# Unveiling Bharalu River's Pollution Crisis through a Choice Experiment

**Abstract**

In recent years, there has been a growing global concern regarding environmental degradation, pollution, and climate change, which significantly impact the development of both developing and developed nations. This growing concern has piqued the interest of economists in the field of environmental economics, which focuses on understanding how economic activities of producers and consumers affect our environment. Environmental economists aim to explain policies and initiatives that can improve the quality of life for present and future generations. Environmental issues hold particular significance for developing countries, where widespread poverty exists and there is an urgent need for accelerated economic growth. One crucial aspect of environmental degradation is declining water quality, which can have various impacts on the economy. These impacts can be observed in the health sector, where labor productivity can be affected, as well as in agriculture, where both the quality and quantity of food production may decrease. Furthermore, sectors such as tourism, real estate, aquaculture/fisheries, and others that rely on environmental quality and ecosystem services can also suffer negative consequences. The Bharalu River in Guwahati, Assam, is a prime example of an essential water resource that has undergone gradual degradation over the years, transforming into an urban municipal drain. Once a river flowing with pristine water and teeming with biodiversity, it has now experienced heavy industrialization and urbanization along its course, resulting in alarming pollution levels. This study aims to analyse the economic impact of Bharalu River's pollution from the perspective of consumers. It employs a discrete choice experiment to determine people's willingness to support the ecological restoration of the river and discusses the associated issues and challenges involved in the restoration efforts.

**Keywords:** Bharalu, pollution, economics, environment, ecology

## 1. Introduction

Rivers are known to be the most integral part of Earth's natural landscape. Functioning as conduits for water, sediments, and other matter, river systems have been vital in driving a wide array of fundamental and inter-related natural processes **(Harman et al., 2012).** They have also eternally played an integral part in the existence of humanity. From being an endless supply of freshwater for drinking and irrigation to the riparian zones where agriculture can flourish, rivers are an excellent source of nutrition and a major means of transport. Today, riverbanks are being transformed into recreational spaces and tourist attractions, mostly seen in European and East Asian nations **(Miaux & DemersRenaud, 2021)**.

However, the world has also witnessed a long-drawn history of lost rivers. One of India's major metropolitan cities, Guwahati situated in the heart of the Indian state of Assam has its own story centering on the Bharalu River. Once a natural lifeline of Guwahati, the Bharalu today exists in a heavily impaired condition in the metropolitan's heart. Today, it carries a hefty portion of the city's household, municipal, and industrial waste. Guwahati is situated on the bank of the Brahmaputra River which is Asia's second largest and the world's ninth largest river by discharge. It is also the main source of drinking water for city dwellers. Bharalu's polluted water is referred to as a huge concern as it directly discharges into the mighty river within city limits. This concern was officially validated when in 2011, the Central Pollution Control Board (CPCB) of India published a report naming Bharalu to be "one of the most polluted rivers in the country" **(CPCB, 2011).** A decade since Bharalu's health has heavily worsened with minuscule restoration efforts in sight. This study makes an effort to investigate the impact of Bharalu's pollution via an economic perspective, performing the analysis from the consumer's viewpoint. It involves a discrete choice experiment that identifies people's willingness toward the river's ecological restoration and deliberates on the varied issues associated with it.

## 2. Materials and method

### 2.1 The Bharalu River in Guwahati

The Bharalu River, situated on the southern bank of the Brahmaputra River, spans between 25°59′ to 26°11′ N and 91°43′ to 91°5′ E. Flowing through the core of Guwahati city, the Bharalu River cuts across densely populated residential, industrial, and commercial areas before eventually merging with the majestic Brahmaputra River at Bharalumukh point (Figure 1). The city itself is characterized by a topography comprising hills surrounding plains, with scattered elevated hillocks. Originating from the hilly catchment of Meghalaya, the Bharalu River remains relatively untouched until it reaches the densely inhabited regions of the city. Stretching for approximately 6.2 km, the river has a total catchment area of about 120 sq. km, with a nearly equal distribution between the hilly and plain regions (Suresh & Pekkat, 2022). It covers a drainage area of 10.94 sq. km, and its flow velocity is estimated to range from 1.07 to 1.37 m/sec.

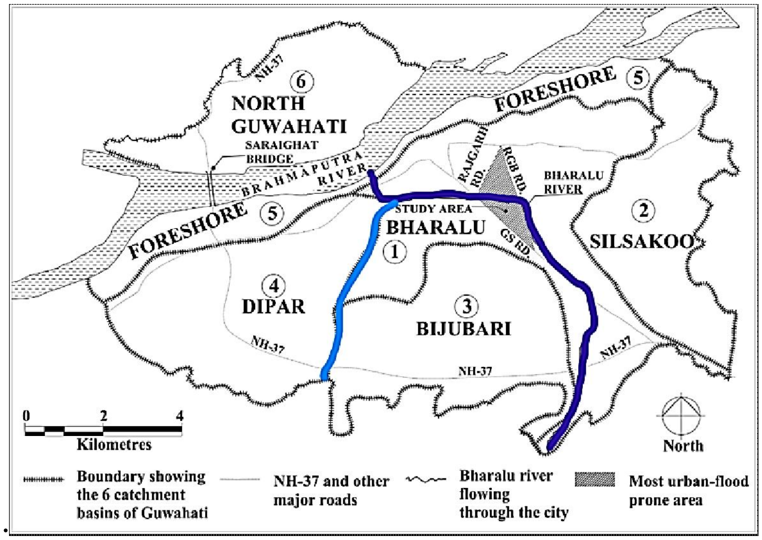



*Figure 1: The Bharalu basin (Source: Guwahati Municipal Corporation)*

## 2.2 Methodology for WQI

Before designing the choice experiment, we performed an analysis of Bharalu's water quality (drinking standards) via a water quality index. The results obtained were meant to help identify the degree of pollution as well as estimate the extent of restoration efforts required to bring back the river to a state of good ecological quality. The WQI calculation involves a 3-stage method. The first stage comprises of assigning weights (0-5) to each parameter (physico-chemical) according to their relative importance in overall water quality by drinking standards. Following this, the relative weight ($W_i$) was calculated using the equation (1).

$$W_i = \frac{w_i}{\sum w_i} \quad (1)$$

where, $w_i$ is the weight assigned to each parameter, and i = 1…. n; n is the total number of parameters.

The second stage comprises of computing a quality rating scale ($Q_i$) for each parameter as denoted by expression (2).

$$Q_i = C_i / S_i \times 100 \quad (2)$$

where, $C_i$ is the concentration of a particular parameter in each water sample, $S_i$ is the permissible limit/standard according to an internationally accredited organisation. We have considered the Bureau of Indian Standards (BIS) guidelines for this study. Finally, expression (3) is the third state which denotes the computation of WQI. The resultant WQI values are distinguished into five types, from "excellent" to "unsuitable for drinking".

$$WQI = \sum (W_i Q_i) \quad (3)$$

### 2.3 Experiment design

To assess the significance of restoring the water quality of the Bharalu River and gauge individuals' perceptions regarding its pollution and their willingness to pay (WTP), a comprehensive field survey was undertaken. The survey targeted a total of 958 households, carefully selected based on their urban location and their reliance on the river for multiple purposes. These households utilize the Bharalu River not only for drinking and sanitation needs but also as a drainage outlet. The survey aimed to gather detailed insights into the perspectives and attitudes of these urban residents towards the river's pollution and their willingness to contribute financially towards its restoration. Purposive sampling technique was applied for obtaining samples. Residential households were sampled depending upon the length of the period of their residence beside the river. Men and women were interviewed separately to capture the individual perception of people towards clean water. The interviews were taken via discrete choice experiment (DCE) technique and the responses gathered were used to examine our objective. The information obtained was then also studied subjectively and later analysed using a partially censored model to obtain the overall willingness to pay for restoring the Bharalu river.

## 3. Results and discussion

### 3.1 Economics of restoration

Ecological restoration has gained immense ground in modern academic disciplines as a field of research linked to several concepts and models that explain how the environment responds to different interventions aimed at ecosystem restoration. The early development of the concept can be traced to writings of Lewis (1989) wherein he described it as the process of returning an environmental resource from a disturbed or completely altered condition to an earlier natural status through human interventions. However, solely focussing on ecological indicators leaving out other factors, is risky, considering the policy implications of a restoration project affects, not just the environment, but also humanity. Hull and Gobster (2000) stressed that restoration should be subject to inclusion of social and economic circumstances as a key pillar.

Later, Sachs et al. (2009) in their report ‘Biodiversity conservation and the Millennium Development Goals’ identified the need to include economic value of ecosystem services while measuring overall benefits from ecosystems. Generally termed as economics of restoration, this overlapping area between two disciplines- restoration ecology and economics has now garnered worldwide interest. Literature pertaining to the area recognises that diminishing stocks of natural capital today is the biggest limiting factor to economic growth, and not manmade capital, as was earlier thought (Recuero and Couvet, 2018). This has brought ecologists and economists in an agreement that it is through bridging natural and economic disciplines.

Literature concerned with the Bharalu river are majorly related to evaluating its environmental condition. Earliest known studies include Lal and Bhattacharya (1989) and Sarma et al. (1994). These studies reflected on slow degradation of the river. Intensification of degradation was soon observed by Kar (2001) and Girija et al. (2007). Recent studies conclude the river's extreme degradation and insist on its urgent restoration (Borah and Bhagabati, 2015; Devi and Sharma, 2019).

Most of these studies pertain to purely scientific disciplines, with very limited purveyance on larger social and economic aspects. Borpujari and Gogoi (2015) studies the social impacts while Devi and Sharma (2019) reflected on the myriad impacts of urbanisation. Notably, an insight into the economics of Bharalu's restoration has been put forward by Hazarika and Kalita (2019). Besides, several reports of government and independent agencies exist in public domain that address the matter.

**3.2 Ecological status of Bharalu**

In recent years, the catchment area of the Bharalu River has undergone rapid urbanization, leading to significant encroachment and widespread dumping of garbage. As a result, the river has deviated from its original course to a large extent. Once a vital source of clean drinking water, the Bharalu River now carries a substantial amount of municipal and other waste from the city, serving as a natural drainage system for stormwater runoff (PCBA, 2013). Wastewater generated by households, commercial establishments, and small to medium-sized industries within the city directly flows into the Bharalu River through a network of interconnected drains.

The degradation caused by the discharge of domestic and commercial waste poses a severe threat, particularly to the inhabitants of Guwahati and ultimately to the downstream receptor, the Brahmaputra River. Given that the Brahmaputra serves as the primary source of drinking water for Guwahati and the entire valley, the high pollution load carried by the Bharalu River is a matter of grave concern for the region. The Bharalu River is notorious for its extremely unsanitary and polluted condition, making it one of the primary sources of contamination that affects the overall water quality of the Brahmaputra River.

Table 2 displays the relative weights, BIS standards for drinking water (BIS, 2012) and the WQI value. As part of the calculation, we have chosen only those water quality parameters whose standards are mentioned under BIS. Finally, the water quality has been rated according to its WQI, viz. WQI<50 – "excellent"; 50<WQI<100 – "good"; 100<WQI<200 – "poor"; 200<WQI<300- "very poor" and WQI>300 – "unsuitable for drinking" (Ramakrishnaiah et al., 2009). As observed, the WQI for Bharalu river is 759.46 (unsuitable for drinking).

Once a pristine water resource teeming with diverse aquatic life, the Bharalu River has unfortunately transformed into an urban drain. Experts from various sectors highlight the alarming fact that the city currently generates approximately 70 million litres per day (mld) of sewage, a number that is expected to rise significantly with the introduction of new water supply systems in the Guwahati Metropolitan Area. By 2025, sewage generation is projected to reach around 280 mld. Guwahati, with an estimated population of about 1.7 million, is recognized as one of the Smart Cities under the Indian government's Smart Cities Mission. However, the city lacks a proper sewerage system, consisting of a network of pipelines to transport sewage, as well as a municipal sewage treatment plant (STP) to treat wastewater. Instead, the city heavily relies on underground septic tanks to manage its sewage, posing a significant threat to groundwater quality. The contamination of groundwater is of great concern, particularly because only 30 percent of the city's population is currently covered by a piped water supply system, with an average consumption level of approximately 70 litres per capita per day. The remaining population relies on groundwater through individual bore wells or private operators who supply water via tankers.

The degradation of the Bharalu River commences from the Basistha hill located south of National Highway 37. Simultaneously, a significant section of the Bharalu River, known as the Basistha River, branches out towards the Borsola Beel before continuing its course and eventually meeting Deepor Beel, situated on the outskirts of Guwahati. As the Bharalu River passes through densely populated residential and commercial areas of Guwahati, its condition worsens considerably. The river undergoes substantial deterioration until it merges with the Brahmaputra River. Furthermore, the wastewater discharged from the Indian Oil Corporation Refinery at Noonmati directly flows into the Bharalu River. Considering the crucial role played by the Bharalu River as the lifeline of Guwahati, it becomes imperative to restore the river to a more natural state, allowing for the effective utilization and distribution of ecosystem services.

The Bharalu River in Guwahati has been recognized by the Central Pollution Control Board (CPCB) as one of the most heavily polluted rivers in India. The CPCB, responsible for monitoring and identifying polluted river stretches across the country, rates rivers based on water quality testing. These ratings range from one to five, with the 'Priority 1' category encompassing rivers with a biological oxygen demand (BOD) concentration of 30 milligrams per liter (mg/l) or higher. It is worth noting that a BOD level of 3 mg/l is considered desirable.

The CPCB has classified the Bharalu River as a 'Priority 1' polluted river stretch due to its recorded BOD level of 52 mg/l, with the main source of pollution identified as Guwahati's sewage (CPCB, 2011). Within Guwahati city, there are a total of 330 drains that carry stormwater, often mixed with untreated sewage, which eventually discharge into the Bharalu River and the Bahini rivulet that feeds into it.

In September 2018, the National Green Tribunal (NGT) acknowledged the presence of 45 critically polluted river stretches across the country, including the Bharalu River in Guwahati. In response, the NGT issued an order for the development of action plans aimed at restoring these polluted river stretches to the prescribed standards. Specifically, for the Bharalu River, the action plan committed to achieving a pollution-free state within one year, with a target deadline of

March 31, 2021. However, it is surprising to note that no progress has been made towards initiating the required restoration work thus far.

### 3.3 Design of DCE experiment

The core aspect of the discrete choice experiment (DCE) application lies in designing the experiment itself, which entails selecting attributes, specifying attribute levels, and developing choice sets comprising alternative combinations of attribute levels (Rose and Bliemer, 2009). For this particular study, attribute selection was based on an extensive review of existing literature and in-depth discussions with environmental officers and experts involved in the management of the Brahmaputra River. Five distinct categories of feasible changes were identified, including water quality, ecological status (represented by species diversity in the river and its riparian areas), hydro-morphological features, livelihood, and recreational opportunities. These categories were deemed relevant and significant for the densely populated urban area under consideration. The attribute levels were chosen to align with policy interests and practical constraints.

Additionally, a cost attribute was incorporated, represented by the local water tariff increase per household per year. This cost increase aimed to support a municipal program responsible for the restoration of the Brahmaputra River. The levels of the cost attribute were determined based on empirical evidence from studies on Belgian residents' willingness-to-pay for nature restoration (Schaafsma et al., 2014). The inclusion of the cost attribute enables the examination of residents' preferences for various attributes and their respective levels, as well as estimation of the maximum amount individuals are willing to pay for different alternatives. The specific attributes and their corresponding levels can be found in Table 1.

To generate the alternative restoration scenarios for the choice tasks, a D-efficient design approach was employed using the NGene software package version 1.1.2. This software facilitated the exploration of main effects, potential interactions, and minimization of uncertainty in parameter estimates by reducing the determinant of the covariance matrix. By employing this approach, more reliable estimates of willingness to pay (WTP) could be obtained (Lourenço-Gomes et al., 2013). A total of 36 choice sets were generated based on this process and organized into six sets of choice pairs, which were presented on choice cards.

To ensure the inclusion of a range of options, each choice set consisted of two hypothetical alternatives with different cost levels, as well as a status-quo option representing the "no restoration" scenario with no associated cost. This inclusion of the status-quo alternative allowed respondents to make trade-offs between optimality and plausibility, enhancing the congruence with consumer theory and real-world choices (Dias and Belcher, 2015).

While the use of manipulated photographs has been employed in some studies to simulate real landscape experiences and reduce judgment errors by respondents (Bateman et al., 2009), it was challenging to effectively convey different levels of water quality and biodiversity through photographs in this case. Hence, a standard tabular format with narrative text-pictures illustrating the attributes was utilized in order to minimize cognitive burden and task complexity for respondents, facilitating their comprehension of the choice tasks (de Ayala et al., 2015).

Figure 2 serves as an example of a choice set that was included in the questionnaire. The order of the choice questions presented to each participant was randomly generated to ensure fairness and minimize any potential order effects. To ensure the logic, consistency, and comprehensibility of the preliminary questionnaire and the format of the pictorial choice cards, a focus group consisting of environmental managers, academic experts, and ordinary residents was engaged in a pilot study. This pilot study helped assess the questionnaire's effectiveness and made improvements where necessary.

The final version of the questionnaire comprised four parts. Part I focused on gathering information regarding respondents' general knowledge and attitudes towards river ecosystems and river pollution, as well as their experiences with river-based recreation. This section aimed to enhance respondents' understanding of the benefits associated with restoring the Brahmaputra River and establish a cognitive and behavioral link between urban rivers, restoration, and willingness to pay (WTP). Although the inclusion of these questions may introduce a bias towards environmentally oriented alternatives (Pouta, 2004), a similar technique has been successfully employed in previous discrete choice experiment (DCE) studies, providing respondents with a warm-up phase (Andreopoulos et al., 2015).

Part II of the questionnaire consisted of the choice experiment itself. Prior to the choice tasks, respondents received clear instructions emphasizing budget constraints and trade-offs among alternatives. The instructions reminded respondents that the choices were hypothetical but stressed the importance of providing truthful answers to ensure relevant decision-making. Respondents were instructed to consider their household income and expenditures carefully, evaluate each choice alternative independently (regardless of previous choice sets), and specify their preferred alternatives.

After completing the choice tasks, individuals who declined to participate in the choice exercise were given the opportunity to explain their reasons for refusal. This step aimed to avoid assuming that these respondents preferred the status quo when they were actually protestors or held different reasons for non-participation. Part III of the questionnaire requested respondents' socioeconomic information, including gender, age, place of residence, education level, occupation, household size, and household income. These variables were deemed valuable supplementary factors for the econometric analysis of choice data (Andreopoulos et al., 2015). In Part IV, a set of post-survey questions was included to ensure the internal consistency of respondents' answers and validate the study. Respondents were also reminded about the opportunity to review and revise their answers if necessary. The final version of the questionnaire is available from the authors upon request.

In this study, respondents who consistently chose the status quo option on all six choice cards presented in Part II of the questionnaire were categorized as protest respondents. However, protest respondents who provided reasons for their choice other than "I cannot afford to pay" and "I do not value river restoration" were excluded from further analysis, following the standard approach in the discrete choice experiment (DCE) literature (Martin-Ortega and Berbel, 2010). Furthermore, respondents who provided incomplete socioeconomic information were also excluded from the econometric analysis to ensure data completeness and reliability.

### 3.4 Observing WTP for restoration

Of the households surveyed, respondents comprised of 46% males and 54% females (Table 3). To extract the WTP from respondents, the chief question asked was "are you willing to pay $x_j$ for restoring the water quality of Bharalu?" The choice range of prices we offered them was between INR 5 and 100 which also had to be a multiple of 5, i.e. 10, 25, 50, 75, etc. They had to answer with a 'yes' or 'no'. If the chosen price was equal to or higher than the given prices, a 'yes' was recorded. Otherwise, the answer was considered 'no'. We fed the probability of obtaining responses in a Probit model. Specifically, a 'yes' was included as $P(WTP_i \geq x_j)$ and a 'no' was included 1- $P(WTP_i \geq x_j)$. Considering the standard CVM model, the two sets or probability were censored over the interval.

The model was formulated based on Cameron (1991). Considering the disturbance term to be independently and identically distributed, the model used is as follows:

$$WTP_i = Y_i \beta + u_i \quad (1)$$

Besides, we constructed a second model to record responses of people answering 'no' at first. Later they were asked whether they had another price in mind. The log-Lagrange model constructed as is as follows:

$$\log L = \sum\{R_1 \log \emptyset \left(\frac{Y_i\beta - x_j}{\sigma}\right) + R_2 \log \emptyset \left(\frac{x_j - Y_i\beta}{\sigma}\right) + R_3 \log \theta \left(\frac{x_j - Y_i\beta}{\sigma}\right)\} \quad (2)$$

In this model, $R_1$ denotes affirmative responses to the primary question, $R_2$ represents the negative responses which were followed with positive, and $R_3$ represents the negative responses to the primary question. $\emptyset$ and $\theta$ denotes the probability density function and cumulative distribution function respectively. $Y_i$ is the row vector of exogenous variables affecting a respondent's chosen price.

Our findings suggest that people are willing to restore the river which invariably conditions their willingness to pay. If we attach a personal value to WTP besides its existing monetary value, we realised that there exist positive correlations between attitude of dwellers towards restoring the river and their willingness to pay for it. This is because they realise that the river is an important natural resource, and preserving it would mean great benefits for the society as well as the environment. They are concerned about the negative health impacts that may arise from its deterioration. This also means a decline in their personal enjoyment through recreational use of the natural resource.

In addition to the significant factors mentioned earlier, other variables also played a role in determining the willingness to pay (WTP) for water quality restoration. For instance, the education level of respondents was found to be statistically significant, suggesting that individuals with higher education levels tend to value water quality more and are willing to pay a higher amount for its restoration. Furthermore, the findings revealed that the proximity to the Bharalu River (LOC) significantly influenced respondents' WTP. Those living in closer proximity to the river were more likely to recognize the importance of clean water and were willing to pay a higher amount to improve its quality. Another noteworthy factor was the size of the household (CHI). Larger households tended to have a higher WTP, possibly due to increased water consumption and a greater awareness of the impact of water quality on the health and well-being of multiple family members.

As stated in Table 3, The proportion of income spent on water-related expenses (PROP) was also found to be statistically significant. This indicates that households with a higher proportion of income allocated towards water-related costs were more likely to recognize the value of improved water quality and express a higher WTP. Moreover, the belief in the relationship between sewage contamination and river pollution (BSC) strongly influenced respondents' WTP. Those who strongly believed that sewage contamination was a significant contributor to river pollution expressed a higher willingness to pay for water quality restoration. This finding suggests that public awareness and perception of the causes of water pollution can impact individuals' motivation to take action and support initiatives for environmental improvement.

Overall, the mean WTP of INR 24.20, with confidence intervals of 21.1 and 19.40, indicates that the average individual or household is willing to contribute financially to restore the water quality of the Bharalu River. The stated willingness to pay reflects the value placed on achieving a certain level of good ecological quality that meets the respondents' requirements. This information can be useful for policymakers, environmental organizations, and other stakeholders in designing and implementing strategies to restore and preserve the water quality of the Bharalu River.

## 4. Conclusion

In conclusion, this study sheds light on the economic implications of water pollution in the Bharalu River and the willingness of consumers to pay for its ecological restoration. The findings reveal that deterioration of water quality significantly impacts individuals, influencing their willingness to pay (WTP) for restoring the river's ecological health. Factors such as the perception index of water quality, the adverse health effects of poor water quality, household demographics, and the belief in sewage contamination as a major contributor to river pollution all play significant roles in determining WTP. Moreover, variables like education level, proximity to the river, household size, and the proportion of income spent on water-related expenses are also found to influence individuals' WTP. These factors reflect the awareness, concerns, and priorities of respondents regarding water quality and its impact on their lives. The mean WTP of INR 24.20 indicates that the average individual or household is willing to financially contribute to restore the water quality of the Bharalu River to meet their ecological requirements. This willingness demonstrates the recognition of the importance of clean water and the need to preserve it for the present and future generations.

The study highlights the significance of policies that address environmental degradation and promote sustainable development. Particularly in developing countries, where poverty is prevalent, environmental issues have far-reaching implications on various sectors, including health, agriculture, tourism, and more. The Bharalu River serves as a prime example of the consequences of industrialization and urbanization on water resources. The findings from this study can be valuable for policymakers, environmental organizations, and other stakeholders involved in restoring and preserving the Bharalu River's water quality. The insights gained regarding consumer perspectives, the factors influencing WTP, and the economic impacts of water pollution can inform the design and implementation of effective strategies to mitigate pollution, protect the environment, and improve the quality of life for communities relying on this essential water resource. Ultimately, addressing the degradation of the Bharalu River can contribute to sustainable development and enhance the well-being of both current and future generations.

**Table 1: Attributes and levels considered in the DCE**

| **Attributes** | **Description** | **Levels** | | |
|---|---|---|---|---|
| Physical feature | Enhancing the river channel and transforming artificial banks into a more naturalized state | Fully covered, highly engineered straight channel | Open, still artificial channel | Open, more naturalised channel |
| Water quality | Improving water quality through enhanced wastewater treatment | Bad, highly polluted | Average, slightly polluted | Good, meeting the standards defined in environmental law, ensuring that the water is suitable for |

| | | | | |
|---|---|---|---|---|
| | | | | swimming and supports a diverse range of species. |
| Ecological status | To enhance the richness of fish, invertebrates, and other aquatic species biodiversity. | Very limited species diversity | Average, 50% increase in species diversity | Good, 75% increase in species diversity |
| Livelihood opportunities | To receive livelihood benefits from the river via fishing, transportation and allied activities. | No livelihood facilities available | Moderate livelihood activities with marginal income | Decent livelihood opportunities with good income stream |
| Recreational opportunity | To promote biodiversity along the riverbanks.<br><br>To create amenities for various water-based recreational activities such as swimming and boating, as well as land-based activities like picnics and jogging along the riverway. | Unavailability of recreational facilities | Recreational zones will be developed, accompanied by the provision of essential facilities and infrastructure for activities such as jogging, picnicking, boating, and more. | |

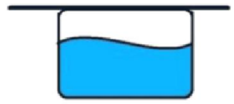
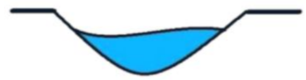
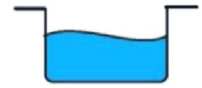
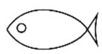
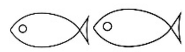
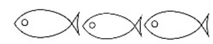
| Description | Status quo | Alternative A | Alternative B |
|---|---|---|---|
| Hydromorphological feature | Fully covered, highly-engineered straight channel | Open, still artificial channel | Open, more naturalised channel |
| |  |  |  |
| Water quality | Bad, highly polluted | Average, slightly polluted | Good, meeting the level defined in environmental law (swimmable and suitable for diverse species) |
| |  |  |  |
| Ecological status | Very limited species diversity | Average, 50% increase in species diversity | Good, 75% increase in species diversity |
| |  |  |  |
| Livelihood opportunities | No livelihood facilities available | Moderate livelihood activities with marginal income | Decent livelihood opportunities with good income stream |
| |  |  |  |
| Recreational opportunity | No recreational facilities available | Recreational areas would be established, necessary facilities and infrastructure provided for jogging, picnicking, boating, etc. | |
| |  |  | |

***Figure 2: Example of a choice card*** **(Source: Chen et al., 2017)**

**Table 2:** Calculation of WQI

| Parameters | $w_i$ | $W_i$ | C | S | $q_i$ | WQI |
|---|---|---|---|---|---|---|
| **pH** | 4 | 0.097561 | 6.065 | 6.5 | 39.4225 | 72.8461 |
| **Transparency** | 2 | 0.04878 | 70.55167 | 30 | 2116.55 | 23.2463 |
| **Hardness (mg/L)** | 2 | 0.04878 | 68.21667 | 30 | 2046.5 | 67.82927 |
| **Chloride (mg/L)** | 3 | 0.073171 | 12.22917 | 25 | 305.7292 | 22.37043 |
| **Magnesium (mg/L)** | 1 | 0.02439 | 10.855 | 30 | 325.65 | 76.94268 |
| **Nitrate (mg/L)** | 5 | 0.121951 | 2.328333 | 45 | 104.775 | 32.77744 |
| **Iron (mg/L)** | 3 | 0.073171 | 1.615833 | 0.3 | 0.48475 | 50.03547 |
| **Phosphate (mg/L)** | 1 | 0.734924 | 0.302612 | 0.31 | 1.240912 | 63.37043 |
| **Temperature** | 4 | 0.686143 | 3.253831 | 1.5 | 1.192131 | 17.94268 |
| **Conductivity** | 4 | 0.686143 | 4.253831 | 1.8 | 1.192131 | 23.77744 |
| **Alkalinity** | 3 | 0.710534 | 7.278222 | 1.4 | 104.216522 | 51.03547 |
| **$CO_2$** | 4 | 0.661753 | 10.229441 | 4 | 221.167741 | 41.373 |
| **DO** | 4 | 0.759314 | 14.327002 | 5.3 | 131.265302 | 82.8461 |
| **BOD** | 5 | 0.710534 | 10.278222 | 15 | 303.21652 | 23.2463 |
| **COD** | 5 | 0.893134 | 5.354311 | 13 | 311.3246 | 109.8293 |
| **Total** | **50** | | | | | **759.4684** |

**Table 3: Results of econometric analysis**

| Variables | Description | Mean | Standard Deviation | Partial censor model |
|---|---|---|---|---|
| AIV | Initial value | 24.10 | 32.14 | 20.83 |
| AFH | Do you think the water quality has a negative impact on your health? | 0.92 | 0.54 | -2.17** |
| BSC | Is the river water quality excellent? | 0.064 | 0.14 | 15.72** |
| BQ1 | Is the river water quality good? | 0.042 | 0.21 | 34.72 |
| BQ2 | Is the river water quality poor? | 0.39 | 0.74 | -13.73 |
| BQ3 | Is the river water quality unacceptable? | 0.28 | 0.19 | -27.96 |

| | | | | |
|---|---|---|---|---|
| BQ4 | Perception index of water quality | 105.9 | 32.21 | 4.59 |
| PIN | Do you consider sewage contamination to be a reason for poor water quality? | 0.69 | 0.24 | 2.57* |
| CHA | Do you use river water for drinking? | 0.42 | 0.19 | 18.91 |
| CENV | Does the river water quality affect your environment? | 0.31 | 0.73 | -3.84 |
| GEN | Sex of the respondent | 0.91 | 0.29 | -9.75 |
| CHI | Do you have minor children at home? | 0.42 | 0.71 | 7.12* |
| SEN | Do you have senior members (above 60) at home? | 0.62 | 0.18 | 33.27 |
| LOC | Are you a local resident? | 0.32 | 0.34 | -20.76 |
| PROP | Is this house your own? | 0.77 | 0.36 | -59.06** |
| INC1 | Do you earn less than 8 lakhs per annum? | 0.81 | 0.23 | 5.77 |
| INC2 | Is the value of your house more than 10 lakhs? | 0.53 | 0.74 | 8.04 |
| Constant | - | - | - | 65.09* |
| Insigma | - | - | - | 1.51** |
| Likelihood | - | - | - | -1231.15 |

Mean Willingness to Pay = 22.6, SD = 0.21, Confidence intervals (95% CI) = 21.7 & 22.4

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