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INTEGRATING SOCIAL EMPOWERMENT AND MEMBRANE TECHNOLOGY FOR CLEAN WATER ACCESS IN A RURAL INDONESIAN COMMUNITY CASE STUDY IN NGANTI VILLAGE, BOJONEGORO

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ABSTRACT

Human resilience is related to the availability of natural resources, such as water, which is developed through community empowerment and technology. Nganti Village, Bojonegoro is one of the villages that is vulnerable to the availability of clean water for daily consumption. So, this research aims to (1) analyze the problems and potential of water sources that are not utilized by the Nganti community, (2) analyze community strategies in dealing with water problems, and (3) simulate alternative membrane technology based on community empowerment. This research used a combined approach, quantitative and qualitative, involving key informants, including the Village Head, Head of the Clean Water Association, Ngraho Sub-district Head, and Community Leaders, in addition to a survey of 40 Nganti-Ngraho residents. Data analysis is descriptive statistical and qualitative. The water quality of a spring in Nganti Village shows that the water is not suitable for drinking, washing and latrines (MCK) due to the high content of iron and other metals. Meanwhile, the community's strategy is to use water reservoirs as an alternative water source and introduce membrane technology through community empowerment activities.

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INTRODUCTION

Global issues and resilience problems are multidimensional phenomena of social, economic, health, as well as physical and non-physical environment changes (Binh et al., 2022; Bruce et al., 2020; Falkenmark et al., 2019; Fallon et al., 2022; Rendon et al., 2021). Climate change, ecology, education, technology, economy, politics, social

(illegal logging), hydrology (reduced water resources, poor water quality), negligent water management, and other factors, in particular, have an impact on the needs and issues of water resilience (Binh et al., 2022; Fletcher, 2019; Saikia et al., 2022). Whereas water resilience indicates if a city is capable of addressing the water needs of the community and how well it does so (Fletcher, 2019).

Water is a resource that everyone within the community needs, whether as individuals, groups, countries or even the entire world. The 2030 agenda for sustainable development, which the UN has firmly defined, consists of 17 Sustainable Development Goals (SDGs), one of which is the equal distribution of demands for clean water and sanitation (un.urg, 2022). The Indonesian government prioritizes expanding access to drinking water and water production capacity based on the Presidential Decree Number 59 of 2017 about Implementing the Achievement of Development Goals (Peraturan.bpk.go.id, 2022). More than 80% of Indonesian citizens have access to adequate and sustainable drinking water sources in both urban and rural areas. However, fewer than 40% of villages and cities have independently provided and managed access to such sources (BPS, 2022). This indicates a gap in the independent and sustainable management of water in rural and urban areas. In addition to the Government of Indonesia, in an attempt to supply clean and drinkable water, synergy and cooperation from the community and other stakeholders are also required. Local community knowledge, community motives and preferences, community empowerment, use of local or advanced technology, planting of wood plants, use of agroforestry systems, and several other attempts to supply quality water are efforts to provide drinking water (BPS, 2022; Jonsa & Suharmi, 2018; Le & Nunes, 2016; Sugiyono & Dewancker, 2020).

Lack of optimal water management is found in the Bengawan Solo River Watershed area, specifically in Nganti Village, Bojonegoro Regency. The location often experiences drought in the dry season and floods in the rainy season due to a destroyed pipeline system and water treatment plant that disrupts the distribution of water sources. In addition, non-optimal water treatment causes water quality that does not meet the quality standards for drinking water. Therefore, it is important to empower the Nganti Village community in implementing membrane technology to improve the feasibility and quality of water according to drinking water quality standards.

The need for clean, drinkable, good-quality, and sustainable water can be resolved using a community empowerment approach, whether carried out by individuals, groups, or the government (Dwiratna et al., 2018; Jonsa & Suharmi, 2018; Sianipar et al., 2013). This is due to the belief that community empowerment focuses on improving mindsets, attitude patterns, and developing the potential of oneself using a variety of different strategies to solve various problems from upstream to downstream (French et al., 2017; Handono et al., 2020). With community empowerment, it is intended that views will change, mindsets and attitudes will shift, and the community will then be able to address issues with water sources using either local or other technologies.

This research involves the community empowerment theory as a process of individual competence development, collective efficacy, and participation (Perkins & Zimmerman, 1995; Wallerstein et al., 2017), aiming at psychological, organizational, and community change levels (Zimmerman, 2000). Essentially,

community empowerment is understood as the process of knowledge, skills, attitudes, and competencies development in identifying needs, mobilising resources, and implementing sustainable solutions (Laverack, 2006). Empowerment processes are essential to involve collaboration between communities, facilitators and stakeholders to increase collective capacity (Trickett, 2009), develop technical competencies and community organizational structures for sustainable initiatives (Fazey et al., 2018). In the context of water technology adoption, community empowerment theory provides a framework for understanding how communities can develop the capacity to evaluate, adopt, and maintain water treatment technologies such as membrane systems. This theoretical approach emphasizes local expertise building and decision-making capabilities rather than simply transferring technology (Marks et al., 2013).

Previous studies examined water issues from a technical perspective to determine how much water is used for drinking water, washing, toilet facilities, agriculture, fishing, and other uses (Gittins et al., 2021; Hasani et al., 2021; Hothi & Hothi, 2022; Katsanou & Karapanagioti, 2019; Orgill et al., 2013; Pandey et al., 2014; Rahut et al., 2015; Satriani et al., 2022; Williams et al., 2015). Moreover, additional studies studied the dynamics of water issues from a social, economic, health, governance, or political standpoint (Daniel et al., 2020, 2021; Falkenmark et al., 2019; Lilje et al., 2015; Sugiyono & Dewancker, 2020). The relationship of water issues with the aspects of empowerment was also examined in earlier research studies (Akurugu et al., 2021; Ashifa, 2020; Dickin et al., 2021b; Zikargae et al., 2022). Whereas other research is about aspects of water needs or problems and membrane technology (Barlokova et al., 2020; Ezugbe & Rathilal, 2020; Hoslett et al., 2018; Ji et al., 2015; Lu et al., 2022; Milescu et al., 2019). Based on prior research, integrated research starting from problems or water resilience associated with how the process of empowerment or strategies to overcome them from social, relational and technological components (membranes) has not been conducted.

Therefore, in an effort to promote the sustainable development of Bojonegoro City (locally known as MATOH), this research specifically focuses on the challenges of water resilience through community empowerment processes and local community strategies, particularly in relation to the implementation of membrane technology. Considering that Bojonegoro City is an exceptionally large city, we purposefully selected Nganti Village of Ngraho Subdistrict as a case study for this research due to its severe water source problem. Although a water source is available, it cannot be utilized for bathing, washing, cooking, toilet facilities, agriculture, farming, and other activities. Furthermore, Nganti Village also faces additional water scarcity during the dry season due to its significant distance from the Bengawan Solo River, one of the sources of clean water in Bojonegoro City. This research is expected to contribute theoretically, namely, by developing a conceptual framework for community empowerment in the membrane technology adoption process. In addition, the expected contribution is the intervention of membrane technology that can be accessed easily, so that the Nganti Village community can access clean water, which is suitable for consumption. With the consideration of various problems in Nganti Village, the objectives of this research were (1) analyze the problems and potential of water sources that are not utilized by the Nganti community, (2) analyze

community strategies in dealing with water problems, and (3) to simulate alternative membrane technology based on community empowerment.

RESEARCH METHOD

The membrane technology has the capability to reduce the concentration of solutes, remove colour and odour, and remove biological contaminants such as bacteria and viruses. This research was conducted in Nganti Village, Ngraho District, Bojonegoro Regency, East Java Province, Indonesia. Nganti Village was selected as the research site due to its representative characteristics for the study objectives. The research was carried out over eight months from December 2021 to August 2022, and consisted of several methods (Figure 1).

This research involved the active participation of the Nganti Village community, so field procedures were carried out by prioritizing the ethical principles of social research. Before the activities began, researchers obtained written consent from all respondents, explaining the purpose of the research, the expected benefits and potential risks. Personal data, including names, addresses, and interview recordings, was kept confidential by identity coding. Researchers ensured that the membrane technology intervention did not cause disadvantages or inequality of access, especially for vulnerable groups such as women, the elderly, and low-income families. In addition, the study complied with local regulations and applicable university ethical guidelines and involved approval from the village government prior to program implementation.

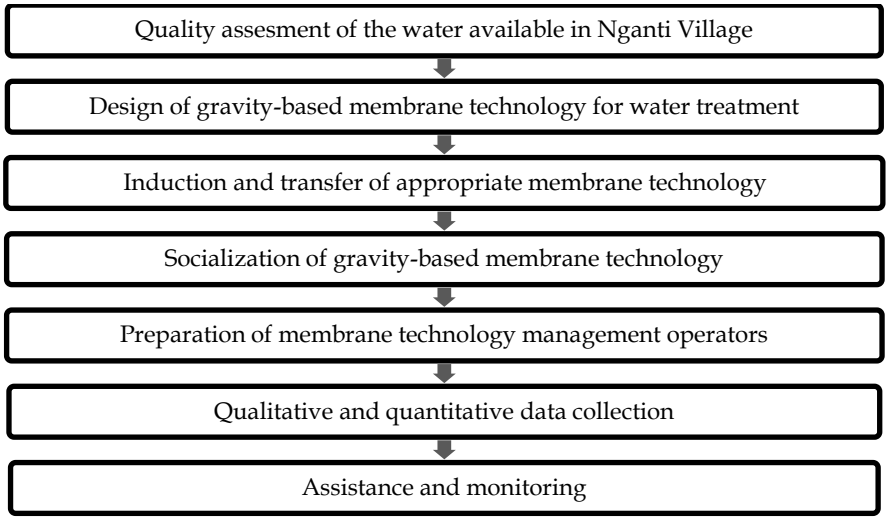

Figure 1.
Implementation of Membrane Technology Innovation Diffusion Activities in Nganti Village

This research uses a combined approach between quantitative and qualitative approaches. This research uses descriptive statistics and qualitative research. This research involves the government and village officials as the informants and the 40 Nganti Village community as the purposively-selected respondents, who consist of people who participated in the empowerment activities

of membrane technology. Informants were purposively selected from the local government because they were considered to understand the water treatment process and water distribution regulations in Nganti Village. The data collection technique, consists of:

(1) In-depth interview with prominent members of the community with key questions, such as who is involved in providing clean water, what are the obstacles and solutions to supplying water, what are the strategies or ways to fulfil clean water and how to cooperate with others to provide clean water.
(2) Questionnaire-assisted interviews with residents of Nganti Village in Bojonegoro City were conducted to gather information regarding their socio-economic characteristics, water needs, problems with and solutions for water supply, and knowledge and attitudes toward alternative membrane technologies.
(3) Focus Group Discussion (FGD) to the stakeholders (Village Head, Head of the Clean Water Association, Ngraho Sub-district Head, and Community Leaders) involved in the research problems, ranging from the history of obtaining water sources, restrictions on water sources that cannot be utilized, what efforts have been made by stakeholders from the Bojonegoro city government and the Nganti Village government or related stakeholders.
(4) Observation of the research location, particularly of water sources that can be used or not.
(5) Sampling of water for laboratory testing from unused sources by residents (water content, whether drinkable or not).

This study has several limitations, among others: First, the case study-based research design in one village limits the generalization of findings to other rural areas with different socio-economic conditions and water sources. Secondly, the duration of post-intervention monitoring is relatively short (e.g. only 6-12 months), so it has not been able to assess the sustainability of using membrane technology in the long term. Third, external factors such as extreme weather, water infrastructure damage, or village leadership dynamics may affect implementation outcomes but were not fully controlled in this study. Fourth, the measurement of health impacts still relies on self-reported data, which has the potential for perception bias. This limitation is expected to be taken into consideration in the interpretation of the results and can be the focus of further research with wider coverage and longer duration.

The data analysis in this study was descriptive statistical regarding the percentage of the water source content as well as qualitative data analysis. The analysis used the interactive model by Miles, Huberman, and Saldana that consists of 3 (three) main components, there are data condensation, data presentation, and conclusion (Miles et al., 2014). This research uses triangulation of methods and data sources to determine the validity of the information obtained. This research involved data triangulation consisting of triangulation of data sources, methods, and time. Data source triangulation involved informants and a number of respondents, with diverse viewpoints and information. The method triangulation used in this research is in-depth and structured interviews, observation, and FGDs, with time triangulation, which means carried out on various data collection schedules. Also, the process and strategy of empowerment was analysed to fulfil the needs of solving water source problems, and simulating or conducting limited trials of membrane technology (currently still in the process of making this tool) as in Figure 2.

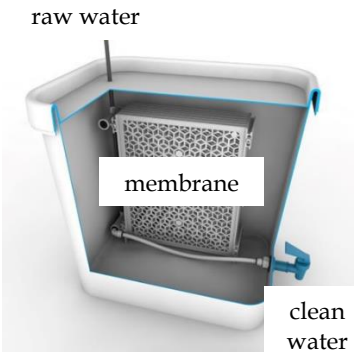

Figure 2.
The Design of Gravity Pressure-Based Membrane Technology

Water quality testing to meet the needs of livestock and agriculture is carried out on raw and embung (***Embung*** is a water storage building that is usually made in a basin or lowland area to accommodate rainwater or water runoff from small rivers and hills. Its function is to provide an alternative water source, especially during the dry season, for the needs of agriculture, livestock, and the daily needs of the community) water samples, then the water goes through a membrane technology process, and clean water can be used.

RESULT AND DISCUSSION

Water Source Assessment

One of the villages with potential for agriculture, animal husbandry and fishing is Nganti Village in the Ngraho District of the Bojonegoro Regency. Geographically, Nganti Village is in the western part of Bojonegoro Regency, or East Java Province, and it borders with Blora District of Central Java (Figure 3); where it is also located 5 kilometers from the Bengawan Solo River.

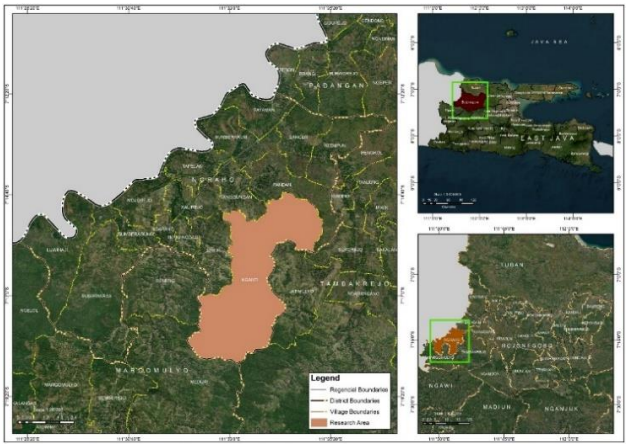

Figure 3.
The Location of Nganti Village of Bojonegoro in East Java is borded by Blora District of Central Java

Based on figures 3 Nganti Village has a land are of 9,36 km², 315 hectares of rice fields, and 124 hectares of fields. This village has a population of 2.413 people, with 1.600 of the residents working as farm laborers, which represents 70% in the agricultural sector. Agriculture, especially rice, covers an area of 443 hectares (Pemkab_Bojonegoro, 2018).

Nganti Village has a significant amount of potential for the land resources, particularly for agriculture, this village faces water scarcity issues during the dry season because there is insufficient water accessible. The results and discussion focus on the types of water sources (spring source), potentials and problems or constraints for daily life or the agricultural, livestock and other sectors (Table 1).

Table 1. Types of Springs, Utilization and Problems in Nganti Village, Bojonegoro

Type of Spring	Utilization/Potential	Problem
1. Household Well	- Bath - Washing - Watering Flowers/Plants - Washing Motorcycle - Drink for Livestock	- Undrinkable - Unable for cooking - A little or runs out during dry season - Yellowish color, if for washing yellow clothes
2. Artesian Well	- Drug therapy for skin diseases (a small portion) - Cannot be used because it contains metal levels - The source is large, during the dry season there is still a water source - Alternative use of membrane technology	- Yellow - Strong scent - High metal content - High detergent content - Harmful if drunk - Membrane technology is still being tested and not completed
3. Dam (Water Reservoir)	- During the dry season for agriculture - Potential to be used for household - Fishery (pond)	- Limited agricultural irrigation, farmers who own land around the dam - Cannot be used for cooking and drinking
4. Rainwater	- Agricultural irrigation - Only during rainy season	- During dry season, most of the agriculture does not exist (farming)
5. Bottled Drinking Water (Bottles, Gallons and Others)	- Drink and Cook	- Expensive - Limited to wealthy people
6. Water Tank (Truck)	- For drinking, cooking and bathing - Bojonegoro City Irrigation/Tirta Service	- when there is no water source from anywhere - limited quantity - must sometimes replace each jerrycan for five thousand rupiahs

Table 1 shows that Nganti Village has a large amount of potential for water resources; however, not all of these resources can be used by the community. The demand for bathing, cooking, and drinking is extremely limited, and in the dry season, tanker trucks from outside the village must even be brought in at a cost.

Despite the fact that there is a continuous source of artesian water (deep water), the water is too unsafe to be consumed thus cannot be used. The results of the water test lab from Pepe Sub-Village of Nganti Village are presented in (Table 2).

Table 2. Water Test Results from Pepe Sub-Village, Nganti Village

Parameter	Test Result	Drinking Water Quality*)	Summary
Color	91.030 TCU	15.00 TCU	Above the threshold
Total Dissolved Solid	21980 mg/L	500 mg/L	Above the threshold
Chloride	94700 mg/L	250 mg/L	Above the threshold
Ammonia	1.3240 mg/L	1.50 mg/L	Above the threshold
Detergent	0.1586 mg/L	0.05 mg/L	Above the threshold

Note**:** Standards of Health Regulation Ministry (Permenkes) No. 492 Year 2010*)
Source: (Kemkes RI, 2020)

The water source tested in Nganti Village came from the Pepe water source. As shown in Table 2, the amounts of chloride, ammonia, and detergent are over the average requirement of Minister of Health Regulation No. 492 of 2010, regarding Drinking Water Quality Requirements (Kemkes RI, 2020). As a result, the water is not acceptable for drinking, cooking, or washing; Physical requirements: water is free from pollution in terms of turbidity, color, taste, and smell; Chemical requirements: drinking water must not contain toxic chemicals that can interfere with health, aesthetics, and economic disturbance; Bacteriological requirements: water is free from germs, which include bacteria, protozoa, viruses, insects, and fungi; Radioactive requirements: drinking water that is free from alpha and beta rays that can harm health.

In order for the water to be filtered to fulfil the Drinking Water Quality Standards of Permenkes no. 492 of 2010, the findings of the water test from Pepe Sub-Village (Figure 4) need to be treated, or an alternative technology (membrane) is available. The installation of portable wireless drinking water supply equipment will also be extremely advantageous for the residents of Nganti Village.

Figure 4.
The Artesian Water in Pepe Sub-Village Not Being Used
Source: Researcher Documentation (2023)

Figure 4 shows an abandoned water source that residents do not use because the water content is very high in detergents and metals. If the water source were to be used, much harm would happen to the condition of the human body, or even cause death in agricultural crops, or livestock death. Another potential water source

is the reservoir in Nganti Village (Figure 4), which can be used by the community for agriculture during the dry season, as well as for fisheries. However, the use of the reservoir is limited to those who own agricultural land around the reservoir.

Figure 5.
Water Reservoir in Nganti Village
Source: Researcher Documentation (2023)

The potential of reservoirs (Figure 5) is intended to be utilized for sources of drinking water that are directed to reservoirs (Figure 6). These two figures show the interconnectedness of the community's need for clean water during the dry season. The community needs water with an alternative source of embung water (figure 5), from which embung water is diverted (figure 6) to be distributed to residents. In addition to water sources from the embung, from groundwater, and from artesian water, which still contains iron and others, so it requires a water membrane.

Figure 6.
Water Tanks from the Bojonegoro Regency Government
Source: Researcher Documentation (2023)

Due to restrictions on power sources, water filters, pipelines, and institutional support (financing, actors, and agreement rules), whether to become a Village PAM (Mineral Water Company) or otherwise, the water reservoir (Figure 6) cannot be used. There is no collaboration and synergy between the Bojonegoro Regency Government, the Nganti Village Government and related institutions (Corporate CSR and others). The importance of collaboration and synergy with various elements of community can lead to create various benefits from network, social, economic and

ecological aspects. However, this certainly needs to be increased or strengthened by institutions or individuals.

Membrane Technology of Nganti Village Community

The basic principle of separating components using a membrane is by grouping these components. The grouping is usually based on the size of the component to be selected. The membranes used in the separation can be organic, such as synthetic polymers, and inorganic, such as ceramics. Based on their size, membranes can be divided into microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). Daneluz et al., (2023) stated that the pore size of the semipermeable membrane decreased from MF (0.1-10 □m/10-7-10-5 m), UF (1-100nm/10-9-10-7 m), NF (0.5-1 nm/5x10-10-10-9m), and finally RO (<0.5 nm/5x10-10m). The smaller the pore size, the greater the hydrostatic pressure that occurs in the layer (Coy et al., 2022; Handono et al., 2020; Issaoui et al., 2022b; SPC, 2019). Due to the difference in pore size, it can be concluded that the hydrostatic pressure will increase from MF, UF, NF, and RO. In MF and UF, the operation takes place based on the pore convective flow mechanism (Darcy's Law), while the operation on the RO takes place based on the solution diffusion mechanism (Fick's Law). The NF membrane is between the pore rate and the diffusion mechanism (BPS, 2022; Daniel et al., 2020; Dickin et al., 2021; Jonsa & Suharmi, 2018; Le & Nunes, 2016; Muhari et al., 2018; Rusmaya et al., 2021; Sianipar et al., 2013; Soula et al., 2021; Sugiyono & Dewancker, 2020).

Based on the description of several membrane technologies MF, UF, NF, and OR, the membrane technology that should be offered to the Nganti Village community is a microfiltration membrane (MF), given the characteristics of the water in the village containing high iron (Fe). In line with previous research, that water polluted with Fe content can be removed efficiently with microfiltration membranes. (Daneluz et al., 2023) also mentioned that MF is widely used to sterilise beverages, and microfiltration membranes have been used in tests to remove pathogenic bacteria and reduce microbial concentrations from beverages. MF membrane technology is often applied in conjunction with other separation processes, such as ultrafiltration (UF) types. According to (Shoshaa, Ashfaq, & Al-Ghouti, 2023) UF membranes have advantages over other membranes because with low pressure, UF can separate contamination in water. The smallest MF membrane pore size, supported by the use of low-pressure UF membranes, is considered the right choice in the desalination process. The visualisation of this membrane technology can be shown in Figure 7 below.

Due to a number of obstacles, including the need to import equipment and supplies, the process of creating membrane technology is still being tested at this moment (Figure 7). However, this membrane technology needs to be developed in order to optimize water. The importance of poly (vinylidene fluoride) (PVDF) as a membrane material has long been recognized in many membrane processes. Compared to other types of polymer membranes, PVDF membranes have received great attention due to their outstanding properties including high hydrophobicity, thermal stability, chemical resistance and excellent mechanical strength. Recent developments in PVDF membrane processes, with a focus on commercial PVDF membrane products for water treatment where no substantial commercial PVDF membrane process is available so far (Ji et al., 2015).

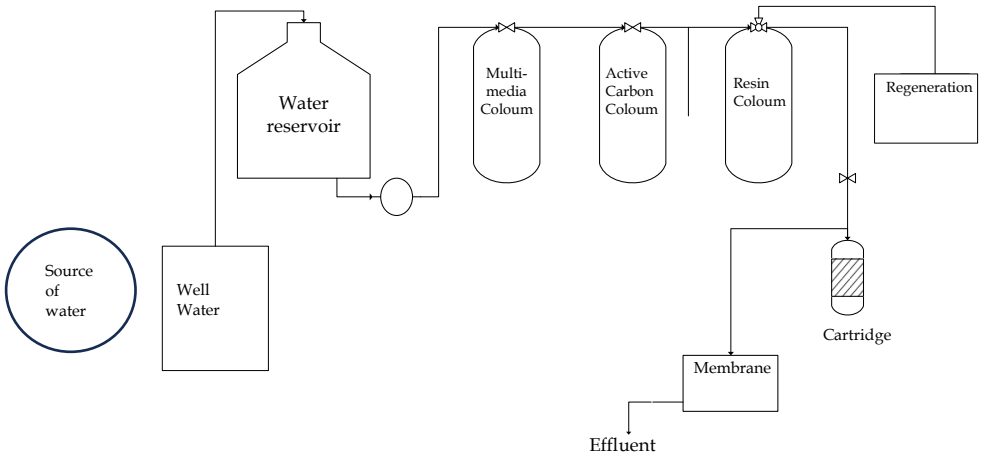

Figure 7.
MF Membrane Technology

Ultrafiltration membrane based on PVDF (Poly Vinylidene Flouride). From an economic point of view, the use of this tool can save 50% of costs compared to purchasing 600 ml bottled water (BPS, 2022; Daniel et al., 2020; Dickin et al., 2021; Jonsa & Suharmi, 2018; Le & Nunes, 2016; Muhari et al., 2018; Rusmaya et al., 2021; Sianipar et al., 2013; Soula et al., 2021; Sugiyono & Dewancker, 2020). These results indicate that the new HSPVDF membrane filtration can significantly reduce suspended solids, turbidity, and COD in wastewater effluents. In particular, pathogenic microorganisms can be completely removed from the effluent. Moreover, it can be a simple and sustainable approach to reduce overall costs, footprints, and disinfection demands during tertiary care (Ayyaru & Ahn, 2022).

To reduce the possibility of contamination, Microfiltration/Ultrafiltration (MF/UF) can be very effective in removing bacteria and/or act as a pre-treatment prior to Nanofiltration/Reverse Osmosis (NF/RO). However, NF/RO systems require pre-treatment of influents, increased power supply, and a high level of technical expertise. As such, they are often very expensive additions to developing countries (Barlokova et al., 2020; Ezugbe & Rathilal, 2020; Hoslett et al., 2018; Ji et al., 2015; Lu et al., 2022; Milescu et al., 2019). Treatment of water from mechanically or biologically polluted surface water sources, pretreatment before the next water treatment technology step is one of the typical applications where UF is used technology. (Barlokova et al., 2020; Ezugbe & Rathilal, 2020; Hoslett et al., 2018; Ji et al., 2015; Lu et al., 2022; Milescu et al., 2019) has proven to be a more profitable option in the wastewater treatment process in recent times.

Community Attitudes

The socio-economic characteristics of the community, especially the respondents, are very important in the process of understanding the actual conditions socially, economically, and the problems experienced by them. The urgency of the socio-economic background of the community is to understand and obtain their socio-economic profile including age, type of work, active organization,

problems and water needs, ways of handling to obtain water and etc. As for the percentage of socio-economic characteristics of the community in Nganti Village is shown in Table 3.

Table 3. Socio-Economic Characteristics of the Community in Nganti Village

	Socio-Economic Characteristics	Frequency	Percentage (%)
	Occupation		
1.	Civil servant, police, and military	09	22.50
2.	Farmer	22	55.00
3.	Trader	05	12.50
4.	Other occupation	04	10.00
	Total	40	100.0
	Family size		
1.	spouse (husband or wife) only	09	22.50
2.	both husband and wife	06	15.00
3.	husband, wife, and a family member	05	12.50
4.	husband, wife, and two family members	10	25.00
5.	husband, wife, and three family members	06	15.00
6.	husband, wife, and four family members	04	10.00
	Total	40	100.0
	Active in groups, organizations and others		
1.	*Tahlil* (Islamic recitals) & farmers group	32	80.00
2.	Apparatus	06	15.00
3.	Etc.	02	5.000
	Total	40	100.0

Table 3 shows that the percentage of respondents' occupation was dominated by farmers at 55%, meaning that this is in accordance with the potential of the village regarding the area of agricultural land of around 70%. Moreover, farmers urgently need water for rice plants. If rice is unable to be planted due to limited water sources during the dry season, alternative commodities are secondary crops (soybeans or corn). Based on the data of family size, respondents with 1 to 3 family members (50%), and the number of families with more than 3 family members (50%) show a balanced percentage regarding the number of family members. Nevertheless, they still need water, but the difference is that if there are more family members, then the need for water is also greater. In addition, the majority of the respondents are active in farmer groups (poktan), and the Yasin tahlil congregation is 80%. This indicates that the Yasin and tahlil groups are very effective in communicating and sharing various information regarding activities and problems related to work (farmers) or family problems. Regarding the characteristics of water sources and their management or utilization, it can be seen in Table 4.

Table 4. Characteristics of Water Sources and Management/Usage

No.	Indicator	Frequency	%
1	Water quality (household wells) in terms of color, smell, and taste		
	a. colorless, odorless and good	13	32.5
	b. slightly clear, yellowish, slightly smelly, moderate	11	27.5
	c. yellowish, smelly, ugly (not drinkable)	16	40.0

No.	Indicator	Frequency	%
2	Existing water conditions and quality		
	a. Good	13	32.5
	b. Adequate	11	27.5
	c. Bad (not good)	16	40.0
3	Average clean water used for household purposes every day (bathing, washing, toilet facilities) non-drinking and cooking		
	a. 100-200 lt/day	15	37.5
	b. 300-400 lt/day	15	37.5
	c. more than 400 lt/day	10	25.0
4	Use of water sources (wells)		
	a. Bath, Cook, Wash, Toilet, Others	24	60.0
	b. Bath, Wash, Cook, Drink, and more	16	40.0
5	Source (origin) of drinking water needs		
	a. Gallon, Refill, Bottled Water	29	72.5
	b. Wells, Mining Water	11	27.5
6	Use of well water outside the household		
	a. Livestock, farming, other refill business	21	52.5
	b. None	19	47.5

Table 4 shows that about 70% of household well water sources and poor quality. This indicates that the general problem in the village community is related to the low quality of drinking water; therefore, about 70% of the community buys refill water, or gallons and bottled drinking water. This is because approximately 60% of the community only uses the well for bathing and washing. However, around 52,5% of the people use well water for agriculture, animal husbandry, the gallon water business, and watering plants in their yards. In addition to the frequency of respondents, in this case, the community who fulfil their daily water consumption (Table 4), water problems in Nganti Village were also assessed based on the constraints they cause, both in terms of the environment and health, as outlined in Table 5 below.

Table 5. Types of Management Tools and Constraints

No.	Indicator	Frequency	%
1.	Equipment to obtain water from household wells		
	a. Electric water pump	37	92.5
	b. Manual with dipper	03	7.50
2.	Public opinion about the availability of a tool to process drinking water		
	a. Agree	38	95.0
	b. Neutral (depending on the situation)	02	5.00
3.	Community knowledge of ultrafiltration membrane technology to filter water for consumption		
	a. Not Known	38	95.0
	b. Known	02	5.00

No.	Indicator	Frequency	%
4.	Application of drinking water treatment equipment with ultrafiltration membrane technology in Nganti Village		
	a. Agree	40	100
	b. Disagree	00	0.00
5.	Obstacles in meeting the need for clean water?		
	a. There are obstacles (water runs out/less when dry, great distance)	27	67.5
	b. No problem	13	32.5
6.	Adequate amount of clean water for household needs in the dry season		
	a. Enough	09	22.5
	b. Not enough (less)	31	77.5
7.	History of illness in family members may be caused by lack of availability of clean water, for example kidney stones?		
	a. No	35	87.5
	b. Yes	05	12.5
8.	Solutions to overcome obstacles in obtaining and managing water		
	a. Use of tool	31	77.5
	b. Local water company available, water delivery, efficient usage	07	17.5
	c. Unknown	02	5.00

Table 5 shows that more than 90% of the people have used well water pumping machines in their households, except during the dry season, as water is not available in the household wells. Furthermore, 100% of the people agreed to procure tools to filter water sources and improve their quality. Considering that most (77.5%) of the community lack or have insufficient water sources during the dry season. Therefore, it is necessary to have equipment that is able to filter water and as a solution to overcome obstacles in obtaining clean water.

Based on the results of the research regarding the mapping of potential and problems of water sources and water quality, it can be seen that, in general, the Nganti village community has problems obtaining water sources during the dry season, and the quality of the water is poor. According to research findings, the lack of water sources causes difficulties for people to access drinking water, and this leads to difficulties for socioeconomic development to proceed. This is primarily because of the climate, but it is also a result of topographical conditions and poor management of water resources (Soula et al., 2021).

Water shortages are not only affected by consumption aspects but also health aspects, which is in accordance with previous results that have stated that water scarcity, which includes water availability and water quality, is an important indicator of health. Apart from drinking, water supply is closely linked to food security, sanitation and hygiene, which are major contributors to the global disease burden. The poor and disadvantaged populations are those who will suffer the most

from the negative impacts of climate change on water supply and associated human health problems (DeNicola et al., 2015). The effect of this water shortage is one of the consequences of climate change. This is in line with the results of previous studies, which explain that the long-term effects of climate change on the water quality of different water bodies are discussed, and changes in climate factors affect water quality directly and indirectly by affecting sources, migration and transformation, biochemical reactions, and ecological effects of pollutants (Xia et al., 2015). The direct and indirect impacts of climate change on water quality include biological, physical, and chemical changes. Biological changes include pathogenic microbial pollutants in freshwater systems. Physical changes include increased water temperature, more stable vertical stratification and reduced mixing of deep-water lake water, as well as changes in water flow. Chemical changes include increased nutrient concentrations, water colour and decreased oxygen content (Mujere & Moyce, 2016).

As a result, the impact of water shortages is not only on the Nganti community, but also on the company. The company has adapted their infrastructure into the Sponge Cities model, which contributes to better resource administration by absorbing water from rain, promoting natural filtration by the soil and minimizing wastewater; however, it is still challenging to optimize water use in some parts of their process (Adrielly Nahomee et al., 2021; Binh et al., 2022; Fletcher, 2019; Mujere & Moyce, 2016; Saikia et al., 2022; Salehi, 2022; Zikargae et al., 2022). It also impacts the agricultural and nature sectors; one watershed supplying water to urban areas does not meet the demand during the dry season, and another is degraded and has reduced ability to provide ecosystem services. The methods chosen to address the problem of water shortage, even though they are valid, are insufficient, apart from demanding major engineering interventions in the natural environment, and do not guarantee water security without effective land use policies for the watershed. It is therefore imperative to identify potential hazards resulting from alternative water supply and distribution practices in order to develop temporary and long-term monitoring and mitigation plans and reduce microbial as well as chemical contamination of drinking water delivered to consumers (Salehi, 2022).

Community Empowerment Process and Technology Readiness

Community empowerment processes and strategies in meeting water needs or dealing with water problems are certainly not individual or family problems but are related to common problems (starting from individuals, families, groups, Village Government and until the Central Government). The problems of water scarcity and dry water sources in Nganti Village risk hindering the community's ability to fulfil their daily water needs for bathing, washing and toileting. Some of the water problems in the village are related to many other needs, including the need for a water supply in agricultural cultivation, so that water scarcity risks crop failure. Some of the water scarcity problems experienced by individuals, village community groups, and NGOs in Nganti Village are outlined in Table 6 below.

The ability to identify problems correctly or not cannot be separated from the processes and strategies used by different stakeholders to address issues at every level. According to the survey results of 40 respondents, 30% of them claimed to have no issues with their water sources, but when the homes were check, the color and smell were yellow and unpleasant. The findings of this study can be helpful to the residents of Nganti Village, the village government, the city government of

Bojonegoro, and other related stakeholders. If every stakeholder can work together to find clean, healthy, and sustainable drinking water sources, Bojonegoro (MATOH) can be accomplished.

Table 6. Community Empowerment Process and Strategies at Multiple Community Levels

	Empowerment Process	Individual/Family Strategy	Group Strategy/Village to Central Government	NGO, Universities/ Private Educational Institutions /Company (CSR) or others
1.	Identification of Problems	- The family well is yellow - Cannot cultivate during dry season - Less well water sources during dry season	- Artesian water sources (deep wells) are not optimal - The use of the reservoir is not working - The use of the water reservoir has not started	- Mapping of potential and problems in the village is not clear - Limited time, cost and manpower - Partial program, not integrated
2.	Planning and Organizing	- Use of reservoirs in each house - Use of portable water filter technology - Selection of alternative agricultural crops during the dry season (polowijo)	- Road map (blue print) of the village government to address various problems, especially water needs in a sustainable manner - The village government needs collaboration and synergy with all parties in optimizing artesian water sources or water reservoirs	- External agencies are required to coordinate with the Village Government (adjusted to the needs of the community) - Communicate openly what contribution will be made
3.	Implementation	- training and coordination with Neighborhood Association, Urban Village and other agencies in the application of wireless	- Commitment of leaders (village officials in implementing the road map) - Opening opportunities in collaboration	- Coordination and communication with all stakeholders - Provide training, technology or

Empowerment Process	Individual/Family Strategy	Group Strategy/Village to Central Government	NGO, Universities/ Private Educational Institutions /Company (CSR) or others
	filters or other technologies - optimizing farmer groups or Farmer Groups Association and coordinating with related agencies	with anyone to overcome water source problems	others according to community needs
4. Monitoring and Evaluation	- stimulant funds or capital assistance or soft loans are needed (without interest from individuals or institutions) - Families or community individuals need to increase their knowledge, skills and networks	- Institutional strengthening in overcoming various problems in an integrated manner - Minimizing individual and group interests in sustainable village development efforts	- Maintain good communication and cooperation - Gradual recording and delivery of programs to the community and village government

This suggests that each person or household head (respondent) is unaware that their water still has issues and is unsafe to drink. So far, there has been no innovation in the form of new technology to overcome the problem of scarcity of clean water sources among the Nganti Village community. Therefore, there needs to be an integrated effort between several parties to overcome the water problems in Nganti Village. Figure 8 depicts the connections at each level (individual to village government).

Figure 8 shows that in overcoming various problems, especially water needs, whether they are individual, group/community or village government, until the centre, and with the existence of NGOs, State or Private Universities and companies, synergy, communication, and collaboration are needed in building a sustainable social system. Each party (family to government) has a priority scale of problems and solutions that can work together in an integrated or partial way (according to the needs of each level).

In addition, the results demonstrate that the village government's efforts to provide support and facilities, as well as the Nganti Village community, were enthusiastic during the training, as evidenced by the active role of participants who implemented the membrane technology. There is a possibility for village government leaders, in cooperation with the Bojonegoro district government, to implement a strategy that facilitates self-mobilisation, creating awareness of the current situation and position. The empowerment process requires external stimuli to draw attention

to systemic injustices and inequalities (Akurugu et al., 2021; Ashifa, 2020; Dickin et al., 2021; Zikargae et al., 2022). The empowerment of membrane technology requires an instrumentalist-structuralist approach to ensure policy support, pedagogical approaches to build technical understanding through education, and interactionist approaches so that technology adoption takes place through social relations and co-constructed meanings. The three complement each other to encourage effective and sustainable adoption at the local level to solve the issue of water needs.

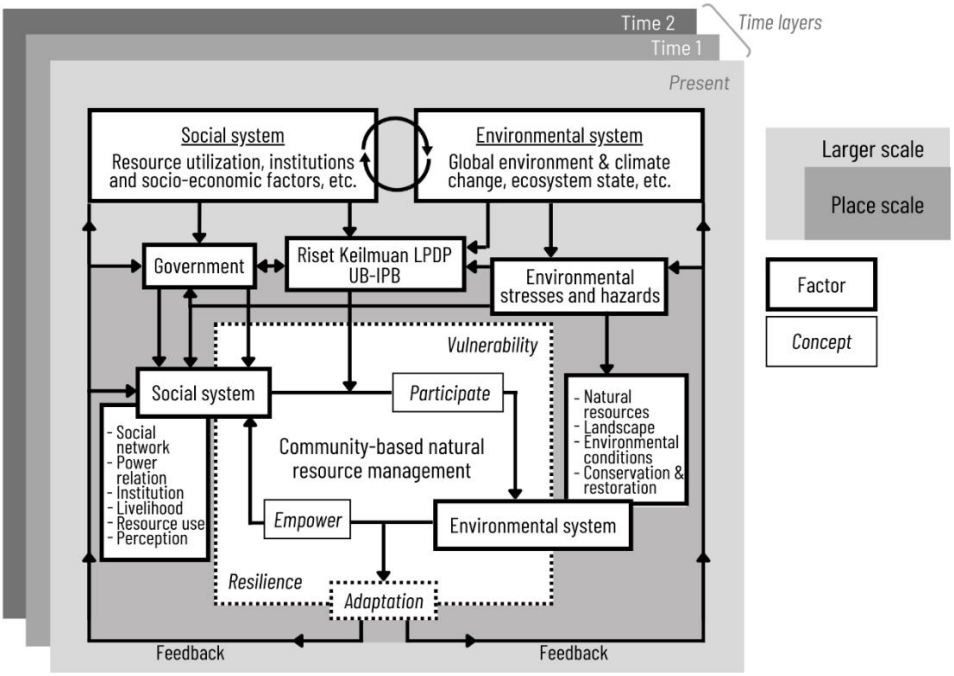

Figure 8.
Emporwement process and strategy, including the role of universities in providing and introducing membrane technology, adapted from (Lin, 2019)
Source: Researcher Documentation (2023)

The findings of this study support the findings of research by Berthold, Cologna, & Siegrist (2022) that people adopt more pro-environmental behaviours and become more open to new sustainable technologies when they believe that there will be fewer resources available in the future, being more concerned about resource scarcity. This study provides empirical support for assumptions regarding community empowerment strategies. Both individuals, families, and the environment need adaptation and innovation in various things.

Sustainable management of water resources is needed to avoid widespread water scarcity. As prolonged droughts impact these key water resources, resistance to resource collapse is shown to be low, and feedback is lost between water resources and communities. The collapse of water resources ("Day Zero") can be prevented through a combination of government-led and community-led actions that incorporate forms of water resource management. (Gittins et al., 2021; Hasani et al., 2021; Hothi & Hothi, 2022; Katsanou & Karapanagioti, 2019; Orgill et al., 2013;

Pandey et al., 2014; Rahut et al., 2015; Satriani et al., 2022; Williams et al., 2015) In areas where droughts have occurred, or where they are anticipated, water availability is a major concern for local residents, organizational leaders, and government officials who fear socioeconomic hardship. Focal theory, construal level theory, was expanded by: (1) exploring the population's understanding of water vailability and climate change, and (2) assessing the impact of population proximity to environmental crises and drought conditions (Craig, 2019).

Empowerment strategies also require aspects of collaboration and synergy in the use of technology for both rural and urban communities in meeting water needs. So far, the community has not been aware of any technology that can overcome water problems in Nganti Village. So it is necessary to collaborate and synergise in the empowerment strategy by forming a Focus Group Discussion (FGD) attended by academics to introduce new technology to the Nganti Village community. In the FGD meeting, education and training were conducted related to the operation of water treatment equipment with membrane technology that functions to filter water so that it is suitable for consumption. Based on previous research, membrane technology is an alternative for desalination treatment or the process of reducing salt content in water (Adam et al., 2022; Ahmad et al., 2020; Barlokova et al., 2020; Ezugbe & Rathilal, 2020; Francis et al., 2016; Hoslett et al., 2018; Issaoui et al., 2022a; Ji et al., 2015; Katsanou & Karapanagioti, 2019; Lu et al., 2022; Milescu et al., 2019). In addition, membrane technology is able to filter the content of pollutants in wastewater, so that this technology is considered effective in treating and recycling wastewater.

Technically, membrane technology is considered one of the solutions to the problem of water scarcity in Nganti Village. The implementation of membrane technology in Nganti Village is known to be able to filter the availability of water from water sources in Pepe Hamlet and artesian water. If the water source in Pepe Hamlet is still experiencing drought, then the artesian water source becomes the community's solution in meeting water needs. In line with the results of research that artesian water benefits rural communities in developing countries, because artesian wells are a supply and flow freely with or without water pumps. The adoption of membrane technology innovation is known to be effective because of the efficient involvement of various actors, such as the local government, community, and academics. Thus, it is very easy to achieve the optimization of the diffusion of membrane technology innovations that are in accordance with the problems of the community in Nganti Village.

The implementation of this water treatment device is expected to help local villagers get clean water easily, safely, and at an affordable price. Given that small to medium-sized rural communities in developing countries often lack the financial resources to support technologically complex and expensive centralized public water treatment systems, the focus is on proven technologies that are sustainable and acceptable to rural populations (Thomas et al., 2022). This has forced many rural communities to embrace community management models in rural water systems. Community participation in rural water management is said to be a key element in making community water projects sustainable. As a result of community involvement in the sub-watershed, local communities now consistently have access to adequate water for household, agricultural, etc. (Waithaka et al., 2016).

Emphasis on empowerment strategies also lies in initiatives and participation from local communities, as well as those outside the village community. One example of previous research is a water restoration initiative that has been planned and implemented on a large scale. Initiatives are also being taken to improve water quality, which is one of the main concerns among residents (Gittins et al., 2021; Hasani et al., 2021; Hothi & Hothi, 2022; Katsanou & Karapanagioti, 2019; Orgill et al., 2013; Pandey et al., 2014; Rahut et al., 2015; Satriani et al., 2022; Williams et al., 2015). In addition, participation in workshops and focus group discussions designed to increase our understanding of the environmental factors that affect health may be most promising to address based on local priorities and circumstances. The participants identified ways to support communities in identifying and implementing solutions to their environmental problems, which could be useful for community leaders to make future changes to address these problems. Science and technology, as well as efforts to reduce poverty and address economic difficulties, are crucial elements of any solution to the most pressing issues facing rural areas. Higher education institutions have also joined this initiative at the same time (Akurugu et al., 2021; Ashifa, 2020; Dickin et al., 2021; Zikargae et al., 2022).

A sustainable empowerment process can be implemented by integrating the roles and participation of various parties to overcome the problem of water scarcity in Nganti Village. In addition, supporting tools or technology are also needed so that empowerment can be sustainable. In this case, membrane technology is an alternative solution and is introduced to the Nganti Village community to at least have the facilities to filter water so that it is suitable for consumption.

CONCLUSION

Potential water sources in Nganti Village include shallow water for family use, deep water for agricultural or animal use, and water sources in the form of reservoirs (artesian). However, all of these water sources often have problems that can only be used for bathing and are not suitable for drinking or cooking. Water reservoirs in Nganti Village can only be used during the dry season, and even then, are limited to those around the reservoir. Meanwhile, deep water sources cannot be used for anything because of the high content of iron and other metals.

Despite a number of issues and potential problems, the Nganti village government has made an effort to provide clean water. For instance, water reservoir assistance from the Bojonegoro Public Works has been received. Still, it is constrained by the installation of electricity and water pipelines, resulting in its inability to function as intended. The village water community has also attempted to use artesian water sources (deep water), but this has not yet been successful. On the other hand, household water source (shallow water) has only been used for bathing, while purchasing bottled water (Packaged Drinking Water) is needed for cooking and drinking.

Presenting membrane technology that can filter chemicals, such as iron or other metal content (Zn, Detergents, and others) is a breakthrough in the attempt to use deep water (artesian). The membrane technology uses the MF type with UF support, which has the advantage of filtering water from low-pressure iron (Fe) contamination. This MF/UF membrane technology is possible to be implemented by the Nganti Village community because the price is affordable rather than having to

buy bottled water. The water sources filtered in this technology are pepe water sources and atesis water sources. The City of Bojonegoro and other stakeholders are anticipating that it will be successful and on a small scale, and if it is, they will develop membrane technology widely and with greater capacity. Membrane technology has the potential to be developed into a viable source for bath and wash toilets.

Based on the potential of membrane technology in accordance with the needs of the community, the local government provides institutional support in the form of the formation of a potable water awareness group. This institution is expected to be able to process a variety of potential natural resources, especially water sources (shallow water sources, reservoirs, and deep water/artesian. However, limitations are an important finding in this study because they allow them to carry out various adaptation processes and strategies, especially efforts to realize membrane technology.

Short-term recommendations for water treatment in Nganti Village using a community-managed MF/UF membrane filtration system specifically targeting iron and metal contamination in deep artesian water sources. This intervention is structured as a small-scale pilot project with robust documentation of performance metrics, cost-effectiveness and social impact. Simultaneously, the establishment of village water management committees strengthens local governance structures while providing technical capacity building for community members in the operation and maintenance of the system, thus ensuring sustainability and reducing dependency on external support. Further, a long-term recommendation could be to develop an integrated water resources management plan that incorporates all available water sources (shallow wells, reservoirs and deep water) within a climate change-resilient framework. Strategic public-private partnerships should support this to secure funding for infrastructure development and technology scaling, complemented by research collaborations with academic institutions to continuously refine filtration technologies. Successful implementation would position Nganti Village as a model for rural water management in regions facing similar contamination challenges, potentially influencing regional water policy development and resource allocation.

AUTHOR CONTRIBUTION STATEMENT

[Author 1]: research ideas design, data collection and analysis, manuscript writing, and responded to reviewer comments; [Author 2]: financial supported, literature reviewed, data collection and analysis, initial manuscript draft and edited; [Author 3]: provided suggestions and edited the manuscript; [Author 4]: reviewed the draft manuscripts, data analysis, and edited the manuscript. All authors have read and approved the final version of the manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ETHIC STATEMENT

Ethical review and approval were waived for this study because it did not involve any intervention and posed minimal risk to the participants; however, informed consent was obtained from all respondents prior to their participation, and all data were anonymized and treated with strict confidentiality in accordance with established academic research ethics.

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