Willingness to Pay and Economic Feasibility of Household Greywater Treatment System

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Abstract This paper evaluated the net present value of the investment in a single-family constructed wetland system that provides water for reuse for non-potable purposes. Different price scenarios were considered, using Purchasing-Power Parity (PPP) and different rates of water saving in the USA, Brazil and Denmark. Moreover, the contingent valuation method was applied to assess the willingness of people to pay for such a system. The payback period for 50% of water saving starts from 5 years depending on scenario, but just about 29% of scenarios presented a positive VPL in 20 years. Generally, water saving systems have a low economic viability, and this mainly in low investment scenarios, like those using a hand made tank or without considering pump costs for example. Considering a tax incentives of US$ 20.00 annually, the payback time of the analysed scenarios improves up to 40%, depending on the scenario. In relation to contingent valuation, 65% of the population were indicating a willingness to pay R$ 2 000.00 (US$ 498.00, considering an exchange rate of January, 2016) for the treatment system for water reuse, but the most desirable value would be between R$ 500.00 and R$ 1 500.00 (between US$ 124.00 and US$ 373.00). No correlation was found between socioeconomic indicators and the willingness to pay for the system.

Keywords Net present value; contingent valuation method; constructed wetland; willingness to pay; alternative system; wastewater treatment

INTRODUCTION

Continued population growth, increased urbanization, changed food consumption patterns and climate change are some of the key drivers that are likely to increase pressures on water resources in the future. The impacts of climate change pose obvious threats to people's access to sustainable water supply, sanitation and hygiene services. Water scarcity already affects more than 40 per cent of the global population and is projected to rise (UN, 2015) even further. By 2025, 2/3 of the world's population could face water stress due to population increases and growing demand, as shown in Figure 1. Thus, action needs to be taken to encourage people to use less water and create an alternative water supply through water conservation, grey water reuse and other sustainable technologies.

Additionally, data show that worldwide more than 1 in 3 people have no access to improved sanitation. Whilst centralized wastewater treatment systems are not available in large parts of the world (Paulo et al., 2013), over 80% of wastewater worldwide is dumped untreated into water supplies (UN, 2015). Inadequate wastewater management pollutes water bodies that are also important sources for drinking water, fisheries and other services. Therefore, the discharge of wastewater, without or with inadequate treatment, involves significant costs, including environmental and social ones (Hernandez-Sancho et al., 2015).

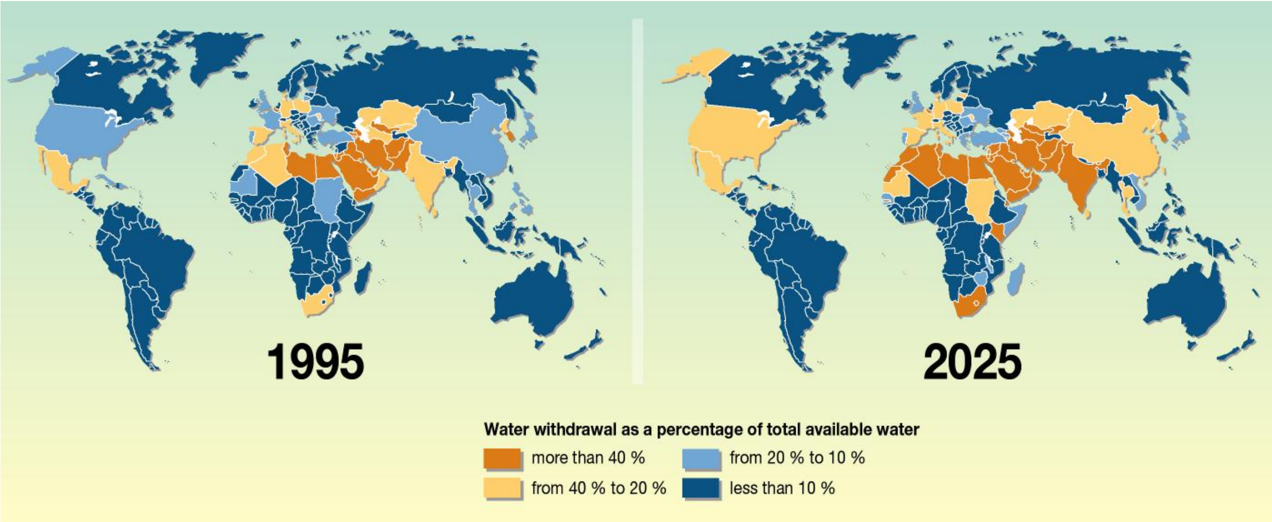

Figure 1. Water stress map from 1995 to 2025. Source: UNEP (2008).

Long-term investments in sanitation are economically favorable because of improved public health leading to an increased productivity of society and reduced expenses (Loosdrecht and Brdjanovic 2014). Especially in developing countries, cities must leapfrog within the sanitation trajectory, going straight from no toilets to hygienic toilets for all that do not use an excessive amount of resources. Open drains might become planted waterways, with the vegetation cleansing the water, and microbes might be used to decompose and de-pathogenize the effluent. In the long run, the challenge can only be met when sewage is treated as a resource (Narain 2012).

The practice of domestic wastewater reuse, essential in water scarcity areas, is gradually becoming common in many parts of the world. The positive and negative consequences of wastewater use challenge decision makers to identify practical, affordable and safe strategies for the reuse of this resource.

Wastewater management and treatment involves significant benefits (avoided costs). The potential benefits associated with improving wastewater management can be grouped into two general categories: market and non-market benefits. Most environmental and health benefits have significant value, but unlike most benefits from productivity a monetary valuation is difficult as market prices do not exist or can only be estimated (Hernandez-Sancho et al., 2015).

However, with the increase in water scarcity, water reuse is becoming more attractive, even in economical terms. The financing of water and sanitation, including the proportion contributed by households, varies greatly as does the Willingness To Pay (WTP) for water and sanitation services. Data on household contributions are few and generally available only at national level, preventing assessment of affordability for the poorest (WWAP 2015).

In addition, water scarcity can significantly affect the WTP for water by the population. The adoption of alternative systems of water supply by households appears to be limited, and depending on available income (Mankad and Tapsuwan, 2011). One method to determine WTP is by application of the contingent valuation (CV) method, which is not based on what people do, but on what people say they will do under certain scenarios in a hypothetical market. The CV method, applied in a survey, may thus directly indicate the maximum WTP for better water quality. (Hernandez-Sancho et al., 2015).

Direct valuation methods, like the CV method, have become common practice for assessing the economic value of such public projects, using surveys with respondents from a representative sample of the population affected by that project (Weldesilassie *et al.*, 2009).

Evaluations of the economic feasibility of water reuse projects will jointly evaluate the environmental questions and the availability of resources (Molinos-Senante et al., 2011). In addition to the economic valuation, it is interesting to highlight the environmental valuation, which becomes a little more complex because it requires knowledge of many different disciplines (Hoyos, 2010). Given this context, the purpose of this paper is to assess the financial viability of the greywater segregation for treatment and reuse of water and identify the willingness of the population to pay for such a constructed wetlands system.

Greywater treatment and reuse

Grey water is generally considered to have lower concentrations of organic compounds, and fewer pathogens than combined domestic wastewater (Hocaoglu et al 2010). Depending on habits of the local population, the amount of greywater may vary between 63% and 75% of the total amount of wastewater generated in a residence (Eriksson et al. 2002; Edwin et al., 2014).

The constructed wetland has been considered as the most environmentally friendly and costs effective technology for grey water treatment (Li et al. 2009). The efficiency of a constructed wetland for greywater treatment can reach more than 90% for removal of suspended solids and biological oxygen demand, and more than 80% for removal of chemical oxygen demand (Sklarz *et al*. 2009; Gross *et al*. 2007).

Depending on the established water quality standards, treated greywater can be used for non-potable applications like toilet flushing, gardening, fire protection, washing and cleaning, thus reducing the fresh water consumption in the residence (Li et al. 2009). As a result, it was reported that reuse of treated greywater can save more than 30% of the fresh water consumption in a residence (Edwin et al. 2014). Early experiences show that reuse of greywater could achieve water savings up to 80% of total household water usage (Muthukumaran et al. 2011; Li et al. 2009).

MATERIALS AND METHODS

Net Present Value

Net Present Value (NPV20) was applied to analyse the economic feasibility of saving water by greywater reuse using a single-family constructed wetland system, considering a period of 20 years in different countries.

The NPV20 was defined as a simplified net present value calculation of the overall financial balance, assuming 20 years of continuous operation according to equation 1, where "NCF" is the Net Cash Flow plus the investment costs corresponding to year "y" and "i" is the discount rate.

$$NPV = \sum_{y=0}^{n} \frac{NCF_y}{(1+i)^y} \qquad \text{(Equation 1)}$$

The costs of water reuse vary greatly from place to place depending on location, water quality requirements, treatment methods, energy costs, interest rates, subsidies, and many other factors. In order to better assess the role of some of the key variables, we compared the predicted probabilities of adoption of different scenarios. A comparative analysis of the results of the proposal technologies evaluated as a function of the percentage of water saving, the geographical location and prices variation.

Household water use depends on a number of sociodemographic factors such as: residents' age, income level, family size, education level and household characteristics. Besides that, water consumption differs depending on region (climate and country), size of the building, consumption habits, and ecological awareness. Thus, first of all, we have to define the conventional household consumption of water. An analysis was carried out for Brazil, and the results were discussed comparing them with data from the USA and Denmark, countries known for their high per capita water consumption and their high water price, respectively.

We considered an effective volume of a constructed wetland of 3 m^3 to attend the demand of 3 residents. The estimative of costs was made regarding scenarios based in USA market. However, prices variation of goods in various countries also makes difference in a global analysis of NPV. The same product in the United States and in Brazil should not carry the same price.

So, in order to estimate the cost in Brazil and Denmark considering the USA cost, we considered the theory of Purchasing-Power Parity (PPP). It follows the notion that in the long run exchange rates should move towards the rate that would equalise the prices of an identical basket of goods and services in any two countries.

Equation 2 shows the PPP in US dollars related to the local exchange rate. In this case, the PPP GDP of USA is equalized 100, and the parity is given in index form, in this case considering data form World Bank Database (2016).

$$PPP = 100(I\$)/(\text{Exchange rate US\$}) \qquad \text{Equation 2}$$

Where: I$ = conversion factor of the local by international dollar.

As well as it is difficult to precise the water savings because the economic analysis always depends on a series of factors that vary for each case. Besides that the system can be made by bricks, fiberglass or in different ways, also influencing the cost. That is why we suggested price scenarios with 80% of variation, determining scenarios of low, medium and high prices in each country.

Table 1 shows water prices, daily water use, the total cost estimated for the construction, installation and operation of the system, the actual exchange rate and the PPP conversion factor in USA, Brazil and Denmark. That cost is supposed to include all materials, sealing, filling, manual labor, water reservoirs, pump, piping and plumbing fitting.

Table 1. Water prices, daily water use, estimated cost variation and undervalued rate of the constructed wetland in USA, Brazil and Denmark.

Reference country	Domestic water use[a] ($l.cap^{-1}.d^{-1}$)	Water cost[b] (US $$.m^{-3}$)	Cost of implantation (US $)			PPP convers. factor, GDP (LCU per I$)[f]	Actual exchange rate [g]
			Low[d]	Medium[c]	High[e]		
USA	562.37	0.949	1000	5000	9000	1	1
Brazil	228.81	3.224	460	2300	4140	1.85	4.02
Denmark	174.91	7.220	1080	5400	9720	7.50	6.94

[a] World Bank, World Development Indicators (2014); [b] Estrada et al. (2012), exchange rate of January, 2012; [c] Estimated based in USA scenario; [d] 80% less than medium cost; [e] 80% more than medium cost; [f] World Bank, World Development Indicators (2016); [g] January, 2016.

The investment is balanced by the reduction of drinking water consumption from the public utility supply and from the reduction of sewage volume destined to the public treatment system. Thus it was possible to calculate the cash flow due to the water reuse considering 2% and 12% of discount rates.

Contingent valuation method

The Contingent Valuation (CV) method was applied to assess the people willingness to pay (WTP) for the water reuse system, considering Brazilian conditions. In accordance with the CV, a range of information was collected in our survey, including the socioeconomic characteristics of the households as income and educational level, to relate socio-cultural factors of the population sampled with the willingness to pay for a constructed wetland to treat the grey water.

Warily, in designing and conducting the survey, attempts were made to minimize biases which may arise in a contingent valuation methodology questionnaire. Thus, in order to reduce any kind of bias, we carefully developed the questionnaire and explained the purpose of the study explicitly.

The Brazilian population is currently estimated to be about 180 million. So, considering a 10% margin of error, 50% of the sample population proportion (no prior information about P is available), and 95% of confidence level, the required sample size was calculated according to equation 3, where “n” is the sample size, “Z” is the confidence level, “P” is the sample proportion (%) and “e” is the margin of error (%).

$$n = \frac{Z^2 \ x \ P \ x \ (1-P)}{e^2} \qquad \text{(Equation 3)}$$

The applied survey is shown attached and it was distributed through an Internet link. A total of 97 surveys were demanded and obtained. In order to obtain consistent results, two types of value elicitation formats were considered to assess the willingness to pay for the greywater treatment system, starting with the open-ended format and then applying the discrete choice format.

RESULTS AND DISCUSSION

Table 2 shows the payback time based on NPV20 for 10% to 50% of water saving by using constructed wetlands, considering different price scenarios of drinking water and for the initial investment in the USA, Brazil and Denmark.

Table 2. Payback times based on NPV20 of the greywater reuse system in USA, Brazil and Denmark, depending on water saving target and initial investment.

Water saving target	Initial investment	USA	Brazil	Denmark
	Low	>20	19	>20
10%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	>20	10	13
20%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	19	7	9
30%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	14	6	7
40%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	12	5	6
50%	Medium	>20	19	>20
	High	>20	>20	>20

Generally, water saving systems are economically viable only in low investment scenarios. Such a scenario can realized using a constructed (rather than prefabricated) system or when not considering pumping costs. Besides that, countries with a high cost of water, i.e. Denmark, present a shorter payback period than countries with low cost of water.

In case a government authorizes a tax exemption (for instance, on the property tax) for properties where a water conservation initiative has been implemented, the feasibility of the scenarios improves. Considering a tax incentive of US$ 20.00 annually, the payback time of the analysed scenarios may improve up to 40%, depending on the scenario, as shown in Table 3.

Table 3. Payback times based on NPV20 of the greywater reuse system in USA, Brazil and Denmark, considering a tax incentives of US$ 20.00 annually.

Water saving target	Initial investment	USA	Brazil	Denmark
	Low	>20	11	18
10%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	18	8	11
20%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	14	6	8
30%	Medium	>20	>20	>20
	High	>20	>20	>20
	Low	12	5	7
40%	Medium	>20	19	>20
	High	>20	>20	>20
	Low	10	4	6
50%	Medium	>20	16	>20
	High	>20	>20	>20

Additionally, we did not consider the avoided cost related to the reduction of wastewater volume sent to the municipal wastewater treatment plant, resulting from greywater reuse. In the same way, electricity costs for pumping water were not accounted.

From the CV questionnaires a correlation was made between the socioeconomic characteristics of the respondents and the willingness to pay for the water reuse system. Socioeconomic characteristics of the respondents are shown in Figure 2.

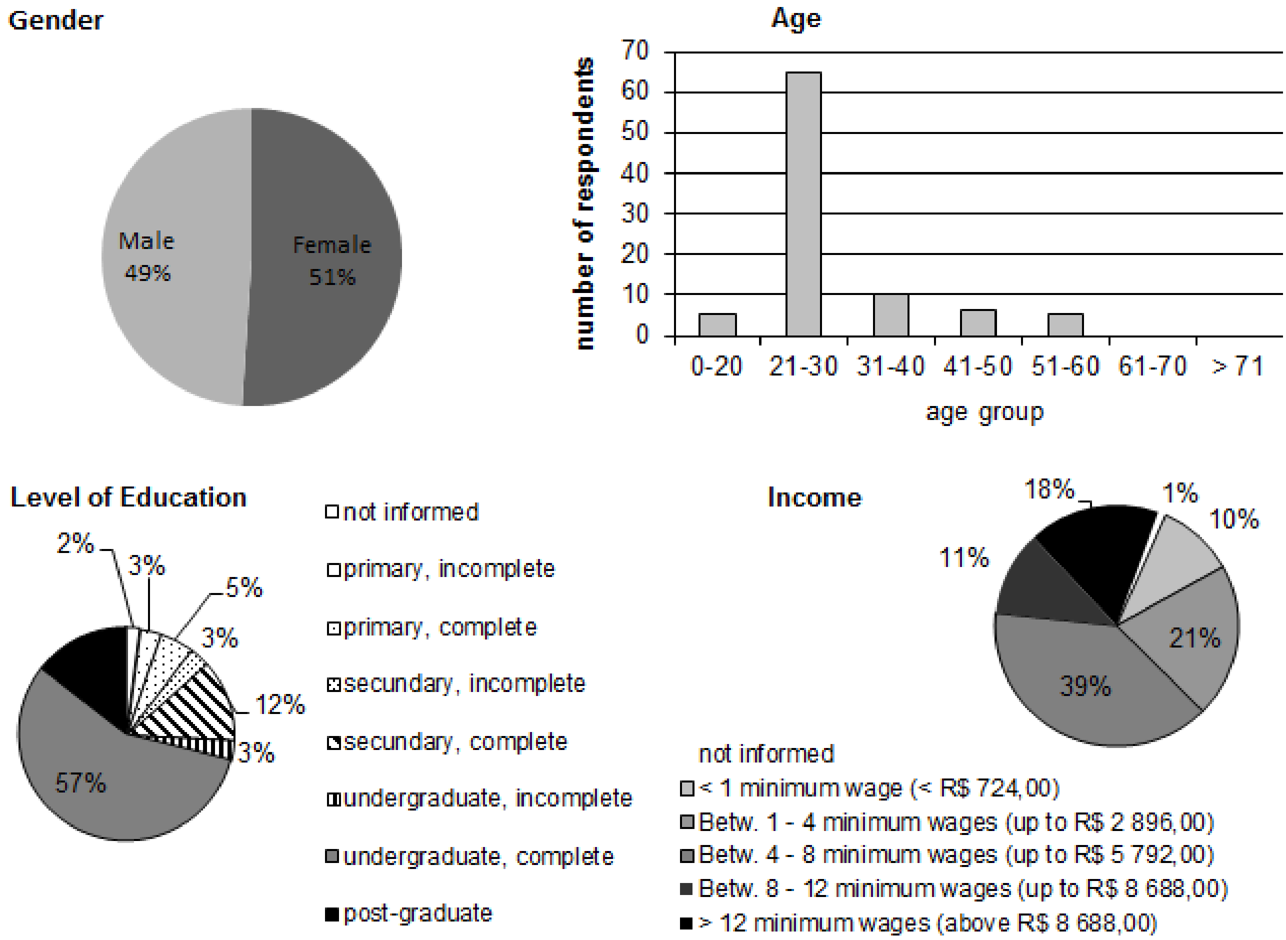

Figure 2. Socioeconomic characteristics of respondents.

The willingness to pay for the greywater reuse system is shown in Figure 3. First, respondents were asked if they would be willing to pay a fixed amount of R$ 2 000.00 for the system and later the real willingness to pay was asked, with multiple choices based in different ranges of values.

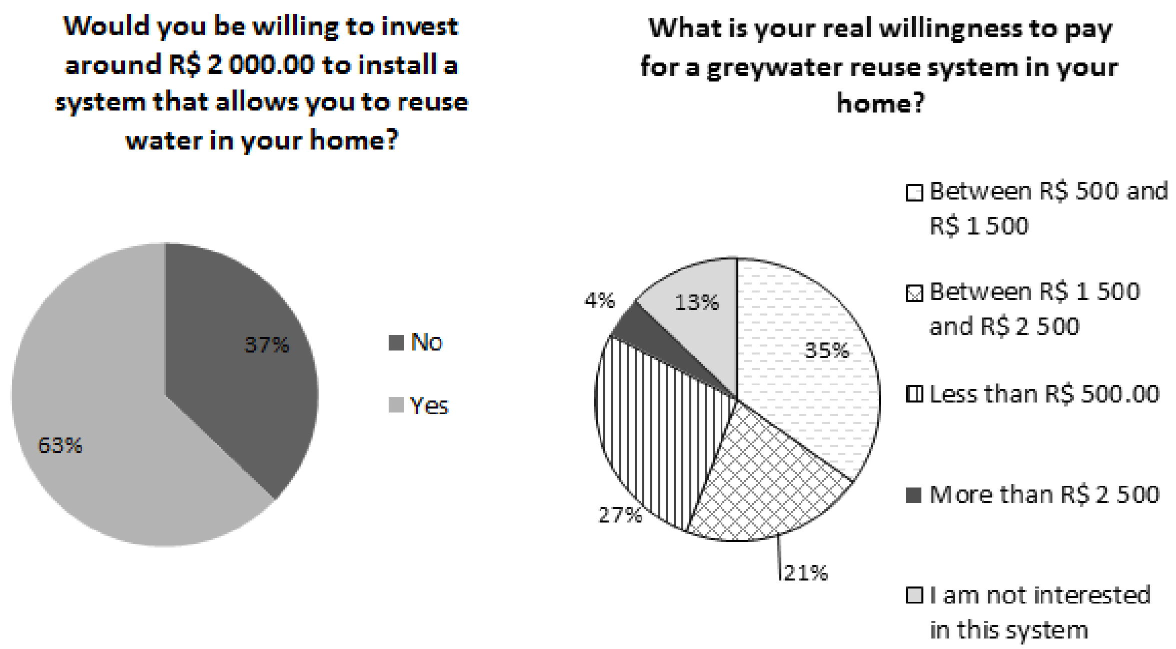

Figure 3. Respondents' willingness to pay (WTP) for a greywater reuse system.

63% of respondents responded to be willing to pay for the greywater reuse system. Regarding the real willingness to pay, a value of between R$ 500.00 and R$ 1 500.00 was predominant, showing that the more desirable value is less than suggested initially.

No strong correlation was found between socioeconomic characteristics of respondents and the willingness to pay for the system. Still, the most important factor analysed was the fact that the person interviewed had previously thought to use the water reuse system. It can be interpreted as the environmental awareness regarding the importance of these systems, which is not linked to income, gender, education level or age.

Governments should encourage the implementation of water and energy saving systems, seeking to improve the return on investment, whereas inaction costs, ie the economic losses arising from climate change, will be greater than the cost of interventions needed for mitigation and adaptation.

Besides that, the increasing pollution of natural water reservoirs, demographic expansion, global warming and failures in water governance could eventually result in a global water price increase. In this case, the demand for greywater reuse systems will increase favouring its financial viability.

CONCLUSIONS

The economic feasibility of 45 scenarios related to reuse of greywater was analysed in this study, of which 13 scenarios (29%) presented a positive VPL in 20 years. The payback period for a 10% to 50% reduction of potable water use, obtained by using constructed wetlands, and considering different price scenarios for USA, Brazil and Denmark, varies from 5 to more than 20 years.

Generally, water saving systems are economic viable mainly in low investment scenarios. It can be reached by hand made tank or not considering pump costs for example. When considering annual tax incentives € 20.00, the payback time improves up to 30%, depending on the scenario analysed.

Surveys show that 63% of respondents are willing to pay up to R$ 2 000.00 (US$ 498.00, considering the exchange rate of January, 2016) for the greywater reuse system, but the predominant price range that the respondents were willing to pay was between R$ 500.00 and R$ 1 500.00 (between US$ 124.00 and US$ 373.00), showing that the majority prefers to pay less than suggested initially. No strong correlation was found between socioeconomic characteristics of the respondents and their willingness to pay for the system.

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ANNEX 1

Survey for contingent valuation

I. Respondents characteristics:
1. City? ....2. Age: ....
3. Gender: ( ) Male ( ) Female

4. What is your highest level of education?
( ) Without education
( ) primary education
( ) secondary education
( ) university (undergraduate)
( ) university (postgraduate)
( ) Other: ....

5. Profession:
( ) Independent Professional
( ) Salaried worker
( ) Retired
( ) Student
( ) Other: ....

6. What is your family income?
( ) Up to 1 minimum salary (R$ 724.00)
( ) From 1 to 4 minimum salaries (up to R$ 2 896.00)
( ) From 4 to 8 minimum salaries (up to R$ 5 792.00)
( ) From 8 to 12 minimum salaries (up to R$ 8 688.00)
( ) More than 12 minimum salaries (more than R$ 8 688.00)

7. How many people live in your home?
( ) Just me
( ) Two
( ) Three
( ) Four or more

8. What is the volume of water consumed monthly in your home?
( ) up to $10m^3$
( ) up to $20m^3$
( ) up to $30\ m^2$
( ) more than $40\ m^2$

9. What are benefits of constructing this system?
( ) Water economy
( ) Produce jobs
( ) Improving health
( ) Political interest
( ) Other: ....

10. Have you ever thought about reusing water in your home?
( ) yes ( ) no

11. Would you be willing to invest around R$ 2 000.00 to install a system that allows you to reuse water in your home?
( ) yes ( ) no

12. If you answered no, what is the reason?
( ) It is expensive
( ) My income doesn't allow me
( ) Water economy is not important
( ) I don't believe that the money will be used for a good reason
( ) These costs must be covered by taxes
( ) Other........................

13. What is your real willingness to pay for a greywater reuse system in your home?
( ) I am not interested in this system
( ) Less than R$ 500.00
( ) Between R$ 500.00 and R$ 1 500.00
( ) Between R$ 1 500.00 and R$ 2 500.00
( ) More than R$ 2 500.00