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Strengthening Emergency Response: Exploring On-site Water Treatment Technologies for Floods

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Abstract

In times of crisis, access to safe and clean water is critical for disaster response teams and affected communities. Water is essential for survival, particularly in the aftermath of disasters like floods. Ensuring sufficient quantities of potable water is a critical challenge in emergencies. This article explores on-site water treatment technologies, emphasising their role in enhancing emergency response. Point-of-use household-level techniques such as straining, sedimentation, filtration, boiling, and chlorine disinfection may be effective and sufficient for a family. However, portable or on-site water purification systems offer a more versatile alternative to cater to larger communities, as they can be customised with various treatment processes to address specific contaminants, making them suitable for camp or community-level responses. Additionally, emerging trends like advanced filtration and scalable on-site treatment units offer improved efficiency during crises. A laboratory prototype of an on-site water treatment system was demonstrated, showing the ability to meet emergency water quality standards. The prototype produced water with pH levels between 6.5 and 8.5, turbidity below 5 NTU, and residual chlorine up to 0.5 mg/L, meeting Sphere standards for emergency water supply.

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Keywords

Disaster response; Point-of-use techniques; On-site water purification; Water quality; Sphere standard

1. Introduction

Floods are among the most common and destructive natural disasters worldwide, causing widespread destruction to infrastructure, communities, and ecosystems. The impacts of floods are loss of life, displacement of people, and property damage (Grayman, 2011). Another critical impact of floods is the contamination and damage to water supply infrastructure. Floodwaters can infiltrate the local water sources and contaminate them with harmful pollutants, like sewage, chemicals, and debris, rendering them unsafe for human consumption (PAHO, 2002). The contamination of water sources and supply lines creates public health risks, as the supply of clean water is essential for the survival of the affected people, as it is needed for drinking, sanitation, and hygiene in emergencies where disease outbreaks can occur (Clarke et al., 2004; Kumar & Dikshit, 2024).

Over the past few decades, the frequency and intensity of floods have increased significantly, mainly due to climate change and anthropogenic activities. Due to its diverse geography and climatic conditions, India has been highly vulnerable to these events. Between 2000 and 2023, 194 flood events occurred, averaging 8 annually. These floods affected over 350 million people in those 24 years, resulting in the loss of approximately 34,000 lives, and the total cost of property damage exceeded 77 million USD (CRED, 2025). To deal with such events and relieve the affected population, we need robust and flexible water treatment solutions to provide access to safe water during and after the disaster events. Conventional water treatment technologies/methods may become obsolete during emergencies due to damage to water treatment infrastructure and scarcity of resources. On-site or portable water treatment technologies/systems provide a key alternative. They can help in rapid and efficient water purification in the affected areas, thus providing critical support in crises.

1.1. Literature review

Water is a critical resource for survival during disasters, with a minimum amount required to ensure health and hygiene. However, the specific water needs in an emergency can vary based on several factors. Climate plays a key role, with hotter regions requiring more water than colder areas. The physical condition of the affected population is also essential, as injured or unhealthy individuals typically need more water than those in good health. Urban communities generally have higher water demands compared to rural ones. Additionally, social and cultural practices can influence water consumption. Finally, water requirements fluctuate throughout different stages of an emergency, with varying needs as the situation evolves (Kumar & Dikshit, 2025; Reed & Reed, 2013).

The Sphere standards provide essential guidelines for water supply during emergencies to ensure the health and well-being of affected populations. According to these standards, each individual should have access to at least 15 litres of water per day for drinking, cooking, and basic hygiene needs. Water must be safe for consumption, free from significant contamination by pathogens or chemicals, with no more than ten faecal coliform bacteria per 100 ml. The turbidity of water must be <5 NTU, pH between 6.5-8.5, and should have free residual chlorine up to 0.5 mg/L. Water collection points should be within 500 meters of households, and queuing time should be at most 30 minutes. Additionally, the collection process should take at most three minutes per person. The standards emphasise equitable distribution, ensuring that vulnerable groups, such as children, the differently abled, and the elderly, have equal access. Moreover, systems must be in place to ensure continuous access to water throughout the emergency and recovery phases (Sphere, 2018).

1.1.1. Water treatment approaches for flood relief

Two approaches can be carried out for the treatment of water in an emergency like floods:

- Point of use household water treatment: This approach can be used by people at the household level and does not require expertise. These methods can meet the basic water requirements.
- Semi-centralized water treatment and supply: This approach may be required to supply water to a population displaced due to the disaster. These systems can be used on a camp level and cater to the needs of many people.

1.1.2. Point of use household water treatment

During a flood emergency, simple techniques can be used by the people at the point of use for immediate requirements at the household level. These methods are sustainable as short-term options for survival until the water supply is revived. The water source for these methods can be any available source unless contaminated by chemical spills or industrial waste. These methods remove microorganisms and visible solid substances. These methods have been suggested in guidelines and manuals by the World Health Organization (WHO) and other organisations for emergency handling (Kayage, 2005). Straining involves pouring muddy water through a clean cloth to remove suspended solids and large microorganisms. Still, it must be combined with other methods for drinking safety. Sedimentation allows solids to settle naturally or with added chemicals, improving water clarity. Filtration, using sand, ceramic, or charcoal filters, removes fine particles, odour, and taste, though it is less common in emergencies. Disinfection by chlorine is a low-cost, effective way to kill pathogens using chlorine bleach or tablets after filtration. Alternatively, heat treatment, such as boiling, is a traditional method that kills microbes but does not remove solids, leaving the water potentially turbid. Each technique offers a practical step toward making water safe for consumption (IFRC, 2008).

1.1.3. Semi-centralized water treatment and supply

On-site or mobile water treatment systems and technologies can be deployed at camps and localities for the treatment and supply of water. The advantage of these units is that they can be transported to the required location and used to treat and provide the necessary amount of water for a community. The disadvantage is that it requires trained personnel to operate and handle the equipment, and the system may also be expensive and not readily available.

Garsadi et al. (2009) describe the development and operational success of the Micro Hydraulic Mobile Water Treatment Plant (MHMWTP) created by the Institute of Technology Bandung (ITB) in Indonesia. The plant can treat 400,000-500,000 litres per day (lpd) and is noted for its simple design, low energy, and chemical consumption. It has been patented and certified by the Indonesian government and is used in emergency relief operations by local authorities, public works departments, and the Indonesian army. The system has been deployed in several disasters, including the 2004 Banda Aceh tsunami, the 2006 Yogyakarta earthquake, and floods in Jakarta and Bandung. Additionally, 50 small-scale systems were developed for remote areas of Sumatra and Java. Capable of treating water with turbidity up to 10,000 NTU, the MHMWTP has proven to be a vital tool for providing clean water in disaster relief and remote regions.

Park et al. (2015) developed a mobile water treatment system by integrating various treatment processes to optimise performance. The researchers proposed four different combinations of treatment stages: pre-treatment with coagulation and flocculation; primary treatment using pore control filtration (PCF), microfiltration (MF), and reverse osmosis (RO); and post-treatment with activated carbon (AC) and ultraviolet (UV) disinfection. The system was designed to achieve a minimum processing capacity of 300,000 litres per day, with process combinations tailored to the quality of the incoming water and the desired quality of the treated water. The study evaluated the energy consumption and removal efficiency of each process combination. The authors suggest that modularised water treatment systems, which allow for flexible selection of treatment processes based on water source characteristics, will become increasingly important. These systems are suitable for both regular services and emergencies.

Clarke et al. (2004) describe a physico-chemical water treatment system with low power and mechanical requirements, incorporating a pump, pipe flocculator, and upflow clarifier. The system proved reliable and effective for treating raw water with high turbidity, consistently producing effluent with turbidity levels as low as 1-2 NTU. Upflow clarifiers are particularly effective in emergency water treatment, reducing high turbidity levels to below 5 NTU at a rate of 10 m^3/h. The system tested in Haiti demonstrated substantial improvements in water quality over an extended period, maintaining a high production rate and low cost (Dorea, 2009; Dorea et al., 2009; Dorea & Clarke, 2006).

This article explores various on-site water treatment technologies designed for floods, and the significance of strengthening emergency response capabilities is discussed. The researchers' approach was situation-specific, resulting in innovation and strategies according to the requirement. However, point-of-use water treatment systems produce small amounts of clean water that may suffice the needs of very few people at a time. The emergency water treatment systems have been designed to provide clean drinking water, whereas drinking water may only be around 30% of the water required for daily needs during an emergency. Most systems are membrane-based, which may not be suitable for use without pre-processing the contaminated water during floods. The cost of the systems may be high depending on the manufacturing quality. Thus, there is a need to develop a system that can be smaller, lighter, easily movable and cost-effective. The goal is to design a simple, cost-effective system that is easy to construct and deploy while meeting emergency water quality and quantity requirements. The scope of the article is limited to showcasing a laboratory prototype of an on-site water treatment system in development and evaluating its functionality in batch operation.

2. Materials and methods

2.1. Research Methodology

A methodology used to achieve the objectives of the research is outlined as follows:

Identify the research problem and objectives: The need for on-site water treatment for emergencies like floods was established. The scope of the study was defined, and specific challenges related to emergency water treatment were studied, which led to the formulation of research objectives.

Review of literature: Literature was reviewed to gather information about various criteria and factors affecting water requirements, and emergency water quality standards were reviewed to identify the requirements for our system. Next, the existing on-site water treatment solutions developed by various researchers were studied to understand the approach used by other researchers. Various technologies and unit processes used in emergency response were studied to identify current solutions' gaps (e.g., size, portability, cost).

Fabrication and operation of the laboratory prototype: A laboratory prototype was developed, and experiments were conducted to evaluate the system's performance in meeting the required water quality for emergencies.

Data collection and analysis: The water quality and operational parameters data gathered during prototype testing were analysed to evaluate the system’s performance.

Conclusion: The key findings from the testing and evaluation of the laboratory prototype were summarised.

2.2. Fabrication of the laboratory prototype

A laboratory prototype of an on-site water treatment system was designed and fabricated from locally available materials as per the schematics shown in Figure 1. The system was designed for a maximum flow rate of 0.2 m^3/h (200 L/hr). The prototype consisted of a 300 L tank as a source of raw water supply. A mini submersible pump was used to pump the water into the system. A rotameter was used to measure the input flow rate. A lay-flat hose pipe of 10 m length and 0.09 m diameter was used as a tube flocculation unit. A dosing pump was used to pump coagulants at the tube flocculator's inlet. A 20 L PET jar was used as an upflow clarifier. A coarse media filter containing coarse silex and a fine media filter containing fine silex were made from a 20 L PET jar. After the media filter, a 10-inch micro-mesh cartridge filter of 120 µm, made of stainless steel, was used. An output collection tank was used to collect the treated water, and a dosing pump was used to dose sodium hypochlorite for disinfection.

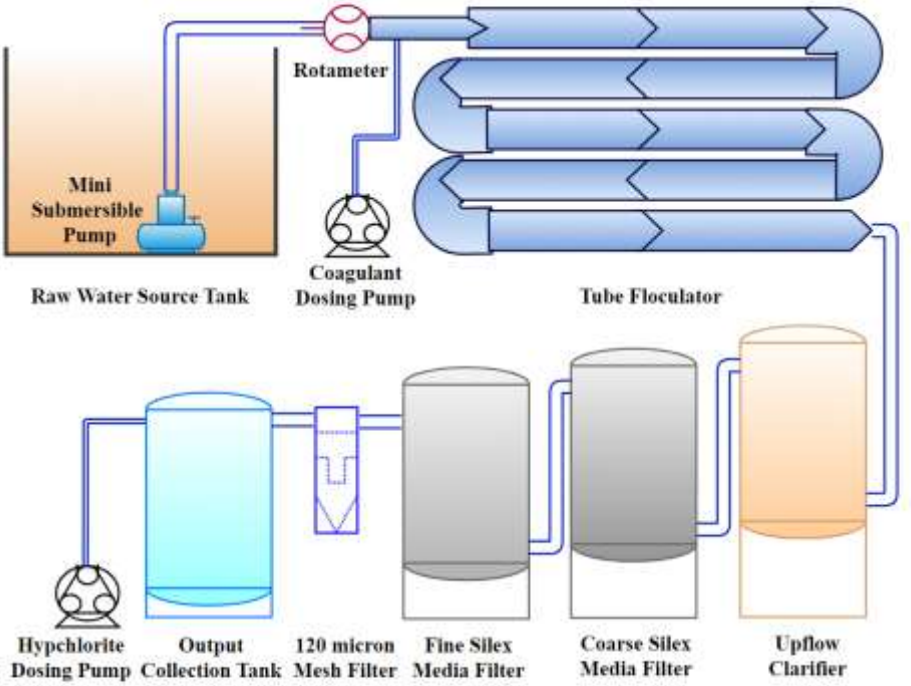

Figure 1: Schematic diagram of laboratory prototype. Source: Author.

2.3. Operation of the laboratory prototype of an on-site water treatment system

To evaluate the effectiveness of the laboratory prototype, raw water was prepared by mixing soil collected from a local nursery. The soil was brownish red, having a pH of 7.8, a specific gravity of 2.47, and a moisture content of about 10%. A 500 gm of soil was weighed and then mixed with 300 litres of tap water in a large tank, and thorough mixing was provided with a stirrer to create a uniform sample for testing. The initial turbidity was measured to note the initial characteristics of the raw water. For subsequent trials, the raw water was diluted as required. The system was tested in three trials, with three raw water samples having different turbidities.

The above-described system was operated at an input raw water flow rate of up to 200 L/hr in batch studies. Our preliminary studies found that polyaluminium chloride (PAC) was the best coagulant compared to alum, ferric chloride, and strychnous potatoram. PAC was used as the coagulant at a dosing rate of 30 mg/L, which was found to be optimum in our earlier studies (Kumar & Dikshit, 2022). Chlorination was done by dosing sodium hypochlorite at a dosing rate of 2 mg/L. The pumps were operated manually, and after each trial run, each unit was manually cleaned, backwashed, and reassembled for subsequent trials.

Based on a review of various literature, the typical raw water that can be expected during floods can have a pH range of 7 to 10, turbidity exceeding 500 NTU, total solids (TS) greater than 5000 mg/L, and total dissolved solids (TDS) above 2000 mg/L (Dorea & Clarke, 2006; Garsadi et al., 2009). Thus, the raw water was prepared to simulate the above raw water characteristics.

The target output quality for the laboratory prototype was set as per the Sphere standards discussed earlier. The main aim of the laboratory prototype was to produce output with turbidity < 5 NTU, pH between 6.5-8.5, and residual chlorine up to 0.5 mg/L to meet the water quality standards for emergency use (Sphere, 2018). Input raw water and output treated water quality parameters were measured using standard analytical methods to assess the prototype's performance (APHA, 2017). The system was tested for multiple trial runs to ensure consistency and reliability in the results and to test the system under varying conditions.

3. Results and discussion

The study was conducted using the laboratory prototype of the on-site water treatment system, as described earlier, operating in batch mode to evaluate its performance. The water quality parameters observed during the tests are presented in Table 1. In trials 1 and 2, the prototype successfully reduced the turbidity of the water to meet the target of 5 NTU. This indicates that the system can achieve the desired water quality under certain conditions. However, in trial 3, although the prototype reduced the turbidity of the raw water from an initial level of 910 NTU down to 10 NTU, it could not meet the required standard of 5 NTU. This suggests system efficiency can vary depending on the initial water quality or operating conditions.

Regarding pH, the output water in all three trials was within the acceptable range. Moreover, the prototype significantly reduced dissolved, total, and suspended solids. At an input flow rate of 200 L/h, the system achieved a turbidity reduction of approximately 97-99%, which is a notable improvement, indicating that the filtration and sedimentation processes in the system were highly effective at removing particulate matter from the water.

Table 1: Water quality parameters for laboratory prototype batch study

Parameter	Trial 1		Trail 2		Trail 3	
	Input	Output	Input	Output	Input	Output
Turbidity (NTU)	240	5.4	510	4.22	910	10.1
pH	7.9	7.24	7.66	6.91	7.6	7.01
Conductivity (mS/cm)	0.12	0.13	0.14	0.13	0.13	0.12
Temperature (°C)	27.5	26.4	29.5	27.2	27.6	27.7
Dissolved Solids (mg/L)	70	70	80	80	70	70
Total Solids (mg/L)	446	78	694	80	1320	150
Suspended solids (mg/L)	376	8	614	0	1250	80
Alkalinity (mg/L)	20	16	20	16	20	16
Total Hardness (mg/L)	40	40	44	40	40	40
Residual Chlorine (mg/L)	0	0.4	0	0.4	0	0.3

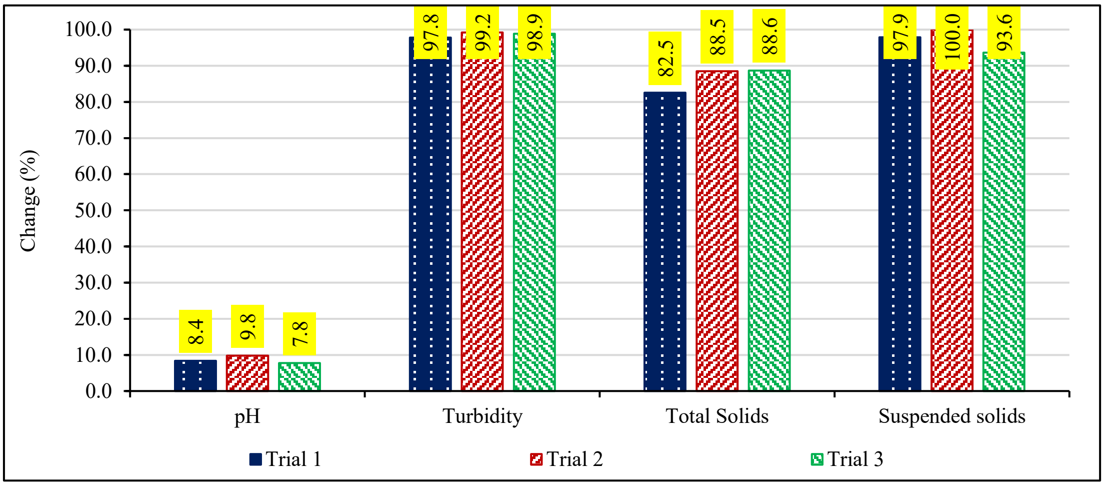

Figure 2: Variation of water quality parameters. Source: Author.

The change in pH ranged between 7-10%, and pH was within the acceptable limits, and total solids (TS) removal was found to be between 82-89%, indicating that the system effectively reduces the overall solid content in the water. Additionally, the total suspended solids (TSS) removal ranged from 93-100%, demonstrating the system's ability (Figure 2). The system's impact on other water quality parameters, such as alkalinity and hardness, was minimal. This suggests that while the system efficiently removes physical contaminants, it may need further optimisation to treat the raw water having any other chemical contamination. Notably, the system also consistently met the residual chlorine requirement of up to 0.5 mg/L, thus indicating that the treated water was disinfected as per requirement and free of harmful pathogens. The laboratory prototype demonstrated in the work met the water quality standards for emergencies as stated by the Sphere standards.

4. Conclusion

The laboratory prototype in the above study successfully met the Sphere standards in most cases. The pH range of 6.5-8.5 was achieved during all the trials. The final turbidity of 5 NTU was achieved during trials 1 and 2. A residual chlorine level of up to 0.5 mg/L was achieved during all the trials. However, based on these trials, we understand that additional modifications and design changes are required to improve its overall performance and efficiency, particularly in dealing with high turbidity raw water. The variability in results under different conditions indicates the need for further research and development. To further validate the prototype's effectiveness, subsequent trials with the modified design and different combinations of raw water qualities will be needed. Testing the system with varying levels of contamination and in various environmental conditions will help ascertain its robustness and adaptability to real-world on-field conditions. Additionally, a scaled-up pilot version of the prototype is currently being considered. This larger version will be tested in field conditions to better understand how the system performs in emergencies, where reliable and efficient water treatment is critical for public health and safety. Thus, we can conclude that an on-site water treatment system can effectively meet the urgent water needs of populations affected by floods or other emergencies. While it presents particular challenges, such systems can be tailored to adapt to varying conditions and ensure reliable access to safe water.

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Conflict of interest:

The author(s) declare that there is no competing interest.

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