Potable Water Purification Costs of Urban People: A Cross-Income Group Analysis in Greater Mirpur, Dhaka

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ABSTRACT

This research examines the economic implications of water purification in urban areas of Dhaka, where foul odors and potential pathogens, have led many residents to use various water purification methods. The study aims to investigate the additional costs incurred by households for water purification and how these costs vary across income groups. Data was collected from households of different thanas in the Greater Mirpur area through structured and semi-structured questionnaires. The findings show that although 89% of households rely on water delivered by the Water Supply and Sewerage Authority (WASA), only 28% have access to clean water. Water purifiers, especially manual ones, are popular choices for water purification. The average monthly cost of water purification was found to be 331 BDT, with considerable variation based on income. Unilever was the most popular brand of water purifier, although a significant proportion of respondents selected their purifier randomly. The study highlights the urgent need for improved water quality management and treatment, particularly for low-income residents, and the importance of raising awareness about different water purification brands and their efficacy. While the research gives helpful information into the water purification practices of city's households, certain limitations, such as its limited geographic scope and sample size, should be considered. Nevertheless, this research provides a foundation for understanding the economic challenges of water purification and encourages further research into these pressing issues.

Keywords: Potable Water; Urban People; Water Purification Strategies; Dhaka WASA; Economic Implications.

INTRODUCTION

A reliable source of potable water that is both safe and convenient is crucial for the safety of health. For decades, approximately one billion people in developing countries have not had door to safe drinking water (Hunter et al., 2010). Currently, 4.4 billion people, or 56 percent of the world's population, reside in cities (United Nations, 2019). Bangladesh is a developing country with a dense population (1119 per square kilometer) with over 42 million people living in cities. The population is rapidly rising on a daily basis (Bangladesh Bureau of Statistics, 2022). The capital of Bangladesh, Dhaka, has the nation's fastest rate of urban growth, with 44,500 people living there per square kilometer. Dhaka is home to one-tenth of the nation's population as well as 36% of its urban population (Bird et al., 2018). It is currently the ninth-largest city in the world and is expected to rise to the fourth rank by 2030 (United Nations, 2019). For meeting up the water demand, the Water Supply and Sewerage Authority (WASA) was established in 1963 in Dhaka as an independent organization to provide water and sewerage services to the city people (Roy et al., 2018). Most of the residents in the Dhaka Metropolitan area use water supplied by WASA for various household chores, including drinking. Meanwhile, some deep well users in different parts of the city still drink water directly without any processing. WASA mostly depends on groundwater as a source of water but people who drink water supplied by WASA have a lot of complaints about it. But the existing research have been more focusing on the quality and quantity analysis in different city areas. These has bypassed the additional economic burden of the city dwellers. So, it is worth studying the economic stress on the urban people of getting pure drinking water. Kerry Smith & Desvousges, (1986) proposed a method to assess the economic burden that individuals place on improved quality of supply water involves examining their actual expenditures on alternative water sources. By analyzing how much people spend on substitutes like jar water or home purification systems, researchers can infer the value consumers place on safer or more palatable water. These defensive expenditures reflect the willingness to pay for better quality water, as individuals actively choose to invest in alternatives to mitigate potential health risks or enhance the taste and odor of their drinking water.

The research questions that have been arisen after considering all those critical issues are: (RQ1) What is the average total additional cost that incur for purifying water? (RQ2) How does the total additional cost for potable water purification vary across the city dwellers of different income groups? (RQ3) Is there a correlation between people's income and the amount spent on purifying water? (RQ4) Are there specific water purification technologies that are more commonly adopted by the city dwellers from different income groups due to cost considerations?

The specific objectives of this paper are to examine the water purification methods and technologies used by the urban people and to identify the relation of these associated costs with their income. Further, some other objectives are to explore the reasons and consideration behind the choice of water purifier brand and to compare the additional expenses incurred for water purification among people of different income level. So, the aim of this paper is to analyze the economic implications of purifying potable water and its impact on urban people of different income groups. By discussing the relevant literatures, the following hypothesis has been developed based on the research questions and objectives.

H1: There is a significant difference in the total additional cost incurred for purifying water among different household income groups.

This study highlights differences in the availability of water among different income levels, assisting policymakers in maintaining fair access. It also emphasizes the financial gains from better water quality and provides guidance for behavioral interventions that work.

LITERATURE REVIEW

Numerous regional and local studies have examined how drinking water purification practice are influenced by economic factors. Currall et al., (2006) and Yoo & Yang, (2000) have discovered that there is a positive correlation between higher income levels, urban residency, and the tendency to purify drinking water. Dupont (2005) examined findings from various surveys in North America focused on water consumers' preferences and attitudes towards tap water quality. He has advocated that success of UK has largely been attributed to regulations that prompt utilities to consider consumer desires and impose penalties for not meeting performance standards. Although regulations related to water safety and health remain crucial for the everyday operations of water utilities, the integration of consumer preferences into pricing and planning strategies is also very important. Granda-Aguilar et al., (2024) designed an economic model to establish a water service tariff in Ecuador, with the goal of ensuring financial sustainability for a public water supply company without relying on government subsidies. The model takes into account that higher investment levels also lead to increased tariffs, and thus considers the maximum investment necessary to mitigate water loss due to social challenges. The proposed tariff framework incorporates the costs of providing potable water to determine a price that reflects financial, environmental, and long-term sustainability factors, promoting greater efficiency in resource management and environmental enhancement. This model is universally relevant and has the potential to be adapted and expanded to other regions facing similar issues.

However, most of the research conducted in Bangladesh are more focused on the quality and availability of water rather than the economic consequences. Jamal et al., (2020) found that the physicochemical and microbiological quality of drinking water supplied by DWASA in Dhaka city was good to excellent. A study assessed by Acharjee et al., 2014 found that the water supplied by DWASA in the greater Mirpur area was microbiologically unsafe due to the presence of high number of serval pathogenic bacteria, some of which are drug resistant. However, Mahbub et al., (2012) examined that many samples of Dhaka WASA drinking water exceeded the acceptable limits for Total Viable Count (TVC), total coliform, and E. coli count. This means that

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the water may be contaminated with harmful bacteria, which could cause illness. Similarly, Fahmida et al., (2013) found that microbial water quality parameters, total coli form (TC) and Escherichia coli (EC), exceeded permissible limits in some samples from the Khulna WASA distribution network. ZuthiM.F., (2009) found that microbial water quality parameters also exceeded permissible limits in some samples from the Chittagong CWASA distribution network. M. Sabrina et al., (2013) found that the drinking water supplied by DWASA was not suitable for human consumption due to the presence of poisonous metal lead in the areas of Elephant Road and Dhaka University, Jatrabari and Demra. It contained toxic Penta Chloro Phenol (PCP) and already had a high number of pathogenic bacteria.

According to research by Transparency International Bangladesh (TIB), 34.5 percent of Dhaka WASA residents complained about poor water quality at various times during the year. It further stated that to make DWASA water drinkable, households utilize Tk 332.37 core worth of gas per year. The research of Lee et al., (2011), which found that water demand is significantly correlated with income. The same study found that income and education are associated with lifestyle and access to assets, which in turn affects water demand. The study conducted by Gunatilake & Tachiri, (2014) explicitly considers the connection cost in addition to the monthly charge, as the high connection cost is seen as one of the major obstacles to expanding the piped network among the poor. The poor have the highest uptake rate of the improved service when the block tariff is increased. The high connection cost is found to be a critical bottleneck in expanding coverage for the poor. M. M. Rahaman & Tahmid Ahmed, (2016) found that slum dwellers in Dhaka pay significantly more for domestic water use than people with legal water connections from the Dhaka Water Supply and Sewerage Authority (DWASA). Haque, (2018) argues that poor governance in water management has resulted in pilferage of water and caused miseries for the marginal dwellers living in the slums. Kashem & Mondal, (2022) proposed a new pricing model for domestic water usage in Dhaka city, which uses an increasing block tariff strategy. This strategy has the potential to reduce domestic water use in the city by up to 27%, increase revenue for DWASA by up to 75%, and reduce the water bill for poor households by up to 67%.

METHODOLOGY

3.1 Study Area

Greater Mirpur area was as the study area depending on the findings from previous literatures. With a rising high influx of population, rapid urbanization, and commercialization, Mirpur is currently one of Dhaka's major residential and commercial zones. Mirpur is a prominent area in Dhaka city. It was founded in 1962 and is located in the northeast of the city. It has a total area of 88.38 square kilometers and a population of 632,664 people and the geographical location of the study area 23°46.0′-23°49.5′N and 90°21.3′-90°23.2′E (Brac, 2016). Mohammadpur lies on the south boundary of Mirpur, Dhaka Cantonment on the east, Uttara on the north, and Savar upazila on the west. It is divided into six stations, namely Darussalam, Shah Ali, Mirpur, Pallabi, Rupnagar, and Kafrul. The Dhaka Water Supply and Sewerage Authority (DWASA) has divided Dhaka and Narayanganj into 11 MODS zones for management, operations, distribution, and services. Our study area is located in zones 4, 10 (except the south side), and the north side of zone 3.

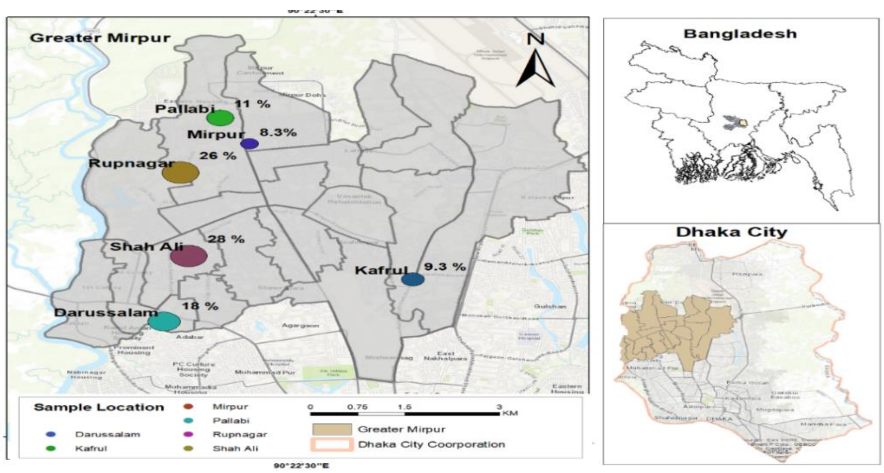

Figure 1: Study Area Map

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3.2 Sample Size and Data Collection

The sample size has been calculated using the Cochran's adjusted statistical formula (**Equation i**) with a 92% reliable level. Cochran's adjusted statistical formula has been utilized in this study as the population size is unknown, but the population portion is known (Cochran, 1954).

$$n = \frac{z^2 \times p(1-p)}{e^2} \qquad \text{(i)}$$

$$n = \frac{1.76^2 \times 0.5(1-0.5)}{0.08^2}$$

Here,

n = sample size

z = value at reliability level (92%) or significance level = 1.76

e = acceptable error of sample size = 0.08

p = the population proportions (Assumed to be 0.5)

According to the report published by Brac, (2016), the total household number of the greater Mirpur area is 187,626. This study considered households who reside under the administrative boundary of the study area both as house owner and as tenant for more than a year. So, the calculated sample size was 121. In order to collect information, a stratified random sampling procedure was followed, and readily available households were surveyed from 120 households employing a structured and semi-structured questionnaire from door to door residents during the months of October and November of 2021 in the study area. Households were randomly selected from different strata, defined by income levels, to achieve a balanced and representative sample.

3.3 Questionnaire Development

To reach the objectives of research structured and semi-structure questionnaires were formulated and a field survey was conducted to collect the necessary information from all the participants. Both homeowners and renters made up the participants' dwelling categories, ensuring a wide sample of metropolitan households. Structured questionnaires were used to gather demographic data, and some semi-structured questionnaires including drinking water purification and the associated cost, followed by Rayhan et al., (2022).

Section 1: Demographic information

Name, age, gender, household location, size of the household, ownership.

Section 2: Water sources, quality and usage

Water usage per day (L), use of water (L), source of water for household works, source of drinking water, odour, appearance, taste

Section 3: Drinking water purification

Do you use DWASA supply water for drinking? If yes, do you satisfy with supply water quality without purification? If not, do you follow further any purification process?

Do you boil supply water for drinking? If yes, what types of energy resources are being used for boiling?

What type and which purifier brand are you using?

How do you select the purifier brand?

Do you satisfy with supply water quality after purification?

Section 4: Water Purification Costs

What is the monthly household income?

How much to pay DWASA for water supply?

What is the approximate excess utility bill for water purification?

What is the purifier purchasing cost and maintenance cost?

What is the total purifying cost?

What is the alternative source cost?

What is the total economic cost for water usage?

3.4 Pre-test Study, Quality Control and Quality Assurance

To ensure the accuracy of the survey, a digital pre-test was conducted by a carefully selected group of 10 experts, including academics from the environmental and economics department, policy expert, engineers from the DWASA, purifier industry experts, and local purifier service provider. After this test, questionnaires were used to conduct the field survey and collect information from the respondents.

Skilled interviewers carried out in-person interviews with household members aged 18 to over 60 years, who were capable of comprehending and responding to the questions. Typically, a house contained multiple families, but only one family was chosen for the interview. The questionnaire began with a brief explanation of the cost of water purification to help respondents understand the questions. Additionally, efforts were made to avoid any terminology that might confuse respondents. A great deal of attention was paid to the content of the questionnaires to ensure external validity.

The research addresses all ethical considerations, including obtaining informed consent from participants, ensuring data confidentiality and anonymity, fair and equitable representation, respecting for autonomy, avoiding biasness, acknowledging limitations. The study adheres to all ethical guidelines and local regulations for use of existing data and consent for data sharing.

3.5 Data Analysis

Appropriate statistical tests were used to analyze the data. In order to compare means across groups for continuous variables, descriptive statistics and perhaps a non-parametric test (Dunn's test) were utilized. The Kruskal-Wallis Test and Fisher's Exact Test were employed to examine relationships between categorical variables because some of the variables are categorical. Since "Monthly Household Income" has low anticipated frequency counts, the simulated Chi-square test was applied. The statistical software (R 4.3.1) used for data analysis.

The Kruskal-Wallis test is a non-parametric test used to compare the distributions of a continuous variable across two or more groups. It is a non-parametric alternative to the one-way ANOVA test, and it does not assume that the data follows a normal distribution. Since "Total Additional Cost (BDT/Month)" is a continuous variable, and "Monthly Household Income" is categorical, the Kruskal-Wallis was used test to check if there was a significant difference in the total additional cost across different income groups.

Instead of the Chi-square test, the Fisher's exact test was used to determine as there is an association between two categorical variables in a 2x2 contingency table. Fisher's Exact Test is a statistical test, which is suitable for small sample sizes and doesn't rely on the Chi-square approximation. In this case it is used to check the association between Purifier Type and Monthly Household Income, and the contingency table is constructed

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using the counts of their categories.

A simulated version of the Chi-square test can be used, where p-values are estimated through simulation, which can handle small expected frequencies better. The simulated version of the Chi-square test is used when the expected frequency counts in any cell of the contingency table are small, and the standard Chi-square test's assumptions may not hold. Instead of relying on the theoretical Chi-square distribution, the simulated version estimates the p-value through simulation, making it more appropriate for small sample sizes or sparse data.

Dunn's test is just one of several post-hoc tests available for non-parametric data. The Dunn’s test function compares all possible pairs of income groups and adjusts the p-values for multiple comparisons using the Bonferroni correction. The output will provide the p-values for all pairwise comparisons, along with the adjusted p-values. For each pairwise comparison, the p-value would be checked to determine if the difference in the "Total Additional Cost (BDT/Month)" between the two income groups is statistically significant. If the p-value is less than significance level (0.05), it indicates a significant difference between those two groups. There is an increased risk of Type I error (false positives) in multiple pairwise comparisons. The Bonferroni correction is applied to adjust the p-values to control for this increased risk. The significance level used for these comparisons is adjusted with the Bonferroni correction to control for multiple comparisons. It's crucial to interpret the results with caution and consider the practical implications of the observed differences.

RESULTS DISCUSSION

4.1 Demographic Profile

The survey data was analyzed and it is shown in **Table 1** that 57% of the respondents were men and 43% were women, which shows that the sample had a fairly even gender distribution. 73% of respondents identified as homeowners, compared to 27% who identified as tenants, implying that a greater percentage of participants were property owners. The age distribution revealed a comparatively even distribution of ages, with 28% falling into the 18–30 age range, 26% in the 31–40 age range, 26% in the 41–50 age range, 20% in the 51–60 age range, and a small number (0.8%) being over the age of 60. There were a variety of household sizes, with four people making up 50% of respondents' households. Smaller and bigger homes (2, 3, and more than 5 individuals) made up the remaining distribution, whereas households with five members made up 20% of all households. The majority (45%) came into the range of 50,001 to 100,000 BDT/month, while 32% fell into the range of 40,001 to 50,000 BDT/month. A household income of over 100,000 BDT per month was reported by 13% of respondents, while incomes between 20,001 and 30,000 and 30,001 and 40,000 BDT per month were recorded by 3.3% and 6.7%, respectively. The distribution of the respondents was uneven among the several regions, with Rupnagar and Pallabi each having 26% of the total respondents, respectively. Darussalam, Kafrul, Mirpur, and Shah Ali each had a proportion of 18%, 9.2%, 11%, and 8.3%.

Table 1: Demographic Characteristics of Respondents (n =120).

Variables	**Categories**	**Frequencies**	**Percentage**
Gender			
	Female	52	(43%)
	Male	68	(57%)
Resident Type			
	Owner of the House	88	(73%)
	Tenant of the House	32	(27%)
Age (Years)			
	18-30	33	(28%)

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	31-40	31	(26%)
	41-50	31	(26%)
	51-60	24	(20%)
	More than 60	1	(0.8%)
Household Number			
	2	10	(8.3%)
	3	18	(15%)
	4	60	(50%)
	5	24	(20%)
	More than 5	8	(6.7%)
Household Income (BDT/Month)			
	20001-30000	4	(3.3%)
	30001-40000	8	(6.7%)
	40001-50000	38	(32%)
	50001-100000	54	(45%)
	More than 100000	16	(13%)
Area			
	Darussalam	21	(18%)
	Kafrul	11	(9.2%)
	Mirpur	13	(11%)
	Pallabi	31	(26%)
	Rupnagar	34	(28%)
	Shah Ali	10	(8.3%)

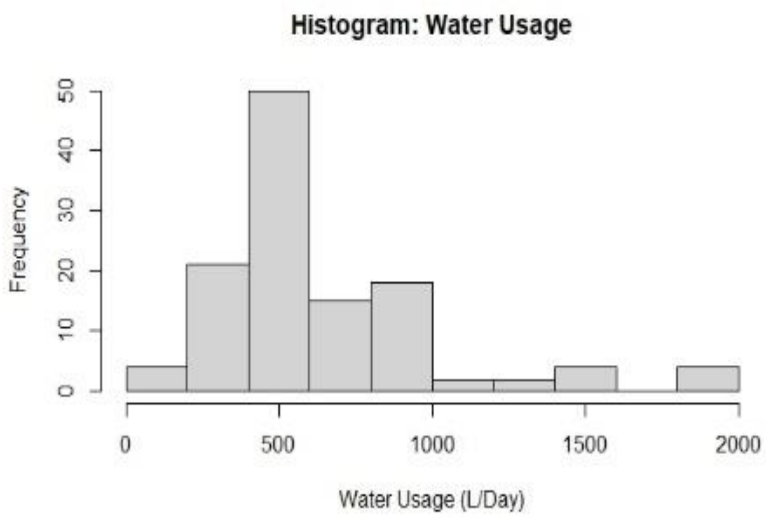
Source: Output of R 4.3.1

4.2 Urban Potable Water Source & Household Purification Practices

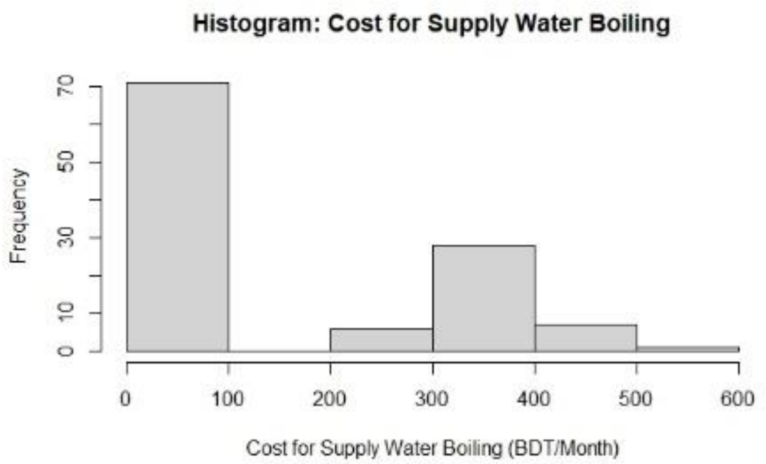
According to a survey, 89% of households in the study area get their water from the municipal water supply of the DWASA. 5.8% of homes use DWASA Booths as their source, while 5.0% of households get their water from deep wells. About 28% of those surveyed said they have access to clean water. 56% of respondents said their water was "Quite Clear." Just 11% of households reported having "Quite Turbid" water, while 5.8% said their water was "Turbid." While taste, color, and smell might seem like mere aesthetic concerns, urban people often use these attributes as indicators of their supply water's safety. These sensory characteristics can influence perceptions of water quality and play a significant role in determining the purification practices (Jardine et al., 1999). The majority of households (63%) pre-treated their water by boiling it before using a water purifier. 37% did not boil the water first. According to the findings of Schriks et al., (2010), the presence of unregulated chemicals that impact the taste or odor of water often leads consumers to prefer bottled water or use point-of-use (POU) treatment devices such as ion exchange systems, reverse osmosis, and activated carbon filters. Of those who boiled their water, 93% used gas as their main fuel, while 6.8% used electricity. The lower usage of electricity for boiling water was attributed to the well supply of pipelined gas supply of Dhaka metropolitan city by the Titas gas supply company. According to a research by Transparency International Bangladesh (TIB), making Dhaka WASA water drinkable, households who have cylinder gas were mainly use electricity. But other neighboring countries like Nepal, around 70% of households opted for gas to boil water, while the remaining 30% used electricity (Shrestha et al., 2018). 90% of households treated their drinking water using water purifiers, while 10% did not use any filters which is even reversed for the middle-income country of Asia, Turkey where only 8.3% household use purifier (Boyraz et al., 2019).

4.3 The Average Total Additional Cost for Purifying Water

Data shown in **Table 2** that the average household in Greater Mirpur consumes 674 liters of water per day. However, there is a wide range of water usage, with some households using as little as 150 liters per day and others using as much as 2,000 liters per day. The median water usage is 500 liters per day (**Figure 2 a.**), which means that half of the households use less than this amount and half use more. A report published by BIGD in 2019 stated that per capita water demand in Dhaka city is 350 liters per day. Udmale et al., (2016) projected the demand would increase 120 to 150 liters per day. But the people of the study area consume more than the estimated demand by the DWASA and close to projected demand. The water usage goes up simultaneously with the income of the people. As they adopted advance facilities like shower and flashing toilet with the increase of their income could rise the demand of water.



(a)



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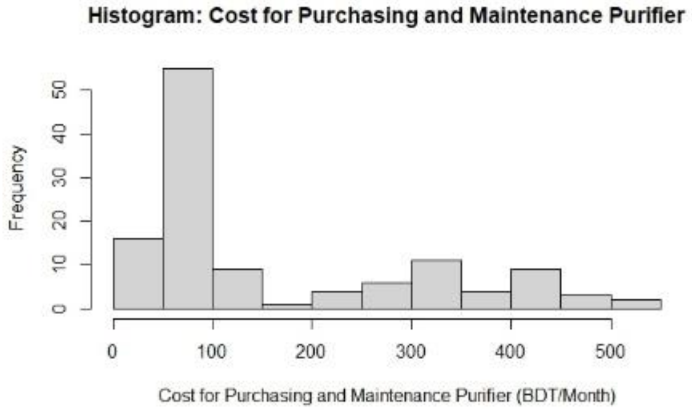

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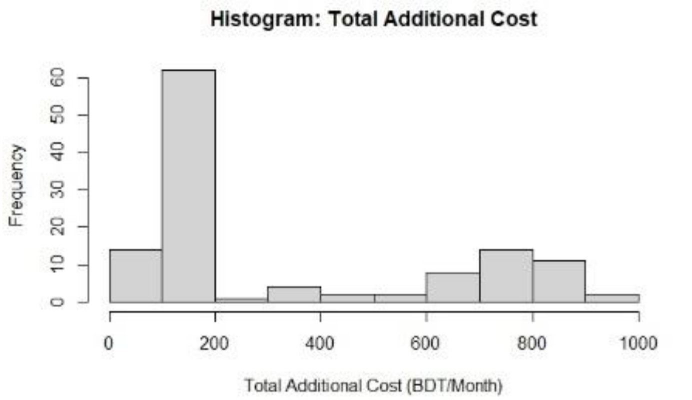

(d)

Figure 2: Histogram of (a) Household water usage, (b) The cost per household for boiling the potable water, (c) The cost for purchasing and maintenance household water purifier, and (d) Total additional cost per month to purify household potable water.

Households spend an average of 181 BDT per month on boiling water for purification. The cost of boiling water varies widely, from 0 to 600 BDT per month (**Figure 2 b.**). The median cost is 75 BDT, which means that half of the households spend less than this amount on boiling water and half spend more. According to the report published by Titas in 2019 estimated that urban people cost 1.7 billion BDT for Titas supplied natural gas only for boiling drinking water. If it would be done by LPG, the cost would be around 26.63 billion BDT. It can be calculated that this process would cost the households 615.89 BDT per year.

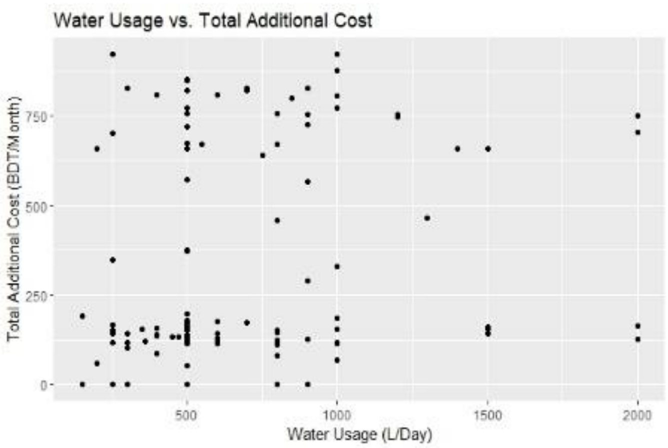

Figure 3: Scatter plot to show the relation between the total additional cost and the water used by total household.

The average monthly cost of purchasing and maintaining water purifiers for households in Bangladesh is 161 BDT. The cost ranges from 0 to 522 BDT per month, with a median of 92 BDT (**Figure 2 c.**). This means that half of households spend less than 92 BDT per month on purifiers, while the other half spend more.

Table 2: Urban Water Usage & Cost Analysis.

Characteristic	**N = 120**[1]
Water Usage (L/Day)	674 ± 390 (Min: 150, Max: 2,000, Median: 500)
Cost for Supply Water Boiling (BDT/Month)	181 ± 166 (Min: 0, Max: 600, Median: 75)
Cost for Purchasing and Maintenance Purifier (BDT/Month)	161 ± 144 (Min: 0, Max: 522, Median: 92)
Total Additional Cost for Purifying Water (BDT/Month)	331 ± 297 (Min: 0, Max: 922, Median: 156)
[1] Mean ± SD (Min: Minimum, Max: Maximum, Median: Median)	

Source: Output of R 4.3.1

The total additional cost for water purification, which includes both boiling supply water and purchasing/maintaining purifiers, amounts to an average of 331 BDT per month. This amount is very close to the annual amortized purchase price combining with the annual operating costs in Canada. There, the average annual expenditure for water purification varies based on the type of device used. Container-style devices incur an average cost of $35 per year, while in-tap filtration systems cost approximately $189 annually (Dupont, 2005). In addition to the use of home filtration devices, Canadian households spend about $180 annually on bottled water as an alternative to supply water (Dupont, 2005). The additional cost in this study ranges from 0 to 922 BDT per month, with a median value of 156 BDT (**Figure 2 d.**). This means that half of households spend less than 156 BDT per month on water purification, while the other half spend more. In Vietnam, the cost of water purifiers varies significantly based on the brand and capacity, ranging from $5 to over $40 (Mai & Pham, 2024). In Nepal, the average monthly cost for water treatment was NRs 380 (±393). For households that used any treatment methods, the average cost increased to NRs 503 (±378) (Shrestha et al., 2018).

4.4 The variation of total additional cost across different income groups

Households' perception on spending the amount additional cost for water purification greatly varies across different income group particularly among the wealthier households as shown in **Figure 4**. Two lowest income group under this study who has household income "20001-30000" and "30001 – 40000" (BDT/Month) are spending average 125 and 150 (BDT/Month) for water purification respectively. However, cost of these groups clustered around 100 -150 (BDT/Month) with some outlier in in the minimum income group who are not spending anything for potable water purification. Households belongs to the "40001 – 50000" (BDT/Month) income group are spending average 150 (BDT/Month) though variation of cost among the varies from 120 to 300 (BDT/Month). Moreover, the dotted line indicates there are outliers in these group who are spending more than 750 (BDT/Month) for water purification. The height of the box plots represents greater variation among two most wealthier income group. Though the average water purification cost is 350 and 150 (BDT/Month) of the income group "50001-100000" (BDT/Month) and 100000+ (BDT/Month) respectively their cost varies from 100 to 750 (BDT/Month). The additional costs are associated with the cleaning the underground and rooftop reservoir, boiling, chlorination, purifier curtilage change, other maintenance and purchasing bottled water during scarcity. It is more frequent (yearly) to clean rooftop reservoirs than the underground ones as the cost of underground reservoir is two times higher than underground one (BIGD, 2016). Moreover, the cleaning agents used in Dhaka city are detergents which again requires to purify the supply water before drinking (WHO, 2013)

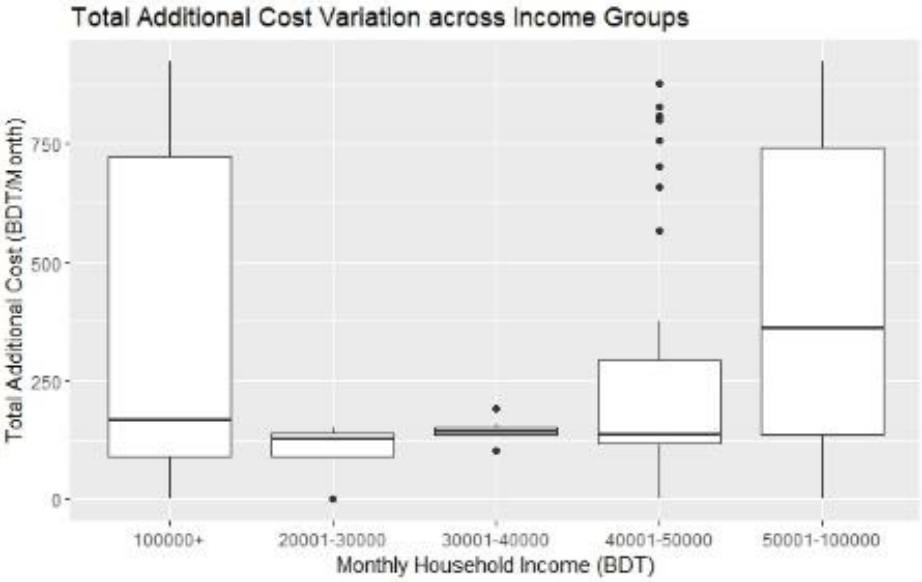

Figure 4: Box plot to show the relation between the total additional cost for purifying potable water across various income groups of people of Mirpur area.

4.5 Correlation between people's income and the amount spent on purifying water

From the discussion points, it can be said that the total additional cost for water purification may directly not be correlated with the household's income only. Though Households with higher incomes often demonstrate a willingness to spend more on premium products that assure enhanced water quality (Mai & Pham, 2024), there might be several aspects that need to be investigated. The quality of water might be good for some household so that they do not have to spent additional purification cost. It also could be the lack of awareness among the households or they just do not willing to spend money on modern technologies rather depends on traditional water purification methods e. g., boiling, normal filtering. However, Sajjadi et al., (2016) carried out a satisfaction study in Gonabad city, located in the south of Khorasan Razavi province. The study revealed an inverse relationship between satisfaction levels and monthly income. Participants with an income below 5,000,000 Rials reported higher satisfaction compared to those with higher incomes ($p < 0.05$). These findings support the result of this study where "50001-100000" (BDT/Month) income (middle income) group people spend sometimes quite equal or more than 100000+ (BDT/Month) income (higher income) group people. Granda-Aguilar et al., (2024) economic models often posit that individuals allocate their expenditures in a manner that maximizes their utility or well-being, particularly when confronted with health risks, such as those posed by unsafe drinking water. But according to Siregar, (2003) middle income group people benefit from subsidized rates for essential services like water in many countries. While these subsidies aim to make services affordable, they often create a financial burden for governments. This can restrict funds available for expanding infrastructure and improving access for poorer communities, who may not receive the same level of subsidization.

4.6 Commonly adopted water purification technologies

The presence of unregulated chemicals and pathogens that negatively affect water quality often prompts people to turn to point-of-use (POU) treatment devices. These health concerns are a significant factor fueling the expansion of the water purifier market for drinking water devices, which now exceeds $20 million annually and continues to grow rapidly (Alspach & Juby, 2018). A diverse array of household water treatment solutions is available, each designed to function optimally in specific situations. Alan et al., (2020) states that the choice of water purifiers is influenced not only by their operational efficiency but also by after-sales services such as warranties, technical support, and maintenance. Brands offering prompt and reliable after-sales support tend to earn consumer trust and preference. Studying different income group, it was found the manual water purification is most preferred by different income group. Particularly the households fall under "20001-30000" and "30001 – 40000" (BDT/Month) income group fully depends on manual purification. Among the of "40001 – 50000" (BDT/Month) income group 28 households adopt manual purification whereas only 9 use electrical purifier.

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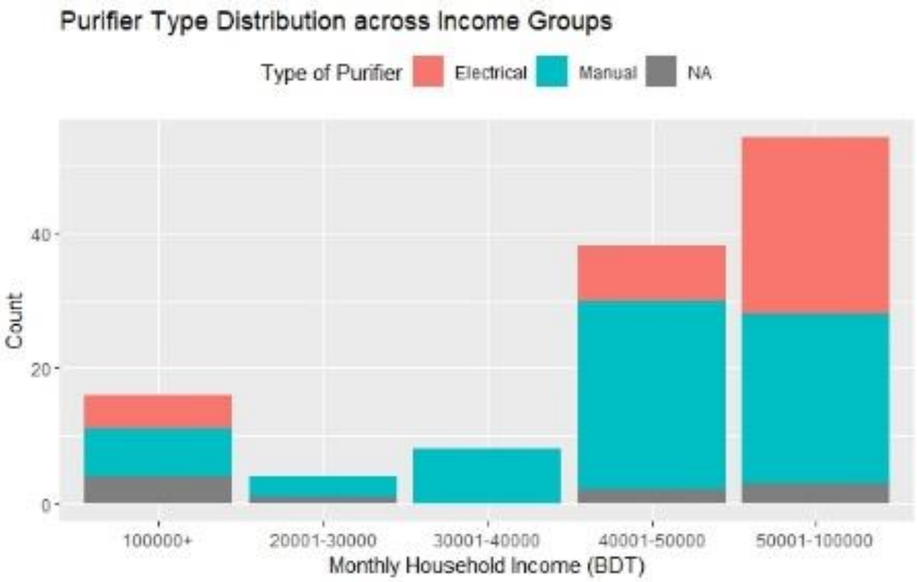
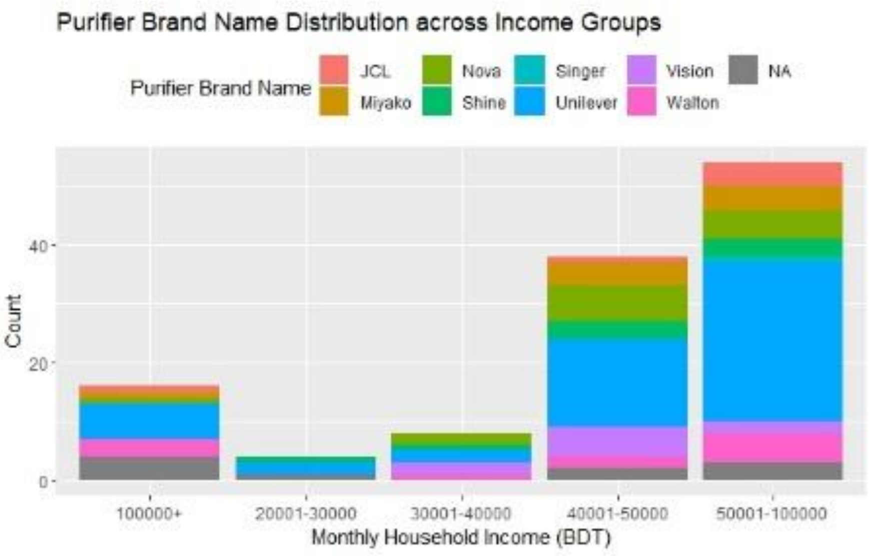
However, electrical purifier found equally preferred by the two most wealthier income group as households from "50001-100000" (BDT/Month) income group 25 adopt electrical and 25 adopt manual water purification. On the other hand, households belong to 100000+ (BDT/Month) income group 8 adopt electrical and 5 adopt manual water purification. Surprisingly, though minimum all the income class except "30001 – 40000" (BDT/Month) income group there are some households who does not use any water purifier. In terms of the brand of water purifier Unilever found most popular among all the income grout followed by Nova and Vision. The most common type of water purifier used was a manual one (64%), followed by an electrical one (36%). A small percentage used an unidentified type of purifier. The most popular brand of water purifier was Unilever (48%), followed by Vision, Walton, Miyako, and Nova (8.3% to 11% each). A small percentage used unnamed brands. The most popular reason for choosing a particular brand of air purifier was random selection (36%). Around 33% of respondents chose well-known brands. A significant number (19%) based their decision on commercial advertisements. A smaller percentage (11%) sought expert advice before planning. A small percentage (unknown) had unspecified reasons for their choice of brand. Whereas a study conducted by Das, (2013) in India, stated that the brand name is the primary motivator for most customers when purchasing a water purifier, followed by purification, technology, and finally, price.



(a)



(b)

Figure 5: Stacked column to show the (a) purifier types and (b) various available purifier brands that are used across different household income group people of Mirpur area.

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4.7 Hypothesis Test (H1: There is a significant difference in the total additional cost incurred for purifying water among different household income groups.)

The Kruskal-Wallis chi-squared of the studied data is 10.292, which measures the overall difference in the "Total Additional Cost (BDT/Month)" across the four income groups and the degrees of freedom are 4 - 1 = 3. The p-value represents the probability of obtaining the observed test statistic (or a more extreme one) under the null hypothesis. In this context, the null hypothesis is that there is no difference in the distribution of "Total Additional Cost (BDT/Month)" across the income groups. Since the p-value is shown in **Table 3** (0.03578) is less than 0.05 (assuming a significance level of 0.05), it has enough evidence to reject the null hypothesis. So, there is a statistically significant difference in the "Total Additional Cost (BDT/Month)" among the different income groups. Therefore, the "Total Additional Cost (BDT/Month)" for purifying water varies significantly across the investigated income groups.

Table 3: Results of Different Hypothesis test.

Kruskal-Wallis Test		
	Chi-Square	10.292
	df	4
	p-value	0.03578
Fisher's Exact Test for Count Data		
	p-value	0.004082
	Alternative Hypothesis	two. sided
Pearson's Chi-squared test with simulated p-value (based on 2000 replicates)		
	X-Square	14.371
	df	NA
	p-value	0.005497

Source: Output of R 4.3.1

In the result of Fisher’s exact test, the p-value is 0.004082, which is less than the common significance level of 0.05. The null hypothesis can be rejected and conclude that there is a statistically significant association between "Purifier Type" and "Monthly Household Income." The alternative hypothesis is "two-sided," which indicates that the test is looking for any kind of association, either positive or negative, between the two variables. The results of the Fisher's exact test indicate that the choice of purifier type is related to the household's monthly income level. It implies that the distribution of purifier types is not uniform across all income groups, and certain purifier types are more commonly used by households from specific income groups.

Pearson's Chi-squared test with simulated p-value indicates that the test is based on the Pearson's Chi-square statistic with the p-value estimated using simulation. The p-value being less than the significance level (0.005497 < 0.05) indicates that there is a statistically significant association between the type of purifier households use and their monthly household income. The results of the simulated Chi-square test reinforce the findings obtained previously through other statistical tests (such as Fisher's exact test and Kruskal-Wallis test). It confirms that the choice of purifier type is related to the household's monthly income level. These findings support the research of Lee et al., 2011, which found that water demand is significantly correlated with income. The same study found that income and education are associated with lifestyle and access to assets, which in turn affects water demand. It suggests that the distribution of purifier types is not uniform across all income groups, and certain purifier types are more commonly used by households from specific income groups. The simulated Chi-square test provides additional confidence in the significance of the association between "Purifier Type" and "Monthly

Household Income" given the small sample size or sparse data.

4.8 Significant Income Group Determination

As there is a significant result from the Kruskal-Wallis test, it indicates that there is a difference in the "Total Additional Cost (BDT/Month)" across the different income groups. So post-hoc tests or pairwise comparisons can be suitable to further investigate which income groups, differ significantly from each other. Here Dunn's test the most commonly used post-hoc test for non-parametric data is performed.

Table 4: Dunn's test.

	Comparison of x by group (Bonferroni)			
Col Mean				
Row Mean	100000+	20001-30000	30001-40000	40001-50000
20001-30000	1.4178733			
	0.07811			
30001-40000	0.7886364	-0.7366852		
	1.0000	1.0000		
40001-50000	0.8554289	-1.0228724	-0.2225098	
	1.0000	1.0000	1.0000	
50001-100000	-1.0002469	-2.0790208	-1.6529407	-2.5485956
	1.0000	**0.1880***	**0.4917***	**0.05407***
*Reject Ho if p <= α/2 as α=0.05				

Source: Output of R 4.3.1

The results show that there are significant differences in the "Total Additional Cost (BDT/Month)" for water purification between specific pairs of income groups. The households with monthly incomes of "20001-30000," "30001-40000," and "40001-50000" have similar "Total Additional Cost (BDT/Month)" and are not significantly different from households with monthly incomes of "100000+." However, households with monthly incomes of "20001-30000," "30001-40000," and "40001-50000" have significantly different "Total Additional Cost (BDT/Month)" compared to households with monthly incomes of "50001-100000." M. M. Rahaman & Tahmid Ahmed, (2016) found that slum dwellers in Dhaka pay significantly more for domestic water use than people with legal water connections from the DWASA. Haque, (2018) argues that poor governance in water management has resulted in pilferage of water and caused miseries for the marginal dwellers living in the slums.

FINDINGS AND CONCLUSION

The study surveyed a diverse group of urban residents to learn about their water sources, purification methods, and preferences. The findings revealed that 89% of households rely on the municipal water supply, but only 28% report having access to clean water. Moreover, water purifiers are a popular choice, with manual purifiers being the most common type. Then the average monthly cost of water purification is 331 BDT, with a significant range depending on income. The Kruskal-Wallis test and Fisher's Exact test both indicated statistically significant differences in water purification costs and purifier types across income levels. Households with monthly incomes "50001-100000" (middle income group) differed significantly from other groups. However, Unilever is the most popular brand of water purifier, 36% of respondents selected their purifier randomly.

There are some limitations of this research that must be considered. First, the study was limited to a populated Mirpur area, which may not be representative of whole Dhaka city. Secondly, the sample size was small with a confidence level of 70%, which may not have captured the full range of water purification practices among urban households. Thirdly, the study relied on structured questionnaires, which may not have captured the full range of reasons behind respondents' choices. Despite these limitations, the research demonstrates that income significantly influences the economic burden of water purification. This suggests a disparity in access to affordable water purification options across income groups, highlighting the need for interventions to ensure equitable access to clean drinking water.

RESEARCH IMPLICATIONS

The research provides a solid foundation for understanding potable water purification strategies among urban households. The data on water usage and associated costs can guide DWASA in allocating resources and investing in sustainable water infrastructure and quality management practices. For water purifier manufacturers, the study's insights into consumer preferences and brand choices provide valuable market intelligence to cater to diverse income groups. Additionally, understanding the factors that influence water purification choices can help to develop effective behavioral change interventions to promote safer water treatment practices. Finally, policymakers can use the findings to design targeted interventions aimed at improving access to safe drinking water, particularly for low-income households.

FURTHER RESEARCH

It also opens avenues for future studies to explore broader geographic regions and factors affecting water quality in-depth. Conducting long-term studies to track changes in water purification costs and choices over time could provide deeper insights into the evolving needs and behaviours of urban households. Expanding the research to include other cities or rural areas in Bangladesh could provide a more comprehensive understanding of water purification practices and economic burdens nationwide. Analysing the impact of existing and new government policies on water purification costs and access could provide valuable insights for improving water management strategies.

Conflicts of Interest

The authors declare no conflicts of interest.

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