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Using Treated Wastewater for Non-Potable Household Uses in Peri-Urban India: Is It Affordable for the Users?

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Abstract: Reuse of wastewater is a promising response to water scarcity. For peri-urban areas served by decentralized wastewater treatment plants, the delivery of treated wastewater to the households may be a viable option to promote reuse on a larger scale. Based on a case study in Eastern India, this paper explores if households would accept recycled water for non-potable purposes and if they would pay for it. While the respondents to household surveys had very positive views about recycling, they were not willing to pay much, even if they were from a middle-income class and could afford more. A closer analysis of the attitudes towards recycling indicated knowledge gaps about the risks and advantages of using recycled water.

Keywords: wastewater treatment; recovery of natural resources from waste; best available technology; willingness to pay; compliance of users

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1. Introduction

Water scarcity is a widespread problem in the Global South [1]. Climate change, population growth, and pollution may exacerbate water stress [2], even in flood-prone areas with large rivers and high annual rainfall, such as the Indian state of West Bengal [3]. In addition, in Eastern India, chemical pollution [4] from natural (arsenic, fluoride) and agricultural sources (pesticides, fertilizers) further restricts potential groundwater sources for potable water. Despite these risks, in India, groundwater is still a major source for drinking water [5]. Thereby, urbanization may result in large-scale extraction from groundwater for domestic needs and, at the same time, a reduction of the recharge of groundwater [6].

To alleviate water scarcity, the United Nations Environment Programme (UNEP) promotes the recovery of natural resources from wastewater.

UNEP [7]. In India, stakeholders across the country have expressed positive views towards resource recovery, whereby they considered irrigation and toilet flushing as the most important household uses of treated wastewater [8]. However, the positive environmental impact of reusing wastewater might be offset by a negative health impact. For, as a study [9] of decentralized wastewater treatment plants across India found, there remained considerable health risks from the reuse of treated wastewater, even if the treatment processes fulfilled the legal water quality standards. Further, emerging challenges for wastewater treatment may still be undetected [10]. Thus, recycling of wastewater requires upscaling of the existing treatment facilities by means of best available technologies and practices (BAT). BAT for urban wastewater treatment is a subject where research has just begun [11]. An international research project, SARASWATI 2.0 [12], aims at identifying BAT for reusing natural resources from treated wastewater with a focus on decentralized wastewater treatment plants in India. In pilot studies, it augmented wastewater treatment plants with innovative technologies that promised to produce safe recycled products.

This paper considers the use of safe recycled water by households. For decentralized treatment plants serving peri-urban areas, we expected that owing to the shorter distances, infrastructure for the delivery of treated wastewater to the households could be built up at reasonable costs (in the view of the concerned municipalities). For instance, where sewer infrastructure was built or renewed, pipelines carrying recycled water from the treatment plant back to the households could be added. Thereby, households would receive taps for recycled water in addition to their taps for potable water. It is understood that at least during periods of water scarcity, households would be required to use the recycled water for all non-essential purposes. Would households be ready to use it, and would they be able to contribute significantly to the running costs of such a system?

2. Materials and Methods

2.1. Household Surveys

In 2023, 305 households from peri-urban areas of Bhubaneswar, Cuttack, and Jatni in Odisha state and of Kharagpur and Midnapore Sadar in West Bengal state were selected at random to take part in a survey. The survey asked sixty questions (including sub-questions) about the socio-economic situation of the households, their views and awareness about reusing natural resources, and their willingness to pay for it. (Details and maps of the study areas are in the Supporting Information). Responses from 281 households (response rate: 92% of 305) were suitable for further analysis. They informed us about the situation of 1131 people.

The responses were anonymized for data protection reasons, coded, screened for inconsistencies, and collected in a spreadsheet (Supplementary Information). For the evaluation, we pooled the 150 responses from Odisha and the 131 from West Bengal into one large sample, as all households were in a similar situation with respect to water supply and wastewater treatment. This allowed us to study social groups that for different reasons were represented by comparably few respondents, only, such as women (97 = 35% of respondents), the elderly of age sixty or higher (51 = 18% of respondents), the better educated with graduate or postgraduate studies (80 = 28% of respondents), households with children below age fifteen (121 = 43% of respondents, 67% of them with one child), and large households with six or more persons (37 = 13% of respondents).

2.2. Evaluation

Data were evaluated using computer algebra software version 14.1 of Mathematica [13]. As the pooled sample of 281 households was still small, we used non-parametric methods for the statistical analysis. For confidence intervals, we used exact Clopper–Pearson [14] limits at a (two-sided) 95% level of confidence. They are suitable for small sample sizes [15]. To detect significant differences (p-values below 0.05) between the median responses of certain social groups, we used the Mann–Whitney and Kruskal–Wallis [16] tests. For correlations, we used Spearman's rho, ρ, and the Spearman [17] rank test, as most data were ordinal and as the sample size was suitable to draw meaningful conclusions [18].

To analyze household incomes, expenses, and willingness to pay, we used histogram distributions with "fixed bins" (defining the bins by Sturges' rule) or with "variable bins" (using mixtures of uniform distributions over, e.g., intervals of income categories or modifications thereof), bivariate (truncated) histogram distributions (income and expenses), and approximations by lognormal distributions (with parameters computed by equating the moments to the moments of the distributions with "variable bins"). We used the latter distributions, as they could describe the income and expenses of individuals well, except for the very rich [19].

To analyze the respondents' attitudes in more detail, we used a variant of the classification-and-regression-tree (CART) algorithm [20] based on the reduction of Shannon [21] entropy (but using base e rather than base 2 logarithm). For each survey question (defining a variable), we checked if the responses allowed to split a given node (sample of respondents) into two classes (the successor nodes), so that their average entropy with respect to the studied attitude (weighted by class size over node size) was lower than the node's entropy. The explanatory power of a variable (its information content) was the higher, the more it reduced the entropy. Therefore, in each step we sought a partition of the given parent node with minimal weighted average entropy. (To avoid overfitting, we required five or more respondents in each successor node).

3. Results

3.1. Sanitation Situation in the Perception of the Households

The households of the study areas in general received basic water and sanitation services. Of the 281 respondents, (70%, confidence limits 64–75%) 197 reported the following situation: Their houses were connected to sewers, received municipal water, were equipped with a sanitary facility, and there was a municipal facility for regular solid waste disposal. Further, they lived in houses, which their families owned.

Of the 281 respondents (96%, confidence limits 93–98%) 270 reported about at least occasional water scarcity in their area as a problem. However, only 99 of these 270 respondents (37%, limits 31–43%) would always or sometimes practice water saving (e.g., low flow fixtures, shorter showers). Further, 191 (68% of 281, limits 62–73%) respondents complained about (sometimes or always) discontinuous water supply. Amongst the households that did not complain, 80% (72 of 90, limits 70–87%) had a groundwater well as an additional or as their sole source of water. To mitigate shorter service interruptions, 271 households stored water in coolers, canisters, or buckets, which most of them cleaned daily.

There appeared to be some dissatisfaction with municipal water. Amongst the 247 respondents from households receiving municipal water, 152 (62%, limits 55–68%) were concerned that their drinking water might be contaminated. Further, 96 (39% of 247, limits 33–45%) reported specific water quality problems (e.g., leaking pipelines, foul smell, red color from iron, or hardness of water). At first, the perceived contamination appeared to be age-dependent, as 55% of the elderly respondents denied a possible contamination, while 67% of the younger respondents were concerned (p-value 0.004). However, 20 of the 25 elderly respondents, who were not concerned, used advanced (meaning more expensive) methods of water purification (e.g., reverse osmosis). Thus, these elderly respondents did not necessarily state their unease about drinking water quality, but they demonstrated it by their precautionary measures.

About half of the respondents (152 = 54% of all 281 households and 124 = 50% of the 247 households with municipal water, confidence limits 48–60% and 44–57%, respectively) practiced water purification (e.g., cooking). Using advanced methods of water purification (e.g., reverse osmosis) was associated with higher income (which made it easier to purchase needed technology) and higher education (which increased awareness about water-borne diseases). Indeed, the Spearman rho was $\rho = 0.47$ between purification and income and $\rho = 0.38$ between purification and education, and the p-values using the Spearman rank test were close to 0.

Respondents were also asked about the costs (installation, maintenance, consumables) of their water purification systems. Considering the high spread of the stated costs for maintenance (100–5000 INR/year), not all households with advanced systems might have serviced them professionally (changing cartridges and filters, removing biofilms). Alternatively, they may have understated their costs or used purified water sparingly. For example, three households with four persons each used chlorination for water purification, stating costs of 1.5–2 INR/day for chlorine. However, an average household with four people would use about 300–500 L of water per day, mostly for non-potable purposes. For them, one purification tablet for 500 L would cost about 9 INR, resulting in 5.5–9 INR/day.

3.2. Socio-Economic Situation

Respondents were asked to roughly classify their total monthly household income and their expenses for essential goods and services (such as groceries, utilities, transportation, healthcare, or education, but not for water) by means of prescribed categories. Using "k" for 1000 INR/month, the income categories were 0–25 k, 25–50 k, 50–100 k, 100–150 k, 150–200 k, and higher incomes, 200–300 k. (In a similar way, they informed me about their spending.) We distinguished "poor" households with incomes below 25 k (126 = 45% of respondents), "better-off" households with incomes above 50 k (61 = 22% of respondents), and households with "intermediate" income 25–50 k (94 = 33% of respondents). These ad hoc definitions were motivated by relating income to expenses: We considered that households had a "sufficient income" if the lower limit of the income category exceeded the upper limit for the respective category of expenses. For the "better-off" households, income was always sufficient, but not so for the other households.

The midpoints of the income categories underestimated the average household income (39.1 k), as specifically for lower and intermediate incomes, the household expenditures often indicated incomes above the respective midpoints. Therefore, for each household, we represented its income by a modified interval, whose lower limit was the maximum of the lower limit of its income and expenses categories and whose upper limit was the upper limit of its income category. The estimated average income was 41.7 k (41.9 k for a histogram distribution with fixed bins).

To assess the extent of poverty, we analyzed the per-capita incomes because the World Bank defined poverty from the available income per person and day [22,23]: In 2023, the poverty line for upper-middle-income countries was 6.85 USD, while extreme poverty meant an income of 2.15 USD/day per person. (We divided the monthly income into thirty days and used the exchange rate of 12 USD for 1000 INR).

First, we estimated the fraction of households where the per-capita income was below the poverty line. We defined intervals for the per-capita household income from the above-defined modified intervals. The average of their midpoints was 4.66 USD/day per person. We then estimated the distribution of per-capita incomes by a histogram distribution of the midpoints, by a distribution using variable bins (mixture with equal weights of the uniform distributions over the modified intervals), and by a lognormal distribution fitted to the latter distribution (parameters $m = 1.11389$, $s = 0.922026$). The estimated fractions of households below the line of extreme poverty and below the line of poverty were 25% and 79%, respectively, for the histogram distribution, 28% and 83%, respectively, for the distribution with variable bins, and 35% and 81%, respectively, for the lognormal distribution.

Next, we estimated the fraction of persons (among the considered 1131 persons) with incomes below the poverty line. Here, we studied the distribution of daily per capita incomes across the population. Figure 1 plots their cumulative distribution functions. The average of the midpoints of the modified individual income intervals was 4.15 USD/day per person. Again, we considered a distribution using variable bins. It was the mixture of the uniform distributions of per capita income over the above-mentioned modified income intervals. The difference to the previous mixture distribution were the weights of the uniform distributions over the intervals. Here, they were proportional to the respective household sizes. Further, we fitted a lognormal distribution to this distribution (parameters $m = 1.06991$ and $s = 0.839546$). We estimated the fraction of persons living in extreme poverty and living in poverty as 34% and 85%, respectively, for the variable bins and as 36% and 85%, respectively, for the lognormal distribution.

To explore the poverty of households in more detail, we considered a "gradation of poverty". Thereby, the "optimist estimate" of per-capita income was the upper limit of the income category of the household, divided through household size. The "pessimist estimate" was the lower limit of the modified income interval (considering the necessary expenditures), divided through household size.

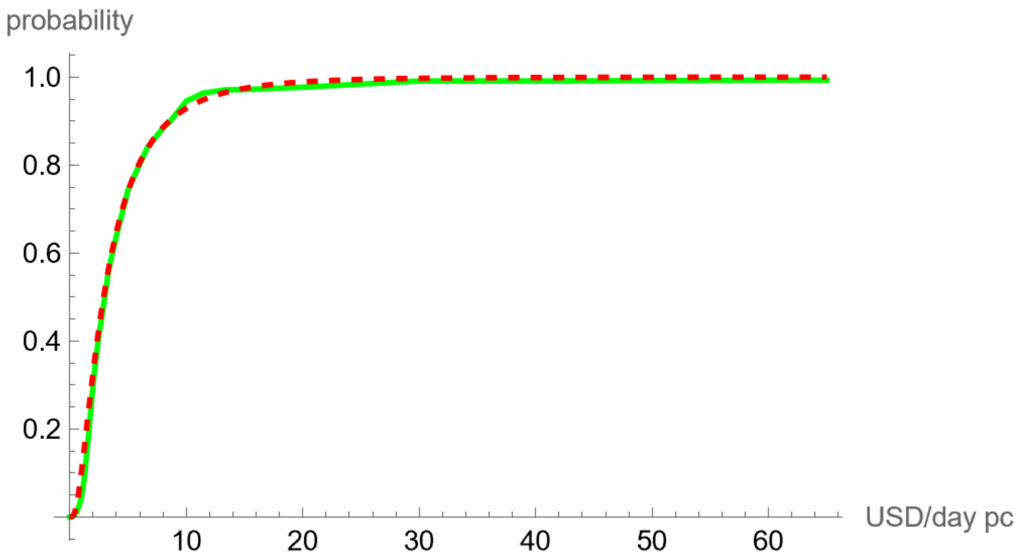

Figure 1. Cumulative distribution function of per capita incomes per day of the 1129 persons living in the interviewed households (green: weighted mixture of uniform distributions over modified income intervals, dashed red: fit by a lognormal distribution to this mixture); plots and computations using Mathematica.

A household was "surely extremely poor" (grade −1) if the optimist estimate of per-capita income was below the line of extreme poverty. Thirty-eight households (14% of 281, limits 10–18%) were "surely extremely poor". Thirty-six of them were in the lowest income category and two were in the intermediate one. We considered the "surely extremely poor" households as the core of the households that might not be able to pay any additional municipal charges.

A household was "perhaps extremely poor" (grade −0.5) if the pessimist estimate of per-capita income was below the line of extreme poverty and the optimist estimate was above it, but below the poverty line. There was no household, where the pessimist estimate was below the line of extreme poverty and the optimist estimate was above the line of poverty. In addition, 102 households (36% of 281, limits 31–42%) were "perhaps extremely poor".

A household was "surely poor" (grade 0), but surely not "extremely pure", if the pessimist estimate of per-capita income was above the line of extreme poverty but the optimist estimate was below the poverty line. Seventy-four households (26% of 281, limits 21–32%) were "surely poor". Therefore, 214 of the 281 households (76%, confidence limits 71–81%) were "surely poor" or worse off. This included 120 households of the lowest income category, eighty-eight intermediate, and six better-off households of the income category 50–100 k.

A household was "perhaps poor" (grade 0.5), but not surely so if the optimist estimate of per-capita income was above the poverty line but the pessimist estimate was below. Fifty-four households (19% of 281, limits 15–24%) were "perhaps poor". This included forty-two better-off households of the income category 50–100 k, six of the intermediate, and six of the lowest income categories. The latter were one-person households.

Finally, a household was "surely not poor" (grade 1) if the pessimist estimate of per-capita income was above the poverty line. Thirteen (5% of 281, limits 2–8%) households were "surely not poor". All these households were better off (income above 50 k). However, the other forty-eight (79%) of the sixty-one better-off households were "surely poor" or "perhaps poor". We considered the "surely not poor" households as the core of the households that should be able to pay a small additional municipal charge.

Using these grades, we could identify potentially vulnerable social groups.

Larger households had a higher risk for poverty. Collecting the household size and the grades of poverty (higher is better, as defined above) into two vectors (one entry for each household), then the rank correlation between these vectors was significantly negative (Spearman $\rho = -0.327$, p-value close to 0). Further, the distribution of the grades of large households (6+ persons) differed significantly from the distribution for the other households (Mann–Whitney test, p-value close to 0). Specifically, 35% (13 of 37, confidence limits 20–53%) large households were "surely extremely poor", but only 10% (25 of 244, confidence limits 7–15%) other households (non-overlapping confidence intervals).

Children were another risk factor for poverty. Comparing the count of children and the grades of poverty, then the rank correlation between the respective vectors was significantly negative (Spearman $\rho = -0.255$, p-value close to 0). Further, the distribution of the grades of households with children differed significantly from the distribution for the households without children (Mann–Whitney test, p-value close to 0). For instance, 21% (25 of 121, confidence limits 14–29%) of the households with children were "surely extremely poor", but only 8% (13 of 160, confidence limits 4–13%) of the other households (non-overlapping confidence intervals).

Education reduced the risk of poverty. Comparing three levels of education (1 higher, 0 some, and -1 no formal education) of the respondents and the grades of poverty, then the rank correlation between the respective vectors was significantly positive (Spearman $\rho = 0.305$, p-value close to 0). Further, the distribution of the grades differed significantly between households with a higher educated respondent and the other households (Mann–Whitney test, p-value close to 0). Where 84% (165 of 197, limits 78–89%) of the households, whose respondent did not have a higher education, were "surely poor" or worse off. By comparison, if the respondent for the household had a higher education, the percentage was 56% (54 of 81, limits 45–67%) "surely poor" or worse off (non-overlapping confidence intervals).

Our data did not show statistically significant differences in poverty between households in relation to the gender or the age of the respondents (Mann–Whitney test, correlation test). However, 63% of the responding women were housewives or unemployed. Further, 55% of the responding elderly were retired or unemployed, and 49% of respondents from large households were elderly.

3.3. Awareness about Reuse Options and Acceptability

To explore to what extent knowledge about recycling might affect the acceptance of recycled water, an initial question asked the interviewees about their familiarity with the concept of reusing treated and disinfected wastewater. Seventy-two respondents assessed themselves as (somewhat) aware about water recycling. We analyzed their views separately from the views of the 122 unaware respondents. Henceforth, we refer to them as the "first group" and the "second group", respectively. The "third group" are the remaining eighty-seven respondents, who did not answer the question about their knowledge. Table 1 summarizes the views. Amongst the 194 respondents of the first and second groups, there was no significant contingency relating group membership to gender, higher (60+) or lower age, large (6+) or smaller household size, or whether there were children. However, there was a highly significant contingency, according to which respondents with higher education were rather in the first group (Mann–Whitney test, p-value 0.004).

In all three groups, a significant majority approved of recycling. For all groups, the two most important arguments for recycling (approved by a significant majority of the first group) were the need to respond to the water scarcity in the area and the hoped-for reduction of the pressure on freshwater bodies. However, knowledge about recycling water might lead to more appreciation of other benefits, too. For example, the second group was significantly more skeptical than the first one as regards environmental benefits from recycling (and the thereby needed treatment of wastewater), the reduction of pressure on overly exploited freshwater bodies, nutrient recovery (which means removal of nutrients from the wastewater and their reuse in the form of treated sewage), the use of treated wastewater for groundwater recharge, health risks from still harmful recycled water, or the state of the art of treatment technology (p-values of the Mann–Whitney test ranging from close to 0 to 0.03). Thus, for the practical implementation of recycling projects there remains a risk, as a non-negligible fraction of up to 20% (upper confidence limit) of the less knowledgeable respondents may have reservations related to health and to the functioning of the technology. The third group showed several significant differences to one of the first or second groups, but it never differed significantly from both groups.

Table 1. Views about the reuse of treated wastewater.

Approval and Reasons and for/against Recycling	72 Persons First Group	122 Persons Second Group	87 Persons Third Group
Approval for water recycling [1]	*69%* [2,3]	*72%*	*64%*
amongst 72 + 109 + 77 with opinion	57–80%	63–81%	52–74%
For: Overexploitation of water bodies	*69%*	*72%*	*64%*
amongst 72 + 122 + 87 with opinion	57–80%	63–81%	52–74%
For: Water scarcity	*65%*	51%	*64%*
amongst 72 + 121 + 87 with opinion	53–76%	42–60%	53–74%
For: Environmental protection	61%	25%	41%
amongst 72 + 122 + 87 with opinion	49–72%	17–33%	31–52%
For: Groundwater recharge	47%	28%	31%
amongst 72 + 120 + 87 with opinion	35–59%	20–36%	22–42%
For: Removal/recovery of nutrients	13%	2%	5%
amongst 71 + 122 + 86 with opinion	6–23%	1–7%	1–11%
For: Other reasons	3%	0%	0%
amongst 70 + 117 + 58 with opinion	0–10%	0–3%	0–6%
Against: Recycled water still harmful	3%	13%	9%
amongst 72 + 122 + 87 with opinion	0–10%	8–20%	4–17%
Against: Insufficient technology	1%	9%	7%
amongst 72 + 122 + 87 with opinion	0–7%	5–15%	3–14%
Against: General health concerns	1%	8%	7%
amongst 72 + 122 + 87 with opinion	0–7%	4–15%	3–14%
Against: Alternative water sources	1%	7%	6%
amongst 72 + 122 + 87 with opinion	0–7%	3–14%	2–13%
Against: Not economical	1%	3%	6%
amongst 72 + 122 + 87 with opinion	0–7%	1–8%	2–13%
Against: Religion	0%	1%	3%
amongst 72 + 122 + 87 with opinion	0–5%	0–4%	1–10%
Against: Other reasons	0%	1%	0%
amongst 72 + 122 + 87 with opinion	0–5%	0–4%	0–5%

Note(s): [1] The number of resolved respondents (i.e., with an opinion) is listed in the first column. [2] The outcomes are percentages of the approval amongst the persons of that group who stated their opinion (second line: confidence limits). [3] Italic percentages indicate significant majorities amongst the resolved respondents of that group (i.e., lower confidence limit above 50%). The same scheme applies to Tables 2 and 3.

Familiarity of the first group with recycling was confirmed, as 56% of them (40 of 72, limits 43–67%) were also aware about non-potable uses for recycled water (e.g., watering of gardens, parks, or of potted plants in the home, toilet flushing, household cleaning, vehicle washing). Further, 24% of the first group (17 of 72, limits 14–35%) were aware that treated sewage could be used, too (e.g., as a fertilizer for use in agriculture or gardening, or for landfilling). These responses were significantly different from the answers of the second group (Mann–Whitney test, p-values 0.005 and 0.0007, respectively). For, amongst them, only 36% (43 of 121, 27–45%) were aware of non-potable use options and 7% (8 of 121, 3–13%) of sewage use (one did not answer).

Table 2. Views about possible barriers for recycling.

Challenges	72: First Group	122: Second Group	87: Third Group
Water quality	*90%*	*85%*	*85%*
amongst 72 + 122 + 87 with opinion	81–96%	78–91%	76–92%
Costs	*88%*	*63%*	*74%*
amongst 72 + 122 + 87 with opinion	78–94%	54–72%	63–82%
Technology	*78%*	57%	60%
amongst 72 + 122 + 87 with opinion	66–87%	48–66%	49–70%
Health concerns	58%	57%	*70%*
amongst 72 + 122 + 87 with opinion	46–70%	48–66%	59–79%
Public acceptance	53%	43%	38%
amongst 72 + 122 + 87 with opinion	41–65%	34–53%	28–49%
Public policy	29%	31%	34%
amongst 72 + 122 + 87 with opinion	19–41%	23–40%	25–45%
Distrust in authorities	11%	16%	18%
amongst 72 + 122 + 87 with opinion	5–21%	10–23%	11–28%
Religious reasons	0%	2%	2%
amongst 72 + 122 + 87 with opinion	0–5%	0–6%	0–8%

Table 3. Views about specific options for using treated and disinfected wastewater.

Approval	72: First Group	122: Second Group	87: Third Group
Toilet flushing with TWW	*100%*	*100%*	*100%*
amongst 57 + 93 + 63 with opinion	94–100%	96–100%	94–100%
Car washing with TWW	*96%*	*93%*	*95%*
amongst 51 + 102 + 65 with opinion	87–100%	86–97%	87–99%
Domestic cleaning with TWW	*93%*	*96%*	*95%*
amongst 42 + 84 + 55 with opinion	81–99%	90–99%	85–99%
Dishwashing with TWW	17%	44%	20%
amongst 46 + 81 + 51 with opinion	8–31%	33–56%	10–33%
Aquaculture with TWW	*84%*	*73%*	*77%*
amongst 38 + 48 + 30 with opinion	69–94%	58–85%	58–90%
Irrigation of food crops with TWW	48%	46%	35%
amongst 33 + 78 + 51 with opinion	31–66%	35–58%	22–50%
Would consume food from such a crop	47%	41%	44%
amongst 72 + 121 + 87 with opinion	35–59%	32–51%	33–55%
Irrigation of non-food crops with TWW	*100%*	*95%*	*99%*
amongst 65 + 107 + 72 with opinion	94–100%	89–98%	93–100%
Would use non-food products from it	*96%*	*86%*	*91%*
amongst 72 + 121 + 87 with opinion	88–99%	78–92%	83–96%
Irrigation of garden with TWW	*98%*	*94%*	*97%*
amongst 48 + 100 + 62 with opinion	89–100%	87–98%	89–100%
Irrigation of public parks with TWW	*98%*	*95%*	*99%*
amongst 52 + 102 + 69 with opinion	90–100%	89–98%	92–100%
Would visit such parks	*93%*	*94%*	*94%*
amongst 72 + 121 + 87 with opinion	85–98%	88–98%	87–98%

Table 2 summarizes the percentage of respondents that considered the displayed barriers for implementing recycling as relevant. For all groups, water quality and costs were deemed problematic by a significant majority of the respondents; for the first group, also technology. Outcomes with significant majorities are displayed in italics. In all groups, a significant majority (upper confidence limit of approval below 50%) dismissed religious reasons, distrust in authorities, or public policy as potential problems for promoting the recycling of water. There were significant differences between the first and the second group with respect to costs and technology (Mann–Whitney test, p-values 0.0003 and 0.004, respectively), whereby the first group was more pessimist.

Coming closer to the question of whether the respondents would themselves use recycled water, respondents were asked about the importance of certain criteria for their decision-making. All respondents answered this question, and for each criterion, a significant majority of each group deemed it important or very important; there was no significant difference between the groups. Ordered by decreasing approval of the first group, the criteria were: risks for health and the environment, costs and benefits, knowledge about reuse possibilities, availability of a complete description of the system, experience from other places, plans for monitoring and inspections of the system, and valid justifications for recycling water. Another question asked whether fulfillment of the following conditions would facilitate the acceptance of using recycled water: the public health shall be protected, there will be only minimal human contact with treated wastewater, there ought to be environmental benefits, the costs for the recycling system shall be reasonable, and the recycled water shall be of high quality. All resolved respondents (they answered the question and were not indifferent) agreed, but the percentage of resolved respondents was low.

Table 3 summarizes the acceptability of specific options for resource recovery. Using recycled water for toilet flushing was the top option that all resolved respondents accepted. In a follow-up question, for all groups, between 92% and 94% considered that it would help in the saving of freshwater. Further, other than for piped potable water, between 89% and 100% of all groups were not bothered by possible foul smelling, discoloration of the toilet bowl, feeling of disgust, or threat to health. (Note that treated wastewater is expected to be free of foul smell.) We observed no significant differences between the groups. For the other options, in all groups a significant majority (lower confidence limits above 50%) accepted them, except for the use of recycled water for dishwashing, the irrigation of food crops, or their consumption. For dishwashing, there was a significant difference between the first group and second group (Mann–Whitney test, p-value 0.002). Notably, it is to be expected that because of the treatment, the recycled water will be free of smell (other than chlorine).

3.4. Willingness to Pay for Recycled Water

In view of the high acceptance for household uses of recycled water, it was of interest if respondents would also pay for dual taps. Therefore, the household survey presented two scenarios to the respondents. They could either continue with the following scenario A, basically the status quo, or move at a cost to scenario B with systematic use of recycled water. They were then asked if, and which amount, they would be willing to pay to move to scenario B. Initially, they were asked if their household would be willing to pay 25 INR/month for recycled water in addition to the water bill, which was 30 ± 10 INR/month per household. Depending on the answer, the amount was stepwise increased or reduced by 10 INR. This defined WTP intervals of length 10 INR, except for five respondents needing broader intervals and two with more accurate replies. Note that this question was about the surcharge only, not about the additional costs for adaptations of the house, such as connecting the toilet to the recycled water tap (the households alone would be responsible for such costs).

Scenario A: During periods of water scarcity, irrigation of gardens is restricted to specified hours at certain days, car washing is only possible at designated facilities, and non-essential water-based recreational activities (e.g., swimming pool maintenance) are put on hold. Violations of these municipal ordinances are fined.

Scenario B: Sewer infrastructure is updated to pipe recycled water from decentralized treatment plants back to the households that receive an additional tap for recycled water in addition to a tap for potable water. At least during periods of water scarcity, households ought to use recycled water for all non-essential purposes.

Consistently with their positive attitude towards water recycling, for all three knowledge groups, a significant majority of respondents approved of a dual system of water provision, with one tap for potable water and another one for recycled water. Most households would also pay for it (scenario B). Of the households willing to pay for dual taps, 208 (74% of 281, limits 68–79%) informed about the amount.

Sixty-nine respondents (22% of 281, limits 17–27%) were not willing to pay. Splitting them into three groups by their familiarity with the concept of recycling, two were in the first group (3% of 72, limits 0–10%), forty-six in the second group (38% of 122, limits 29–47%), and twenty-one in the third group (24% of 87, limits 16–35%). Thus, there was a significant contingency between low knowledge about recycled water and unwillingness to pay for it (non-overlapping confidence intervals of the first and second groups). Exploring further reasons for the unwillingness to pay, thirty-two respondents unwilling to pay were content with scenario A (47% of 68 unwilling-to-pay respondents with an opinion, limits 35–60%), nineteen wanted the municipality to pay for scenario B, and twelve allegedly could not afford an additional contribution (100% of the answers to the affordability question). Further, five respondents considered that the municipality would not use their contributions wisely (56% of nine with an opinion), four had no interest in this problem (44% of nine with an opinion), and for one this problem had no priority (14% of seven with an opinion).

We confined the further analysis to the 247 households that already received municipal freshwater. For them, it was clear that their response would not affect whether they would receive a water tap and that the requested amount was a surcharge for recycled water only and not a combined bill for dual taps (potable and recycled water). Out of the 247 households 184 of them (75%, limits 69–80%) informed us about the amount they were willing to pay.

We approximated the distribution of the willingness to pay of these 184 households by a histogram distribution, a mixture of uniform distributions over the intervals between minimal and maximal willingness to pay of each respondent, and a lognormal approximation to this distribution (parameters $m = 4$, $s = 0.44$). For the mixture distribution (and the lognormal one), the expected value for the willingness to pay (average) was 61 INR/month per household, and the standard deviation was 28 INR/month (rounded to integers).

Next, to obtain more realistic estimates of the revenues that the municipalities might expect from a surcharge for recycled water, we assumed that households would not pay the surcharge or a part of it if the amount demanded by the municipality exceeded their willingness to pay, but that they would pay otherwise. Consequently, given the cumulative distribution function for the willingness to pay, *CDF*, if the municipality requests a surcharge, t, from the households, then the expected revenue of the municipality per household will be $t \cdot (1 - CDF(t))$. What is the optimal surcharge, t, that maximizes the expected revenue per household? Figure 2 plots the expected revenues for the three considered cumulative distributions of WTP. For the green line, the plot shows a peak of 29.5 INR/household for a surcharge of $t = 44.7$ INR/month; for the red line, the peak is 30.7 INR/household for $t = 41.5$; and for the black line, it is 32.3 INR/household for $t = 43.1$ INR/month. Thus, the optimal surcharge was estimated to be in the range of 42 to 45 INR/month with an expected revenue of about 30 INR/household.

As an additional consideration, we assumed that households would not pay for recycled water if they did not even pay their bill for potable water. Therefore, we repeated the above computations for the compliant households that paid their water bill. Fifty-one households were both compliant and willing to pay a surcharge for recycled water. (These were 21% of the households receiving municipal water; confidence limits 16–26%). Now, the expected willingness to pay was higher, 64 INR/month with a standard deviation of 25 INR/month, but the difference was not significant (comparison of the midpoints of the WTP intervals using the Mann–Whitney test: p-value 0.27). The optimal surcharges were 41 INR/month with expected revenues of 33 INR/household (mixture distribution), 44.8 INR/month with expected revenues of 35 INR/household (lognormal distribution), and 44.7 INR/month with expected revenues of 37.3 INR/household (histogram distribution). Further, the mixture distribution had another peak for a surcharge of 65 INR/month (revenues 35 INR/household), but this peak was not supported by the other distributions. Therefore, assuming a surcharge of 41 INR/month per household for recycled water (mixture distribution), the resulting expected revenue of 33 INR/month per household (assuming that hitherto compliant households may not remain compliant if overcharged with 41 INR/month), and the lower confidence limit of 16% households that are both willing to pay and compliant (paying their water bill), we conclude that the municipalities could expect in average revenues of merely 5.3 INR/month for recycled water per connected household (16% of 33 INR).

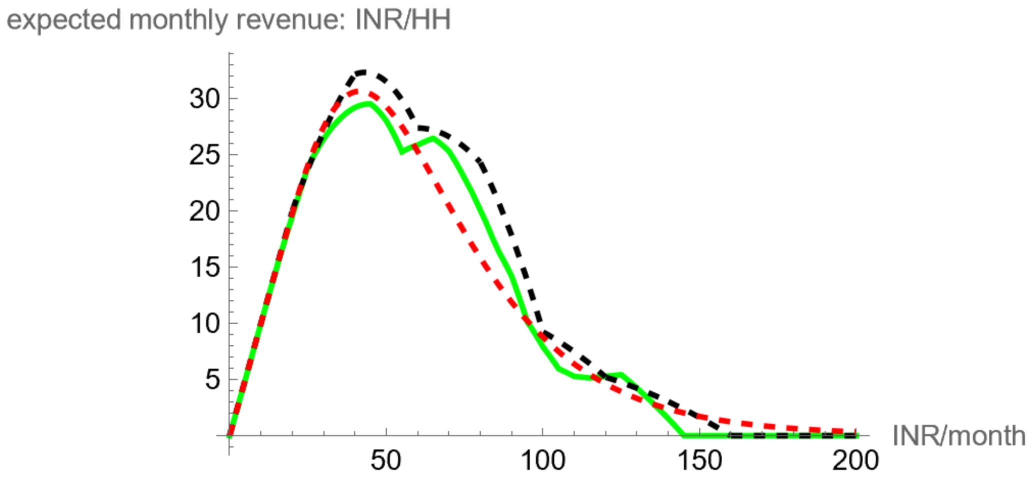

Figure 2. Expected revenues from monthly surcharges for recycled water amongst 184 households with willingness to pay (black dashed revenues from a histogram distribution, green from a mixture of uniform distributions, red dashed revenues from a lognormal distribution fitted to the mixture distribution); plots and computations using Mathematica.

Thus, low compliance was a serious problem for financing water infrastructure: 247 of the 281 surveyed households received municipal water, but only sixty-four paid the municipal charges (at most 40 INR/month) for the provision of drinking water. To explore this matter in more detail, we confined the analysis to the "typical" respondents. They lived in their own houses, which were also connected to sewers, received municipal water, were equipped with a sanitary facility, and had a municipal facility for regular solid waste disposal. Nine did not answer if they paid their water bill, and we removed them from the "typical" respondents. There remained 188 "typical" respondents. Of them, fifty-six paid their water bill (compliant users), and 132 (70%) did not pay.

In a first step, we evaluated the rank correlations (Spearman ρ) and their significance (Spearman rank test) between the views of typical respondents and their compliance (1 yes, -1 no). Amongst 122 variables, twenty-six had a significant correlation with compliance (p-value below 0.05). For instance, we expected that poorer households would be less compliant. Indeed, there were significant and positive correlations between compliance and the variables household income, expenses, grades of poverty, and "sufficient income" (1 sufficient, -1 insufficient). However, these variables could not explain why there were extremely poor but compliant households and better-off but incompliant ones. Similarly, we expected that dissatisfaction with the water services may explain incompliance. To verify this, we collected households with complaints, namely those reporting foul smell of water, irregular availability, or affording advanced purification methods (thereby indirectly showing concerns about water quality). However, the fraction of incompliant households with complaints (67%, confidence limits 59–74%) was lower than the fraction of incompliant households without complaints (92%, confidence limits 74–99%). Further, amongst the ninety-three households that purified their drinking water, the rank correlation coefficient rho between compliance and the cost of used purification technology was significantly positive, whereas we would have expected a negative correlation (more costs, less compliance).

To search for better explanations, we constructed a decision tree from our survey data, Figure 3. It partitioned the households into twelve classes, the red and green end nodes, which were comprised of mostly incompliant and mostly compliant households, respectively. We observed a good overall performance of this decision tree: Its partition of the households reduced the initial entropy (0.61) of the unstructured compliance data to a much lower weighted average (0.21) of the entropies of the twelve end nodes. Further, for most households, the decision tree could correctly forecast if they were compliant or incompliant. (The households in each end node were forecasted as compliant/incompliant if the node was green/red.) Thereby, it correctly forecasted 92% (122 of 132) of the non-compliant households (and 92% of the households that were forecasted as non-compliant were indeed not compliant), and it correctly forecasted 91% (51 of 56) of the compliant households (and 91% of the households that were forecasted as compliant were indeed compliant).

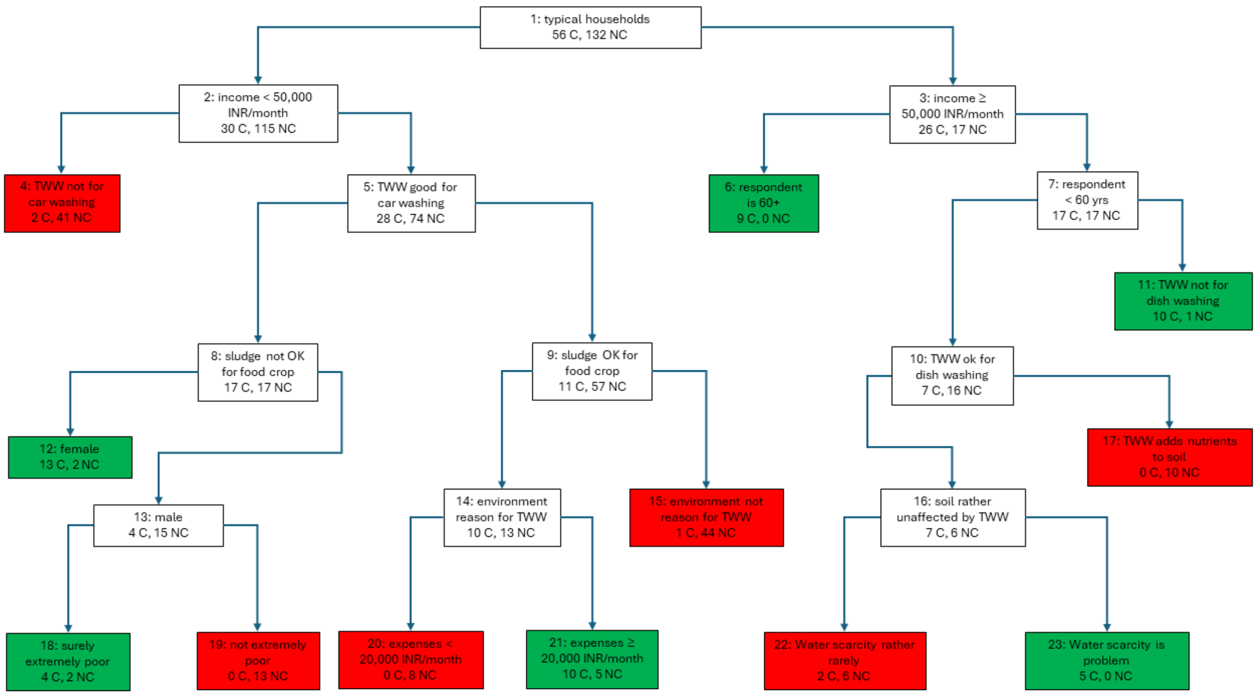

Figure 3. Decision tree to identify compliant (C) and non-compliant (NC) households amongst 188 typical ones (terminal nodes in red or green; red means "classified as NC", and green means "classified as C"); computations using Mathematica and graphics in MS PowerPoint (TWW: treated wastewater).

Some nodes in Figure 3 may appear strange and only superficially related to compliance. Indeed, as with regression analysis in general, the decision tree could only identify associations but not causations between the variables about the use of TWW (treated wastewater) and compliance. However, the variables identified groups of respondents in similar situations that shared common views. For these groups, more detailed investigations of the motives for not paying for potable water were possible, as outlined below.

For the large red node no. 4 with forty-three households, it appeared at first that its mainly incompliant users would prefer potable water over TWW (treated wastewater) for car washing (or similar activities), as for them it was without costs. However, all respondents to this node deemed TWW a threat to health. Further, the compliant households from this node had sufficient incomes, the incompliant ones did not. Thus, for this node, health concerns and poverty might explain incompliance.

For the green node no. 6, with nine elderly respondents, all complained about discontinuous water supply. Nevertheless, they paid for water. Thus, for this group, the higher household income together with civic spirit (to fulfill civic obligations) might explain compliance.

The eleven respondents from green node no. 11 in general had a positive opinion about non-potable uses of TWW, such as washing cars or cleaning the house, but they asked to minimize human contact with TWW, so they rejected dishwashing with TWW. Further, most of these households used advanced methods of purification for their drinking water, and they could afford it (better-off households). A possible explanation for compliance might be the view (separating the compliant from the incompliant households of this node) that water scarcity is a reason to support TWW. Thus, for this node, environmental awareness might explain compliance.

The green node no. 12 collects fifteen women who were skeptical about uses of TWW or sludge with human contact (dish washing, use for food crop), but accepted TWW for non-potable uses (car washing, domestic cleaning). Most households from this node had (potentially) insufficient income. Thus, as for node no. 6, civic spirit or the lack thereof might explain compliance or incompliance, respectively. Notably, the two incompliant households had sufficient income. Another explanation might be the number of adults in the household: Those with four or fewer adults were compliant, the others two were not.

The large red node no. 15 collects respondents from forty-five households, for whom environmental concerns would not count as reason to support TWW. Thus, apparently, their environmental awareness was rather low. Further, except for four respondents (amongst them the compliant one), they were not aware about the reuse options for treated sewage. However, they accepted non-potable uses of TWW, and all (except one) would accept dual taps. Most of them had (potentially) insufficient income, and about half of them complained about service problems (intermittent supply, foul smell, hard water).

The ten respondents of the red node no. 17 from better-off households agreed to the statement that irrigating with TWW would add nutrients to the soil. The question about adding nutrients to the soil may have puzzled respondents, as treated sludge may be used as a fertilizer, while wastewater treatment ought to remove nutrients from the TWW. However, recent literature [24] has shown benefits to the soil from irrigating with TWW. Respondents had in general favorable views about recycling and would accept and pay for dual taps. However, they did not pay the charge for potable water. Perhaps they were dissatisfied with water quality, as all, except two, used advanced purification with stated maintenance costs of 500–2000 INR/year.

The green node no. 18 collects six male respondents from "surely extremely poor" households. Four of them nevertheless paid the charge for potable water. For them, as for nodes no. 6 and 12, civic spirit might explain their compliance. The other two apparently were dissatisfied with water quality and used advanced methods of purification with stated costs of 500 INR/year for maintenance. Owing to their poverty, these expenses might be all they could afford.

The red node no. 19 was comprised of thirteen male respondents from "surely poor" and "perhaps extremely poor" households. For two-thirds of them, income was (potentially) insufficient. All except two considered that the water from the tap was perhaps contaminated, but only about half of them could afford advanced purification methods. Thus, for this node, poverty combined with dissatisfaction about water quality might explain incompliance. As for nodes no. 8 and 12, they were skeptical about uses of TWW with human contact, but they would accept dual taps.

The eight households collected in the red node no. 20 had expenses below 20 k, were from the lowest income category, and were "perhaps extremely poor". All complained about foul-smelling water and, except for two, about discontinuous water supply. The latter two used advanced purification at stated maintenance costs of 500 INR/year. Thus, poverty and poor water services may have caused their incompliance. Most would accept a dual tap in their household. While most considered that human contact with TWW should be minimized, since most would not consume food irrigated with TWW or fertilized with sludge, they were generally open to all other uses of TWW and sludge.

The green node no. 21 was comprised of thirteen households with intermediate income and two from the lowest income category. For all, the income was (potentially) insufficient; four were "perhaps extremely poor" and the others "surely poor", but their expenses were above 20 k. All ten compliant households and three of the five incompliant ones suffered from discontinuous water supply. Together, this suggests that compliance was a consequence of civic spirit. As for an alternative explanation, with one exception, all eleven households with respondents of age 32 or above were compliant, and those represented by a younger respondent were incompliant. The attitudes towards sludge and TWW were comparable to node no. 20.

The red node no. 22 was comprised of eight households with incomes of 50–100 k and two with incomes 100–200 k. All had sufficient income; two were "surely not poor" and the others "perhaps poor". All complained about the foul smell of the water, and, except for two, they used advanced methods for water purification. They would accept dual taps and pay for them. Notably, the compliant users would pay a surcharge of about 40 INR/month, while the incompliant ones allegedly would pay more (which seems to be a strategic response). The compliant respondents were of age 50 or higher. For them, as for node no. 6, civic spirit might explain compliance, while for the others dissatisfaction with the poor water quality might explain incompliance. In addition, all respondents ignored water scarcity; therefore, their environmental awareness apparently was low. Further, the views about TWW were rather heterogeneous and in part related to compliance. For example, only for the incompliant users, it was important that a system for the reuse of TWW ought to be economical.

The five respondents of the green node no. 23 came from compliant households with incomes of 50–100 k. They had sufficient income but were "perhaps poor". All complained about the foul smell of the water, which they suspected to be contaminated, and used advanced purification methods, costing them stated 600–2500 INR/year for maintenance. Their views about recycling were generally positive: They accepted dual taps, would pay for it, and they would also pay TWW for irrigation in their gardens. Their compliance might have been due to their environmental awareness, as they acknowledged the water scarcity in their area, or due to their civic spirit, as they paid for potable water despite its perceived poor quality.

4. Discussion and Conclusions

4.1. Alternative Socio-Economic Analysis

Our socio-economic analysis was based on household incomes only. Considering, in addition, household expenditures for basic needs did partially confirm and partially alter the findings.

We used the same type of models for modeling the distribution of household expenditures as for the income distribution: histogram distribution of the midpoints (expected value of expenses 21.4 k), mixture of uniform distributions over these modified intervals (average of the midpoints 21.2 k), and lognormal approximation. Thereby, for each household, we defined its modified expenditure interval in analogy to the modified income intervals: The lower limit was the lower limit of the expenses category. The upper limit was the smaller of the upper limits of the income category and the expenses category.

The average household spent 2.34 USD/day per person (average of modified interval midpoints); 48% of households spent less than 2.15 USD/day per person; and 99% spent less than 6.85 USD/day per person (estimates based on the mixture of uniform distributions). Similarly, the average person spent 2.11 USD/day, 56% of persons spent less than 2.15 USD/day, and 99.9% spent less than 6.85 USD/day. We conclude that the definition of poverty by an income below 6.85 USD/day per person was appropriate for our study, as our data confirmed that for 99% of households this amount was sufficient to cover the basic needs. However, at the line of extreme poverty, we noted the following discrepancy between expenses and income: While at most 35% of households had an income of less than 2.15 USD/day per person, 48% of households did not spend more than this small amount for their basic needs. This could indicate that they had other obligations, such as paying off debts, or they had other means to fulfill their basic needs, such as food grown in their own gardens. In the latter case, even with a low income, they could accumulate savings and perhaps afford to pay an additional small municipal charge, while in the former case they would be too deprived to pay any additional charge.

To further explore the affordability of an additional municipal charge for recycled water, we considered the "disposable" household income. Thereby, we deviated from the standard definition of "disposable" (income minus taxes) and meant the difference between the household income and the expenses for the daily needs. We considered that additional charges (including the charge for potable water) should remain below 3% of the disposable income to be affordable. As potable water is more useful than recycled water, a viable surcharge for the delivery of recycled water should not cost more than the municipal charge for the delivery of potable water, which was 40 INR/month or less. Therefore, we investigated if a charge of 40 INR/month for potable water or even a combined charge of 80 INR/month for potable and recycled water would be affordable. For the computations, we considered the differences between the (modified) intervals of income and expenses. For each household, the interval of its disposable income ranged from the lowest value of the differences (reset to 0, if it was negative) to the largest one (always non-negative by the definition of the modified intervals).

For a first pessimist estimate, for 195 households (70% of 280), the lower limit of the disposable income was 0, whence for them we could not be sure if they could afford any additional charge. For an optimist estimate, we considered the midpoints of the intervals of disposable incomes (average disposable income: 22 k) and a histogram distribution of the midpoints (mean value of the distribution: 23.5 k). For these distributions, we concluded that affordability ought to be no problem. Less than 1% and 2% of households had a disposable income of less than 1.33 k and 2.67 k, respectively. (In view of the 3% criterion, this means they could not afford 40 INR/month and 80 INR, respectively.) Using instead a mixture of uniform distributions over the intervals of disposable income, we estimated that 7% and 13% of the households could not afford 40 INR/month and 80 INR/month, respectively.

We also considered bivariate distributions of income and expenses, as these allow to model the dependency of expenses on income. First, for each household, we considered the pair of the midpoints of its modified income interval and its modified expenses interval. To smoothen these data, we considered a bivariate histogram distribution (determining the bins using Sturges' rule), which estimated that 21% and 25% of households could not afford 40 INR/month and 80 INR/month, respectively. However, the outcome was dependent on the rule for the bins. (Using the Knuth rule resulted in less smoothening and the estimates of 3% and 5%, respectively.) We also used variable bins defined from the modified rectangles built from the income interval and the expenses interval of each household (i.e., we used a mixture of the bivariate uniform distributions over these rectangles). It estimated that 17% and 22% of households could not afford 40 INR/month and 80 INR/month, respectively. (A similar estimate was obtained for the smooth kernel distribution of the midpoints: 15% and 19%, respectively.) We finally truncated this distribution with variable bins, adding the condition that expenses would not exceed income. It changed the estimate to 8% and 15%, respectively.

Summarizing, several of the findings relating affordability to "disposable income" were more optimistic than the findings from income alone, where 25–35% extremely poor households were not expected to be able to pay. However, the estimates using "disposable income" were strongly dependent on the method for the estimation, so we consider that more empirical research (using larger samples) about the estimation of multivariate distributions of incomes and expenses is needed.

4.2. Implications for the Observed Water Supply Problems

In the Global South, "vast segments of the urban population [. . .] lack access to safe, reliable, and affordable water" [25]. This is not merely a problem of the poor. This paper surveyed the situation in peri-urban neighborhoods that were not slums. The typical household was connected to sewers, received municipal water, was equipped with a sanitary facility, and had a municipal facility for regular solid waste disposal. While there were up to 35% extremely poor households with a per capita income below 2.34 USD/day, 20% of the households were better-off (household income above 50 k) and could be considered "middle class" in the Indian context [26] (annual household incomes above 0.5 Mio. INR). For them, affordability of safe water ought to be not a problem. Nevertheless, most households complained about water scarcity and the poor quality of the tap water, and they did not pay for their tap water.

Intermittent water supply, a consequence of water scarcity, is known to compromise the microbial quality of tap water [27]. It may explain why households complained about the foul smell of the tap water and had health concerns. In comparison, other complaints (due to, e.g., calcium or iron in the water) were less challenging. Thus, if the problem of water scarcity could be resolved, then also the quality of tap water might improve.

To mitigate the problem of water scarcity and thereby also of water quality, a system for reusing treated wastewater by the households was considered. We studied its viability. Most respondents from the households had positive views about reusing treated wastewater, whereby the main reasons were related to the saving of freshwater resources (reduce overexploitation of water bodies, adapt to water scarcity, protect the environment). The most accepted household uses of recycled water were for toilet flushing, car washing, and the irrigation of lawns or non-food crops. Generally, the less personal contact the potential use of recycled water requires, the higher the acceptance. This positive attitude translated also into a high percentage of households that were willing to pay for the delivery of recycled water. Amongst households that already received drinking water from the municipalities, 75% stated a willingness to pay on average, 61 INR/month for an additional tap with recycled water. However, surcharges above 40 INR/month for recycled water were not realistic, as one could not charge more for water of lower quality than for potable water. Thus, the stated willingness to pay was rather a strategic response to demonstrate support for recycling. It might not translate into the same amounts actually paid.

Finally, there was a problem with lacking compliance, as 75% of the households that received municipal water did not pay for it. Taking this into account, a surcharge of 41 INR/month per household for recycled water would maximize the expected municipal revenues, but owing to incompliance, municipalities could expect to collect in average only 5.3 INR/month per household with dual taps. (This outcome was comparable to optimal sanitation charges that we previously found by similar methods for a slum in Raisen, Madhya Pradesh state [28].)

The low level of compliance was surprising in view of our socio-economic analysis. Did we underestimate the level of extreme poverty in the area? According to our analysis, the situation of most households was not particularly dire, as there were only 35% extremely poor households that, in our view, were perhaps too destitute to afford (additional) municipal charges for recycled water, not 75%. Considering income together with expenses, the economic situation of the households might even be better. A closer analysis of the attitudes of respondents indicated that there were even extremely poor households that paid their water charges, while there were well-off households that did not pay. Summarizing the findings of this analysis, poverty and, in the view of the respondents, poor quality of the water services initially may have motivated households to deny the payment of the water charges, resulting in possibly an even higher level of incompliance. However, for some households, "soft" factors, such as environmental awareness or civic spirit, may have reverted their initial decision. These findings indicate that municipalities could raise compliance by increasing environmental awareness. After all, most households had a positive attitude towards recycling of water, and in theory, they were also willing to pay for it in addition to the current charges for water. Further, if water scarcity could be overcome, then also the quality of tap water would improve. This, in turn, might remove one of the reasons for incompliance. For unsafe tap water surely does not meet users' expectations about drinking water and may result in incompliance [29].

We propose that to promote recycling, municipalities might consider free delivery of disinfected recycled water to the households. Such a system could be a significant contribution to mitigating water scarcity because currently potable water is mostly used for non-potable purposes. Further, the current charges of 40 INR/month or less for potable water and a similar charge for recycled water would be rather of a symbolic nature and therefore are expendable. As for an illustration, the papers [9,28] compared the costs of different systems of wastewater treatment. Estimated running costs of decentralized wastewater treatment ranged from 55 INR/month to 995 INR/month per household, depending on the (still conventional) treatment technology. We considered that these costs should be considered as costs for sanitation (covered by a sanitation charge) and not as "production costs for recycled water". Such production costs would come from additional treatment steps, such as the removal of micropollutants. However, the relevant (legal) requirements and thus the costs of treatment depend on the intended uses for recycled water, which does not need to be potable. If it shall be used for irrigation or car washing, lower standards apply [30], therefore additional treatment steps may not always be needed. (Further, for households, no additional costs would arise, as an existing garden hose could be used). Costs for the needed infrastructure could be minimized if municipalities lay down new pipes for recycled water in parallel to replacing the existing old and sometimes leaking pipes for potable water.

As a further incentive for using recycled water, municipalities might consider high volumetric charges for consumption of drinking water above a certain threshold (to respect the human right to water [31] that is highly regarded in India) but continue free delivery of disinfected recycled water. In the context of such a policy, affordability for the users would no longer matter as a criterion for the identification of BAT for recycling water, provided that the municipalities can afford such technologies. In addition, charges for potable water should be enforced strictly, as it seems to be unfair if some extremely poor households pay for it, while some better-off households do not. However, municipalities should consider that, in this case, households might use the recycled water also for potable purposes. To prevent this, a denaturant might be added to the recycled water.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w16192838/s1, Excel file SI_data.xlsx that collects the outcome of the survey and word file SI_survey.docx that informs about the conception of the survey.

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