	3.565	$p < 0.001$	0.227	$p < 0.01$	0.053	$p < 0.05$	1.00
Recovery of fertilising components (C8)	3.378	$p < 0.01$	0.132	$p = 0.16$	0.079	$p = 0.302$	0.95

As a final step, a model of the benefits of grey water use across dimensions was developed in relation to gender and place of residence was developed using PROFIT analysis, the result of which is shown below (Figure 3). The shape of this model indicates that all benefits are directed towards women, regardless of their place of residence, and most of these benefits are located relatively close to women who lived in houses. Women living in houses placed the most importance on benefits related to groundwater level recovery, soil fertilisation, and recovery of fertilisation nutrients. Other benefits are closer to women living in flats; the closest lies the benefit related to lower drinking water abstraction from rivers and other water bodies, while slightly less close are benefits such as successively less pressure on the water and sewerage networks, less use of energy and chemicals, less impact on the environment, and increased vegetation growth. Men, particularly those who live in houses, were not characterised by an interest in any of the benefits of grey water use. Therefore, it must be questioned whether gender, together with the place of residence, constitutes a factor that significantly determines the perception of individual benefits of grey water use.

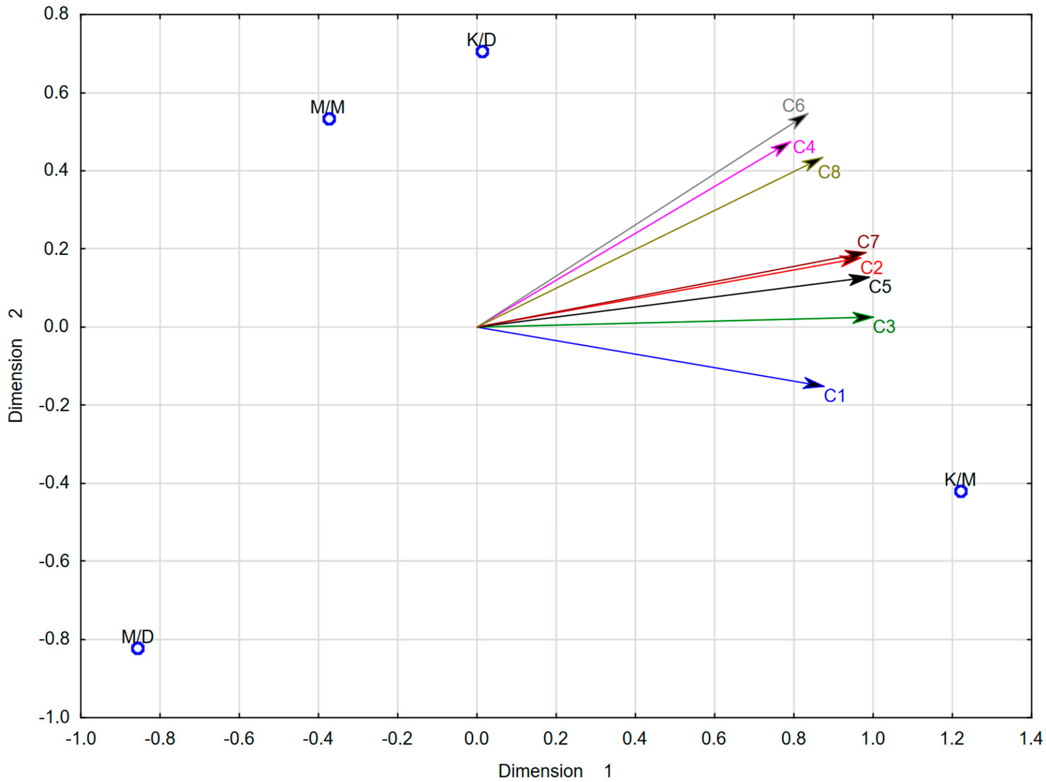

Figure 3. Biplot that incorporates the result of multidimensional scaling for individual sites (groups distinguished by gender and residence) based on individual benefits of grey water use. Explanation of abbreviations: K/D—women living in houses; K/M—women living in flats; M/D—men living in houses; M/M—men living in flats; C1—reduced abstraction of drinking water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage network; C4—soil fertilisation; C5—reduced energy and chemical use; C6—recovery of groundwater level; C7—increased vegetation growth; C8—recovery of fertilising components.

4.2.4. Benefits of Grey Water Use among Groups Distinguished by Residence and Possession of an Irretrievable Water Meter

Similarly to the previous models, the average scores of the potential benefits of grey water use were used in the development of this model. The results are presented in the table below (Table 11).

Table 11. Average ratings of individual grey water benefits among groups distinguished by place of residence and possession of an irretrievable water meter.

	C1	C2	C3	C4	C5	C6	C7	C8
House/owns an irretrievable water meter (D/L)	3.53	3.07	2.99	3.21	3.25	3.55	3.46	3.30
House/does not own an irretrievable water meter (D/B)	3.55	3.24	2.93	3.25	3.34	3.57	3.44	3.34
Flat/owns an irretrievable water meter (M/L)	3.61	3.06	3.13	3.23	3.45	3.61	3.39	3.42
Flat/does not own an irretrievable water meter (M/B)	3.48	3.29	3.17	3.52	3.48	3.60	3.65	3.33

Explanation of abbreviations: C1—reduced abstraction of potable water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage network; C4—soil fertilisation; C5—reduced energy and chemical use; C6—recovery of groundwater level; C7—increased vegetation growth; C8—recovery of fertilising nutrients.

On the group map, these results show a similar distribution to the model for groups distinguished by gender and place of residence, i.e., two groups, in this case those living in a flat, whether or not in possession of an irretrievable water meter, differed from each other and from all other groups in their assessment of the benefits of grey water use. Those who lived in a house, whether or not they were in possession of an irretrievable water meter, were relatively close to each other on the map.

The results of the regression analysis are presented below (Table 12). They indicate that all the studied evaluation dimensions had a very high effect on the variation of the studied units; the lowest fit was for the recovery of fertilisation components (R^2 = 0.81) and the highest fit was for soil fertilisation (R^2 = 1.00).

Table 12. Results of the regression analysis between the individual benefits of grey water use and the resulting dimensions of the surveyed units (applies to groups distinguished by residence and possession of an irretrievable water meter).

	Free Expression		**DIM.1**		**DIM.2**		**R^2**
	b0	***p***	**b**	***p***	**b**	***p***	
Reduced abstraction of drinking water from rivers and other water bodies (C1)	3.543	$p < 0.01$	−0.038	$p = 0.296$	0.052	$p = 0.276$	0.90
Reduced environmental impact (C2)	3.166	$p < 0.01$	0.098	$p = 0.322$	−0.075	$p = 0.472$	0.82
Reducing the pressure on the water supply and sewerage network (C3)	3.057	$p < 0.01$	0.086	$p = 0.23$	0.105	$p = 0.238$	0.93
Soil fertilisation (C4)	3.300	$p < 0.01$	0.159	$p < 0.05$	−0.017	$p = 0.375$	1.00
Reduced energy and chemical consumption (C5)	3.381	$p < 0.01$	0.087	$p = 0.251$	0.092	$p = 0.295$	0.91
Groundwater level recovery (C6)	3.584	$p < 0.01$	0.016	$p = 0.279$	0.033	$p = 0.187$	0.94
Increased vegetation growth (C7)	3.484	$p < 0.01$	0.113	$p = 0.164$	−0.051	$p = 0.408$	0.94
Recovery of fertilising components (C8)	3.350	$p < 0.01$	−0.006	$p = 0.852$	0.062	$p = 0.289$	0.81

A model of the benefits of grey water use along each dimension in relation to residence and ownership of an irretrievable water meter was then developed using PROFIT analysis, the result of which is shown below (Figure 4). As can be seen, those living in houses did not place particular importance on any of the benefits of using grey water; in particular, the issues of restoring groundwater levels, reducing pressure on the water and sewerage networks, and using less energy and chemicals were not of interest to them. On the map, the above benefits are not close to any of the groups analysed; reduced pressure on the water and sewerage networks and reduced energy and chemical consumption are closest to the group of people who live in a flat and do not own an irretrievable water meter, while groundwater level recovery is closest to the group of people who live in a flat and own an irretrievable water meter, respectively. For those who live in a house and own an irretrievable water meter, the closest benefit is less drinking water from rivers and other water bodies, while for those who live in a house and do not own an irretrievable water meter, each benefit is directed in the opposite direction and, therefore, was not significantly perceived by this group. The other two groups perceived significantly more benefits. Those living in a flat and in possession of an irretrievable water meter were particularly attentive to the reduced abstraction of drinking water from rivers and other water bodies and the recovery of fertilising components, and less so to the recovery of groundwater levels, as mentioned earlier. On the contrary, those living in a flat and not in possession of an irretrievable water meter paid more attention than the other groups to soil fertilisation in particular; slightly less so to increased vegetation growth and reduced environmental impact; and much less so to reduced energy and chemical use and reduced pressure on the water and sewerage networks, as also mentioned earlier. The shape of this model indicates that the benefits that are particularly relevant to those living in flats depend on them owning an irretrievable water meter, and that the benefits that are not particularly relevant to those living in houses also depend on them owning the above-mentioned meter.

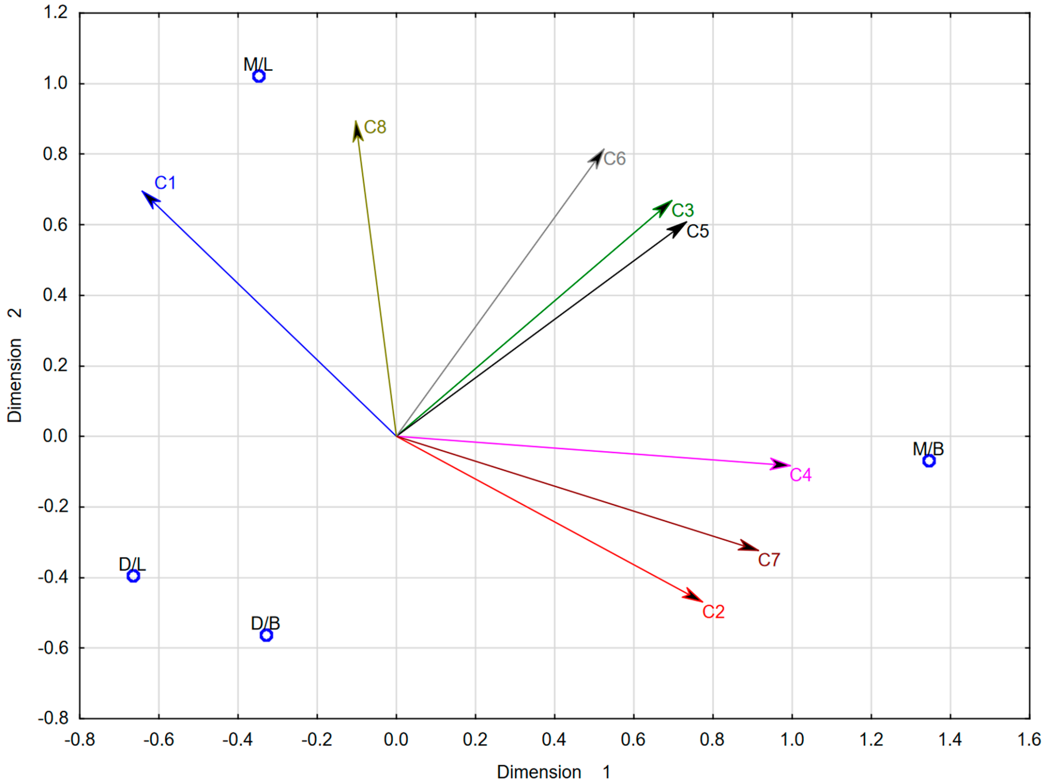

Figure 4. Biplot incorporating the result of multidimensional scaling for individual sites (groups distinguished by residence and having a irretrievable water meter) based on individual grey water benefits. Explanation of abbreviations: D/L—people living in a house who own an irretrievable water meter; D/B—people living in a house who do not own an irretrievable water meter; M/L—people living in a flat who own an irretrievable water meter; M/B—people living in a flat who do not own an irretrievable water meter; C1—reduced abstraction of drinking water from rivers and other water bodies; C2—reduced environmental impact; C3—reduced pressure on water supply and sewerage network; C4—soil fertilisation; C5—reduced energy and chemical use; C6—groundwater level recovery; C7—increased vegetation growth; C8—recovery of fertilising components.

5. Conclusions

The level of awareness of the problem of drought and water demand in Polish households is high. Residents are aware of the problem of the scarcity of drinkable water in Poland and throughout the world and are highly concerned with the extent to which drought periods are increasing and water sources are disappearing, the increasing demand for water in Poland, and the importance of seeking new technologies for the acquisition of drinking water from non-traditional sources.

Some of the most commonly perceived benefits of domestic grey water use include the restoration of groundwater levels, reduced abstraction of drinking water from rivers and other water bodies, and increased vegetation growth.

Residents have several concerns about the use of recycled drinking water, the greatest fears being the need to convert the existing water and sewerage system to produce drinking water from grey water as well as the high cost and parameter stability of drinking water produced from grey water.

Older people place the least importance on almost each opportunity for grey water use (apart from increased vegetation growth and recovery of fertilising components and the possibility of using treated grey water for industrial purposes and soil irrigation, the assessment of which is not related to the age of the study population).

Some groups, distinguished by age and the possession of an irretrievable water meter, pay particular attention to specific benefits of grey water use. Those up to 34 years of age who do not own the aforementioned meter focus a lot of attention on issues such as increased vegetation growth and reduced abstraction of potable water from rivers and other water bodies; slightly less so on groundwater level recovery and recovery of fertilising components, respectively. Those aged 45–54 years who do not own the aforementioned meter pay particular attention to reduced energy and chemical use, while those of this age who do own a meter are most confident in the benefit of increased vegetation growth. On the contrary, those aged 44 and under who own the aforementioned meter see particular benefits in terms of soil fertilisation and reduced environmental impact, and slightly less so in terms of reduced energy and chemical use.

Those living in flats who are owners of an irretrievable water meter focus more attention on the benefits of grey water use related to reduced abstraction of drinking water from rivers and other water bodies and recovery of fertilising components, and—albeit less so—to the recovery of groundwater levels. Those who live in flats but do not own the above-mentioned meter focus more attention on benefits associated with soil fertilisation, while placing slightly less importance on increased vegetation growth and reduced environmental impact. On the contrary, those who live in houses and own an irretrievable water meter are closest to the benefit of less abstraction of drinking water from rivers and other water bodies, while those who live in houses and do not own an irretrievable water meter do not see any particular benefits of the use of grey water (they are particularly uninterested in issues concerning groundwater levels, reducing the pressure on the water supply and sewerage network, and the reduced use of energy and chemicals), which may indicate the need for educational activities aimed at this group prior to a campaign to convince them to use recycled water.

The conclusions presented above and the developed models can be put into practice by drawing attention to promotional and environmental campaigns that can be aimed directly at selected groups in order to further reassure them of the importance of particular aspects of the topic of recycling water and to reduce their concerns about using grey water. It is worth emphasising that this behaviour is in line with the principles of a closed-loop economy and can be promoted both by government or state institutions as well as by companies that supply water and collect wastewater. If the public perception is positive, the implementation of technical solutions to recycle and use grey water will have a greater chance of success. From a scientific point of view, it seems interesting to be able to compare the research conducted in Poland with that conducted in countries that have low, medium, and very high levels of economic, social, and political development. In addition, one could be interested in exploring this topic among small, medium, and large manufacturing and service companies that could use grey water for their operations.

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Institutional Review Board Statement: According to our University Ethics Statement, the following shall be regarded as research requiring a favourable opinion from the Ethics Committee in the case of human research (based on a document in Polish: https://prawo.polsl.pl/Lists/Monitor/Attachments/7291/M.2021.501.Z.107.pdf (accessed on 11 December 2023)): Research on persons with limited capacity to provide informed or free consent or on persons who have a limited ability to withdraw consent before or during the course of the study, in particular: children and adolescents under 12 years of age; persons with intellectual disabilities; persons whose consent to participate in the research may not be fully voluntary, including prisoners, soldiers, police officers, and employees of companies (when the survey is conducted at their workplace); and persons who agree to participate in the research on the basis of false information about the purpose and course of the research (masking instruction, i.e., deception) or do not know at all that they are subjects (in so-called natural experiments). Research involving the participation of persons particularly susceptible to psychological trauma and mental health disorders, in particular: mentally ill persons; victims of disasters, war trauma, etc.; patients receiving treatment for psychotic disorders; and family members of terminally or chronically ill patients. Research involving active intervention in human behaviour aimed at changing that behaviour without direct intervention in the functioning of the brain, e.g., cognitive training, psychotherapy, and psychocorrection (this also applies if the intervention is intended to benefit the subject (e.g., to improve his/her memory)). Research concerning controversial issues (e.g., abortion, in vitro fertilisation, the death penalty) or requiring particular delicacy and caution (e.g., concerning religious beliefs or attitudes towards minority groups). Research that is prolonged, tiring, or physically or mentally exhausting. Our research was not conducted on humans meeting the above-mentioned conditions. None of the participants had a limited capacity to provide informed consent, were susceptible to psychological trauma, or had mental health disorders, and the research did not concern any of the above-mentioned controversial issues and was not prolonged, tiring, or physically or mentally exhausting.

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