FEASIBILITY STUDY OF SOLAR DESALINATION DEVICE TO SOLVE DRINKING WATER SALINITY OF COASTAL BANGLADESH

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ABSTRACT

The escalating salinity crisis in Bangladesh's coastal region has impacted the lives of over 43 million inhabitants. The climate change impacts including increasing salinity levels, saline water intrusion into surface water and groundwater, have threatened the safe drinking water access of this coastal community. This study proposes a home based solar desalination device that uses solar energy to desalinate and purify water. The primary objective of this research is to assess the feasibility of the desalination device as a sustainable solution to the drinking water salinity problem for the coastal Bangladesh. To conduct this feasibility study, Khulna, one of the most salinity affected coastal districts, was chosen as study area. The research methodology began with comprehensive field surveys using participatory research methods to understand the social acceptance towards the solar dealination device. Utilizing questionnaire surveys, Focus Group Discussions (FGD), Key Informant Interviews (KII), resource mapping and data collection on water usage, socio-demographic characteristics, and perceptions related to existing water quality, a holistic overview of the study area was obtained. The results from the field visits and market research indicated an urgent need for cost-effective water desalination technologies tailored to the marginalized coastal communities. Based on the results, about 68% of users expressed satisfaction after using solar desalination devices. The results of the study indicated the potential of solar desalination as a promising solution to the salinity issue.

Keywords: *Solar Desalination Device, Water Salinity, Coastal Bangladesh, Sustainable Solution, Feasibility Study.*

1. INTRODUCTION

The Bangladesh Coastal Zone (BCZ) covering an area of 47,201 km^2 covers 19 districts that accomodates 43.8 million (Bangladesh Bureau of Statistics, 2022). Being a low-lying area with exposed coastal area and having socio-economic factors like high population density and poverty, this coastal zone is one of the most vulnarable areas that are at the high risk of sea level rise and salinity. Climate change impacts may intensify the situation in coastal Bangladesh in future. According to the 2020 edition of Germanwatch's Climate Risk Index, it ranked seventh in the list of countries that are most affected by climate calamities during 1999–2018 (David et al, 2020). According to Bangladesh Climate Change Strategy and Action Plan (2008), the sea levels in Bangladesh are predicted to rise by up to 0.30 meters by 2050 which may result in the displacement of 0.9 million people in the coastal belt. Different research study suggests the annual median projected increase in soil salinity of coastal Bangladesh is expected to be 39 % by 2050 (Dasgupta et al., 2015).

The increasing salinity in coastal region is creating problems in agriculture, environment, and different socio-economic aspects. Particularly the access of drinking water due to increasing salinity in has become a pressing concern for this coastal community. Because of the economic insolvency, a significant portion of the population cannot afford expensive safe drinking water options, hence, ends up regularly consuming water with salinity levels that surpass safe thresholds. This ingestion of highly saline water has been linked to the prevalence of cardiovascular diseases (CVD), diarrhea, and abdominal discomfort. Moreover, IPCC Fifth Assessment Report also identified a number of climate-sensitive diseases such as diarrhea and cholera are waterborne (IPCC, 2014). The consequences of drinking this water are significant, resulting in health effects both in the short term and in the long run. Unfortunately, this health hazard seems to be more significiant in future as the present drinking water sources is going to be at higer risk due to salinity.

Different research and projects led by World Bank, Department of Public Health Engineering (DPHE) and the Institute of Water Modelling (IWM) indicates that aquifer saline zone will increase by 2.27% by 2050, freshwater zone will decrease by 3.44%, severe salinity zone will increase by 14% by 2050 (Choudhury et al., 2014 and annual report IWM, 2012). Moreover, Bangladesh has been historically vulnerable to natural hazards such as storm surges, inundation, cyclones, and seawater intrusion and. When the storm surge comes, the land becomes flooded, and saline water from the Bay of Bengal intruded the land and merged with the surface water. In a study conducted at coastal Bangladesh, 35% of the respondents stated that due to the cyclone, the salinity of the water increases due to the intrusion of the bay water into the surface water, hence overlapping with drinking water. The study indicated these natural calamities of coastal areas are a prime cause for increased salinity in drinking water and the frequency of natural calamities are increasing due to climate change, drinking water salinity problem is going to be severe in near future for coastal community of Bangladesh. (Rabbani et al., 2018).

Currently, the coastal people are collecting drinking water from ponds, rainwater or tube well. Some people are collecting water from distant desalination plants or buying water tanks. None of the solution is sustainable as there is accessibility or affordability issue. In such a serious condition where it is evident that the safe drinking water access for coastal Bangladesh is a critical issue, there is no alternative to propose a home-based drinking water solution for coastal community. This paper introduces home-based solar desalination device as a solution to the saline drinking water problem for coastal community that can desalinate and purify saline water using solar power. The study presents a wholistic scenario of different socio-economic characteristics related to drinking water salinity problem of the study area based on primary and secondary data analysis and examines the feasibility of the solar desalination device in terms of the perception and feedback of users is discussed in the paper.

2. STUDY AREA

In the coastal Bangladesh, Khulna, Satkhira, Patuakhali have been identified as the very high-risk area for salinity (Hasan et al., 2019). Hence, Khulna is chosen as the study area in alignment of the objective of this study. The study has been conducted in some villages of Khulna to understand the current drinking water salinity condition and the feasibility of the solar desalination device. The study area map is shown in Figure 1.

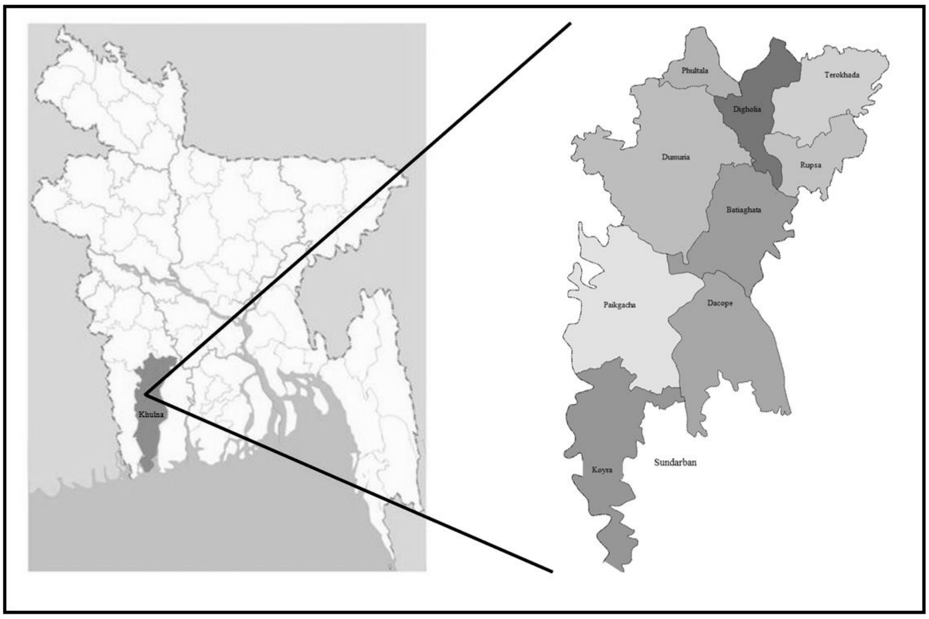


Figure 1: Study area map

3. METHODOLOGY

The research started with reviewing different secondary data and previous research conducted on the study area in recent years. Different Participatory Research (PR) methodologies were adopted to validate the previous results and understand the severity of the present condition. PR is a regarded as a research-to-action approach that emphasizes direct engagement of local priorities and perspectives (Cornwall & Jewkes, 1995). It prioritizes co-constructing research through partnerships between researchers and stakeholders, community members, or others with insider knowledge and lived expertise (Jagosh et al., 2012). The comprehensive field surveys helped to analyze the socio-economics dynamics including the monthly income, livelihood, the perception about water salinity of the community people, their current drinking water source, and the demand of alternative solutions in a micro level. The primary survey results at the study area validates the previous study results and secondary data related to drinking water salinity problem of the coastal community people. After that, solar desalination device was introducted and set up at some households to understand the acceptance of the community towards any innovative technical solution. The user feedback about the water quality, quantity and experience of having a home-based drinking water solution helped to understand the feasibility of the solar desalination device being a proper solution of drinking water for coastal community.

3.1 Review of Previous Studies

Different secondary data and previous research studies conducted by different government authority and Non Government Organizations (NGO) including Soil Resources Development Institute (SRDI), Ministry of Agriculture, Bangladesh, Department of Public Health Engineering (DPHE), Bangladesh Bureau of Statistics, Institute of Water Modelling (IWM), World Bank were throughly reviewed. The review helped to understand the historical problems related to the socio-economic parameters, salinity condition, climate change impact on salinity of the coastal area and prepare the questionarrie for the survey and PR at the next step for the validation of the information.

3.2 Participatory Research (PR)

An integrated approach of the review of previous studies and present field validation were conducted to understand the gap between existing knowledge and the scenario in the locality at present. Hence, utilizing different PR methodologies including questionnaire surveys, Focus Group Discussions (FGD), Key Informant Interviews (KII), resource mapping and data collection on water usage, socio-demographic characteristics, and health perceptions related to water salinity, a holistic overview of the study area was obtained. Our research team conducted the FGDs, KIIs and household survey using semi-structured questionnaire from the communities. Data about 201 households was collected in this survey. The collected dataset included socio-economic and demographical information of the community, people's current drinking water salinity problem, their knowledge and awareness on climate change impacts, their willingness of adopting innovative home-based solutions to solve their drinking water problem. The data set was made to be disaggregated by location, gender, ethnicity, and disability. To collect data and information regarding impacts of saline water, innovative solutions, their willingness to adopt the solution and other key relevant issues, a checklist was developed to conduct the FGDs. The FGDs were conducted with low-income group (men and women), and also seperately with women participants only to ensure there is no biasness in data. Figure 2 presents different PR methodologies conducted at the field.

(a)  (b)  (c) 

Figure 2: PR methods (a) KII (b) Resource mapping (c) FGD

Determination of representative sample size and appropriate sampling technique for the best representation of the population characteristics were considered with importance while designing the sampling. In some cases, the information required to estimate the sample size particularly standard deviation of population was not available. In that case, p = q = 0.50 was considered to ensure maximum size of sample for specific requirements. The sample size of the baseline study was chosen in a way so that the obtained result of the study can remain within 95% confidence interval.

3.3 Feasibility Study of Solar Desalination Device

A social business startup called Tetra has designed and manufactured a solar desalination device specially considering the saline water quality, demand of the coastal community of Bangladesh (Tetra, 2023). The home-based solar desalination device can efficiently desalinate and purify saline water using solar power and can fulfil the drinking water need of a family consisting 5-6 members easily. The device uses Reverse Osmosis (RO) technology to desalinate sea water which is driven by a pressure gradient across a semi-permeable membrane. Desalination technologies can be divided into two different mechanism separations, i.e. thermal and membrane-based desalination. The thermal processes include Multi-Stage Flash (MSF), Multiple Effect Distillation (MED) and Vapor Compression Distillation (VCD), whereas membrane-based processes include Reverse Osmosis (RO), Nanofiltration (NF) and Electrodialysis (ED). Among these methods, RO technology has gained great attention in recent years due to its relatively low energy usage during operation as well as easy of operation and maintenance compared to other conventional technologies such as thermal desalination (Wilf et al, 2005; Misdan et al., 2012). The solar desalination device uses a 12V-15Amp battery that gets charged with solar power that can work upto 6 hours once fully charged. The battery can be charged 4 times to produce maximum 500 Liter of water per day depending on the weather, salinity and Total Dissolved Solid (TDS) amount present in the water. A 30 Liter water jar is attached with the device. Once the jar is filled, the device stops the water filtration process automatically and it starts filtering water again when the jar is emptied at a certain level. Table 1 presents details of solar desalination device. Figure 3 shows the solar desalination device prepared by Tetra and Figure 4 shows the water desalination and filtration process flowchart of the device.

Table 1: Details of Solar Desalination Device (Tetra, 2023)

Topic	Details
Size of device	34”x 15”x 16”
Maximum water production capacity	500 L/day
Power consumption for daily maximum capacity	4.32 KWh
Water desalination method	Reverse Osmosis (RO)

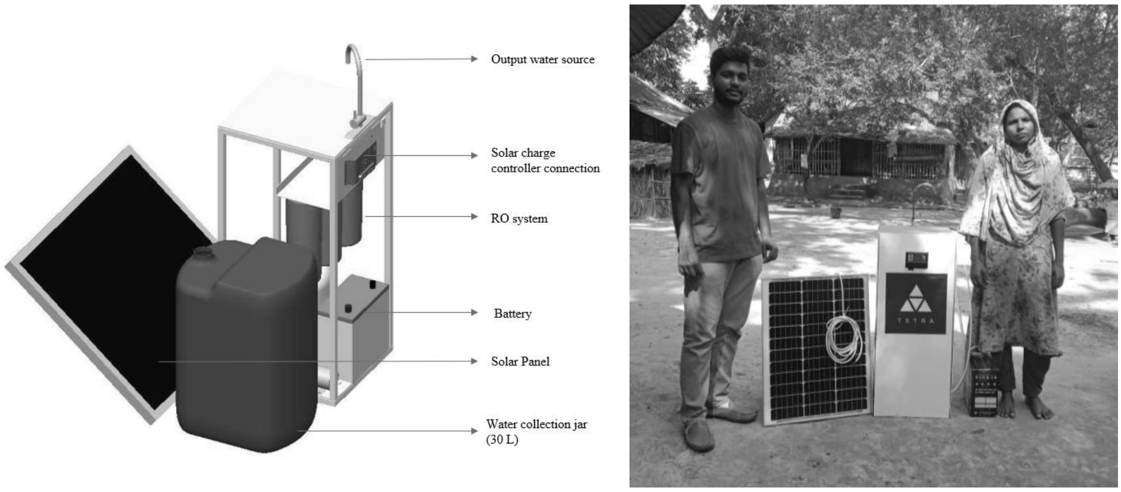


Figure 3: Tetra desalination device

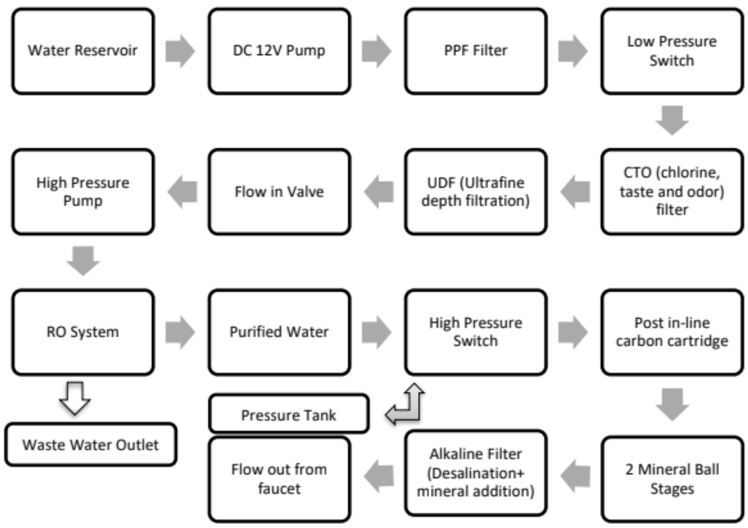


Figure 4: Water desalination and filtration process flowchart of Tetra solar desalination device

This solar desalination device was introduced and set up at 19 households to understand the acceptance of the community towards any innovative technical solution. These households had 3-7 members in the family and they used the device for their drinking water purpose for 6 months. The drinking water demand of these families varied from 12-28 Liters. So, the devices wasn't used at their maximum capacity per day, mostly the families used half-one jar (i.e, 15-30 Liter) of water daily for their water consumption which indicates the solar desalination device was in operation for around 1-1.5 hours/day. Their continuous feedback about the quality and quantity of water including the operation and maintenance of it were taken. Survey were conducted in different parts of Khulna to understand if other people are also willing to adopt and pay for it. Data analysis about the water quality, quantity and experience of using the device and community perception to adopt and pay for the device helped to determine the feasibility of the solar desalination device as a solution for salinity problem for coastal Bangladesh.

4. RESULT AND DISCUSSION

4.1 Analysis of Survey Data

The survey using different participatory methods helped to understand the wholistic scenario of Khulna's socio-demographic characteristics, water usage, and their need of pure drinking water. People of 201 housholds having different gender, age and socio-economic classes participated in the survey. Tables 2,3,4 demonstrate the percentage distribution of the respondents based on gender, villages and age. The distribution of respondents ensures the representativeness of people from all classes.

Table 2: Percentage distribution of the respondents based on gender

Gender	Percentage (%)
Male	71
Female	29

Table 3: Percentage distribution of the respondents based on villages

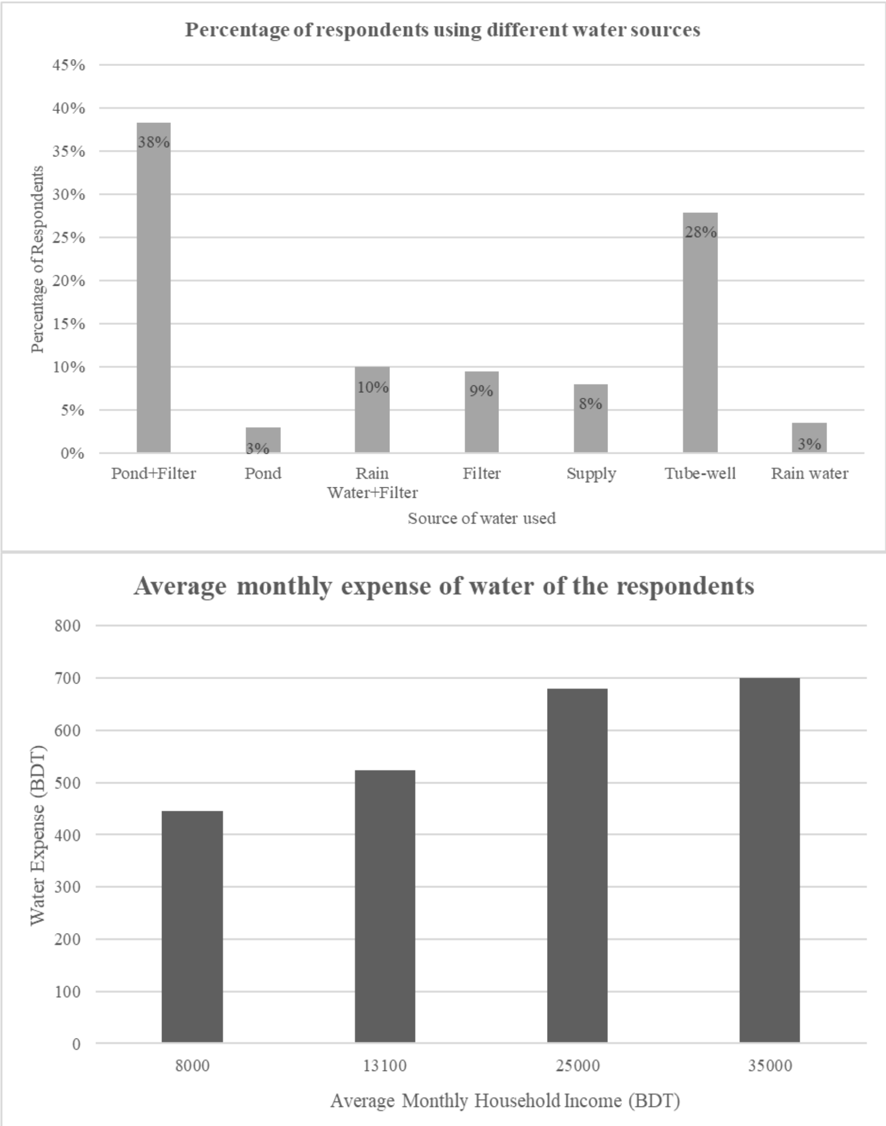
Villages	Percentage (%)
Sheikhpur,Terokhada	64
Raypur	17
Surkhali	35
Kollansiri	26
Khalispur	15
Chalna	14

Table 4: Percentage distribution of the respondents based on age

Age	Percentage (%)
0-30	20.30
31-40	27.41
41-50	23.86
51-60	21.32
60+	7.11

4.2 Existing Sources of Drinking Water

The analysis of survey dataset provides a comprehensive idea about the existing water sources and people's perception of water quality. Figure 5 presents the current water sources, water expense of people having different economic classes. The result shows the major water sources are pond water and tube-well and about 38% of people uses pond water and filter combinedly and 28% of people uses tube-well water. The average water expense of different economic classes varies from about 450-700 BDT which is about 2-5% of their income. The survey result shows 61% of respondents are not happy about the water quality of the existing water sources that they are using. It indicates the people despite of paying a significant portion of their income are not getting desired drinking water quality. There is a need of alternative drinking water solution in this region.



(a)

(b)

Figure 5: (a) Percentage distribution of respondents using different water sources; (b) Average monthly expense of water of the respondents

4.3 Perception towards Using Solar Desalination Device

The analysis of responses about willingness of using solar desalination device gives a key insight about perceptions of coastal people about adopting new technologies. The main features and device demonstration were shown to the respondents and were asked about their willingness of using it. 20% of the respondents immediately agreed to buy and use the device and 79% of people were not sure about adopting it and 1% of the respondents refused. The lack of trust, education, and awareness of potential health hazards from drinking saline water can be the potential reason of the coastal community of being sceptical about new technologies. Seminars, workshops, community engagement about the device can help building the awareness and trust in such product.

4.4 Feasibility of Solar Desalination Device

The solar desalination device was set up at 19 households at Khulna. Their feedback about water quality (i.e. taste, odor, color) and water quantity of the device was collected for 6 months. It gives a key understanding about how feasible solar desalination device is as a sustainable solution for drinking water salinity in coastal Bangladesh. The device had a maximum daily capacity of 500 Liter, but the maximum usage of the devices was about 12-28 Liter per day depending on the drinking water demand and number of members of the households. From the user feedback and data collection of 6 months, the users mentioned they used about half-one jar (i.e., 15-30 Litre) daily for drinking purpose and the device could produce this amount of water easily. No complaints were reported about the quantity of the water produced. However, 68% of the users expressed satisfaction regarding the water quality of the device. According to the data and feedback analysis, the water quality including test and odour was very good in the areas where water contained no or less iron. But 32% people who had high iron quantity in their source water reported unsatisfaction.

The overall results shows though a small portion of the coastal community people (20%) instantly showed willingness to adopt solar desalination device, the satisfaction of the users with water quantity after using the device showed there is potential for solar desaination device to emerge as a sustainable solution for coastal water salinity problem. For that, different awareness programs or seminars will be helpful to develop the education and trust among coastal community towards adopting new technologies. Raising awareness regarding the impact of saline water on health and the possible adaptation strategies may motivate the communities to develop safe water consumption behaviours and adopt new technologies.

5. CONCLUSIONS

The salinity crisis is undoubtedly a serious problem in coastal region of Bangladesh which has impacted the lives of millions. The study shows a wholistic picture of the existing water sources, water quality and the need of better drinking water of people belonging different socio-economic classes from a comprehensive field survey conducted at Khulna. The main objective of the study was to introduce a home-based solar desalination device as a solution of the problem and to analyse the feasibility of the device with the help of perception of users. The conclusions of the study are following:

- About 61% people are not satisfied with the existing drinking water quality even after paying 2-5% of their income. It indicates significant need for alternative and sustainable water desalination solutions for the coastal communities.
- A significant amount of people (i.e., 79%) were not sure about adopting any new technology like solar desalination device which demonstrates a sceptical nature of coastal people to adopt new technologies due to the lack of awareness and trust.
- On the other hand, the positive response of 68% users after using the solar desalination device showed potential of the device as a sustainable solution of drinking water salinity problem.

There are scopes of further research on laboratory testing of different water quality parameters of the output water of solar desalination device that can help to understand the feasibility of using the device in a better way.

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