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Prevalence and correlation between waterborne diseases to household soak pits: a case study

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Abstract

India produces 72.4 billion litres of wastewater daily across all states and suffers from inadequate wastewater treatment, particularly in rural areas, leading to environmental pollution and several health issues. The study conducted a comprehensive examination of a traditional wastewater treatment method, known as a soak pit. Study examines the effects of inadequately managed soak pits on the groundwater system and, subsequently, on human health risk. The wastewater characteristics in the Jabalpur area of Madhya Pradesh were studied in 80 households. The analysed sample indicates that turbidity ranged from 4 to 10.4. The pH values ranged from 6.81 to 7.68, indicating predominantly neutral conditions. TDS concentration ranged from 315 to 938 mg/L, while total hardness ranged from 204 to 414 mg/L NTU. Also, alkalinity ranged from 232 to 327 mg/L, with calcium levels from 30.4 to 110.4 mg/L and magnesium from 16.8 to 37.44 mg/L, exhibiting moderate variability. Heavy metals were found as fluoride (0.12 to 0.27 mg/L) and iron (0.2 to 0.4 mg/L), present at low concentrations, with no detectable nitrates or manganese. Total coliforms were detected in 6 of 10 samples, while EC ranged from 469 to 1110 µS/cm. The manuscript succinctly presents the implementation of a structured questionnaire survey to assess household-level sanitation systems and their implications on groundwater quality and human health. The soak pit system was designed and constructed without consideration of soil conditions, a crucial factor in assessing its technical suitability and durability over time. Those systems without septic tanks pollute groundwater, with no monitoring measures available, posing a threat to livelihoods.

Keywords: Forest dwellers, rehabilitation, relocation, tiger reserves, livelihood security, protected areas, binomial logistic regression, Garrett ranking

Introduction

The amount of wastewater treated worldwide is about 52%, while treatment rates vary significantly across high-income (74%), upper-middle-income (43%), lower-middle-income (26%), and low-income (4.3%) countries (Jones *et al.*, 2021) [15]. The Central Pollution Control Board's latest annual report indicates that India produced 72,368 million litres per day (MLD) of wastewater daily across all states (CPSB, 2024), with a treatment capacity of around 20,236 MLD (Gupta & Gupta, 2025) [12]. Although India faces considerable challenges in managing the volume of wastewater produced by its population, some initiatives to enhance access to sanitation and hygiene have been substantially intensified in recent decades (Mukerjee, 2017) [21]. The Swachh Bharat Abhiyan initiative, meaning Clean India, launched in 2014, seeks to eradicate open defecation by constructing over 100 million toilets nationwide (Biswas *et al.*, 2024) [7]. In 2022, only 75 per cent of rural Indian households had access to basic sanitation, according to the WHO and UNICEF's Joint Monitoring Program (Bose & Dutta, 2024) [9]. Rural communities are also facing many challenges related to wastewater mismanagement and changing lifestyles, underscoring the need for wastewater treatment. In today's time, wastewater management is of utmost importance as all sources of residential wastewater, including toilet wastewater, are becoming increasingly significant,

particularly in developing nations where inappropriate wastewater management is one of the most serious problems, which causes pollution, catastrophic diseases and has a harmful effect on the environment (Boano *et al.*, 2020) [8]. In developing countries, consumption of low-quality water causes health problems, and many waterborne diseases pose significant health risks (Guzmán *et al.*, 2016). Since 1990, around 2.6 billion people have had access to drinking water, yet 666 million still lack access to good-quality water. India has 18 per cent of the world's population, yet its average river runoff is only 4 per cent.

Drought has affected almost 500 million people in India, with 20% of the population living in states that have not yet been declared open defecation-free (ODF). According to the World Health Organisation report, 2013, every year, 102,813 children die from severe diarrhoea around the world, with diarrhoea killing one out of every five children in India (Asthana, 1997) [5]. The world's second-most populous country, India, has 68.84 per cent of its population spread over 638,588 villages, which severely strains India's resource management due to its high population density. A concern yet to be addressed is wastewater management, an emerging challenge for the nation. Wastewater mainly consists of greywater (sludge-free wastewater from kitchens and bathrooms) and blackwater, as shown in Figure 1 (Rahmasary *et al.*, 2021) [24]. It contaminates the environment and becomes the root cause of many diseases.

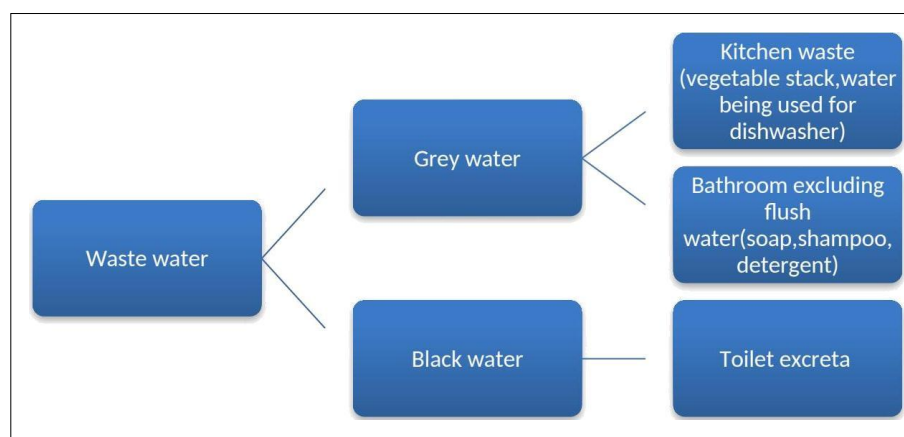


Fig 1: Wastewater classification

In most rural areas, wastewater has been separated from blackwater, knowingly or unknowingly. There is an urgent need for better, low-cost wastewater treatment technology. In rural areas, most greywater runoff flows into open areas/streets or is collected in a place or flows directly into waterbodies, which can be a key issue for waterborne diseases such as diarrhoea, malaria, typhoid, and gastroenteritis (Samudro & Mangkoedihardjo, 2010) [26]. Understanding that, if done correctly, wastewater reuse can offer significant potential as an alternative water source for irrigation, toilet flushing, and other uses.

1.1 Wastewater and SDGs

Following the Millennium Development Goals (MDGs), the United Nations (UN) adopted the Sustainable Development Goals (SDGs) in 2015. There are 17 goals and 169 targets in this set. The theme of Goal 6 is water and sanitation. In this, target 6.3 calls for attaining 50 per cent wastewater treatment by 2030. Under the same purpose, target 6.A. calls for enough resources to be provided to developing nations, as well as technologies for wastewater treatment, reuse, and recycling (Sadoff *et al.*, 2020) [25].

According to the literature, total liquid waste generation in rural India is around 40,000 million litres a day (MLD), of which 60%-80% is greywater (Shaikh & Ahammed, 2022) [27]. Greywater is kitchen and bathroom wastewater that does not contain faecal matter and consists of 60% to 70% readily degradable organic solids and 30% inorganic solids (World Health Organisation, 2006) [36], with nitrogen and phosphorus as the primary nutrients.

1.2 Impact of untreated wastewater on health & environment

Behaviourally, greywater is hazardous and a conduit for various diseases. Certain pathogens and vector-hosts thrive and survive in greywater, as ambient conditions are conducive to their growth (Cissé, 2019). In rural areas, greywater is rudimentarily managed and discarded in an open site, which causes vector-borne diseases, resulting in the deaths of 1 lakh people every year, as reported in the Census, 2011. Drinking water becomes contaminated by leaching of harmful chemicals and other pollutants from nearby greywater sources, leading to waterborne diseases (Anas *et al.*, 2021; Murphy *et al.*, 2014) [3, 23]. Major waterborne diseases include diarrhoea, cholera, typhoid, gastroenteritis, hepatitis A and E, malaria, and poliomyelitis. The severity can be seen in the fact that 1.5 million deaths are reported globally due to diarrhoea, according to the World Health

Organisation (WHO, 2003). In some countries, such as America, Australia, and Switzerland, studies have found that waterborne diseases are caused by microbes, including *Legionella*, *Cryptosporidium*, *Giardia intestinalis*, *Campylobacteriosis*, *Salmonella* species, *Listeria* species, and norovirus (Cissé, 2019).

Segregation of greywater and blackwater is traditionally done by rural people: blackwater is directly released into the septic tank, but greywater is discarded in the open. Hence, there is an utmost need to manage greywater using decentralised techniques. Sixty-three per cent of rural homes lack drains on their property, and 31% have open drains. Closed drainage systems are found in only 6% of residences. Drain cracks and leaks are common due to poor or incorrect construction. There is also a problem with the mismanagement of greywater technologies and leaks, which causes greywater and faecal matter to combine in drainage systems.

1.3 Wastewater management technology:

Out of the total wastewater generated, 50-80% is greywater, and the remaining is blackwater or a mix of both (Khatun & Amin, 2011) [16]. The composition of wastewater varies by geographical soil matrix and flow characteristics. Hazardous metals and chemical waste are likely to dominate wastewater at industrial sites, whereas detergents and synthetic cleaning agents are major contributors in urban and rural areas (Cissé, 2019). Organic garbage and fertilisers are more likely to be blamed for the contamination in wastewater. International organisations such as the World Health Organisation and India's Central Pollution Control Board (CPCB) advocate for strict safety regulations for the reuse of contaminated wastewater (World Health Organisation, 2006) [36]. Poor or absent liquid waste management in the villages has led to drain clogging; in some villages, black water is also discharged directly into drains. Most of the widely suggested urban remedies are infeasible and unlikely to be successful in the context of rural India; wastewater management in rural communities requires unique consideration (Khatun & Amin, 2011) [16]. Consequently, it is a critical problem that requires attention. As we can see in Figure 2, according to the report by UNU-INWEH in India, only 5-25% of wastewater is treated. To address this issue, wastewater treatment is essential for two primary reasons: first, to recycle and reuse wastewater to meet future human demand and alleviate water scarcity; second, to ensure compliance with wastewater discharge standards for environmental sustainability while minimising contamination of groundwater and soil.

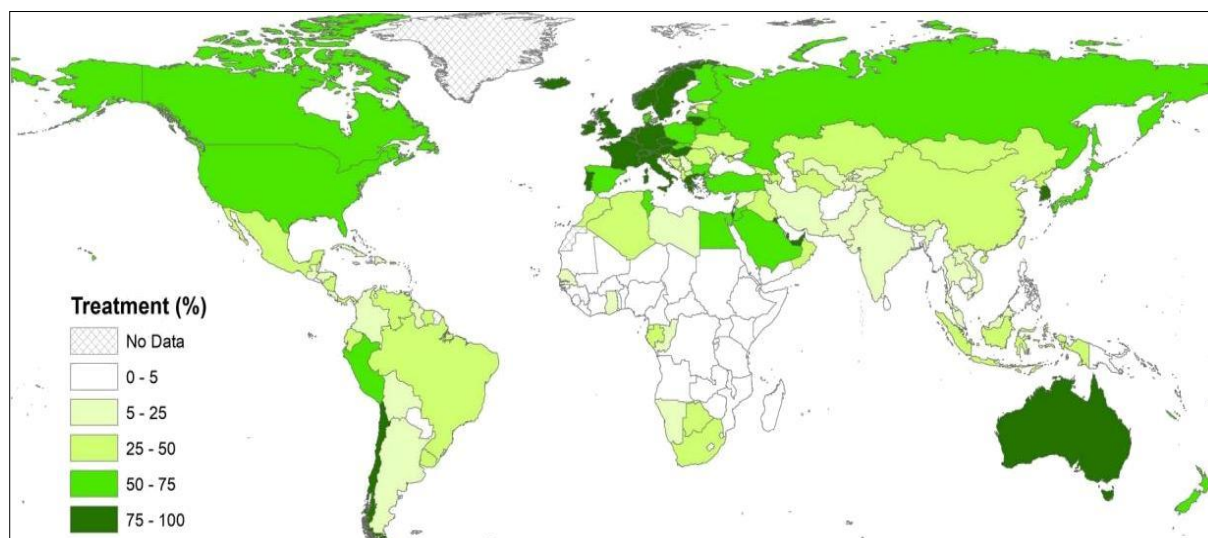


Fig 2: Worldwide wastewater treatment status (Source: UNU-INWEH)

Wastewater treatment and sanitation pose significant challenges in rural India due to inadequate access to proper facilities and infrastructure. Despite the government's initiation of substantial programs such as the Swachh Bharat Mission, open defecation and untreated wastewater disposal remain significant issues detrimental to both the environment and public health. Conventional wastewater treatment technologies, such as twin pits, leach pits, septic tanks with or without soak pits, have served as the principal solutions in central India for many years. Septic tanks are often used because of their inexpensive initial cost and few technical requirements. Nonetheless, their efficacy is considerably diminished by inadequate maintenance, insufficient desludging services, and a lack of proficient operators. Insufficient maintenance results in sludge accumulation, ultimately leading to overflow and pollution of adjacent land and water resources. In addition, septic tanks suffer from inefficiency stemming from inadequate management and prolonged retention durations necessary for efficient treatment (Jeje Julius Olatunji Kamar Taiwo Oladepo, 2013a) [14].

One of the challenges to a wider and faster adoption of effective wastewater management treatment systems is the lack of funding. Other challenges are a lack of expertise and experience in this subject, particularly in developing countries. Scientific understanding of wastewater properties and appropriate wastewater treatment methods for proper and safe disposal or reuse is also limited.

2. Literature review

2.1 Status of wastewater treatment and sanitation in rural India

Septic tanks, the predominant method of wastewater treatment in central India, provide fundamental primary treatment by facilitating the sedimentation and partial decomposition of particles. Nevertheless, several studies affirm that these systems are mostly insufficient for eliminating critical contaminants such as nutrients (nitrogen and phosphorus) and pathogens (Jeje Julius Olatunji Kamar Taiwo Oladepo, 2013a) [14]. Septic tanks are used in conjunction with soak pits and leach pits, which are the other two methods, respectively.

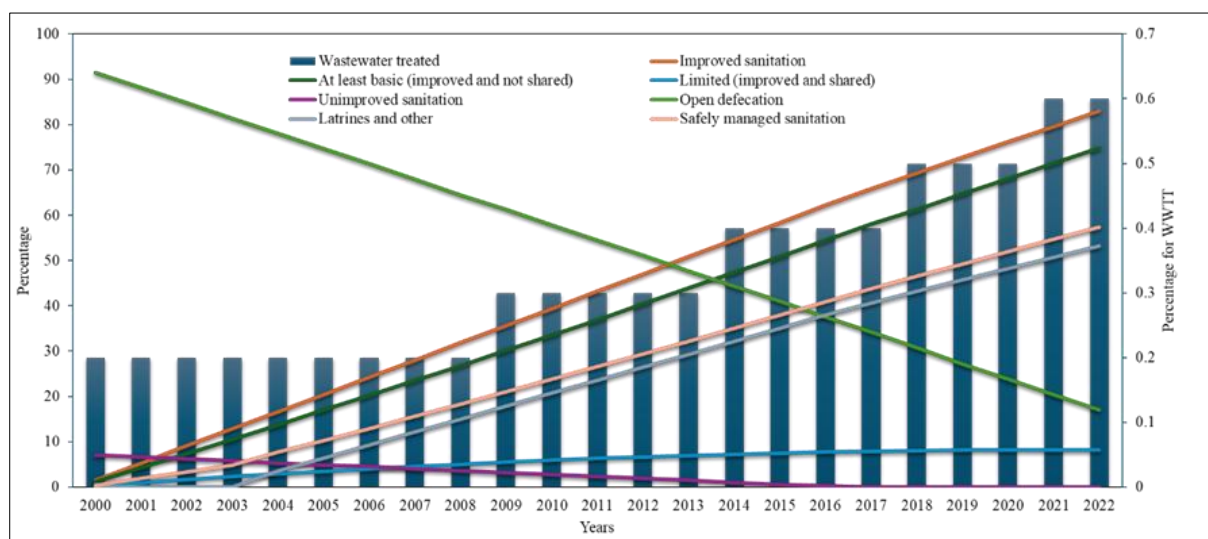


Fig 3: Sanitation data of rural India from 2000 to 2022 years (Source: JMP/WHO 2023)

2.2 Soak pit

An enclosed area with porous walls that allows water to gradually seep into the ground is called a soak pit or soakaway. It is also known as a soaker. As the name implies, soak pits are used to soak wastewater, but they do not work with all types of wastewater (Ghangrekar *et al.*, 2022) [37]. Generally, a soak pit is used in those semi-urban areas where the soil is unstable. In rural areas, no wastewater overflows because water infiltrates vertically and horizontally into the

ground (Akshitha *et al.*, 2023; Annan *et al.*, 2022) [38]. The soak pit, a small hole typically 1 m³ in size, should be at least 2 m above the groundwater table and 1.5 to 4 m deep. It needs to be placed in a secure location, far from any drinking water supply. With the help of soak pits, groundwater bodies can be replenished by partially treating greywater or stormwater from a primary treatment system (such as a septic tank, pour-flush toilets, twinpits, biogas settler, ABR, etc.) in a relatively safe manner (Gaikwad *et al.*, 2022).

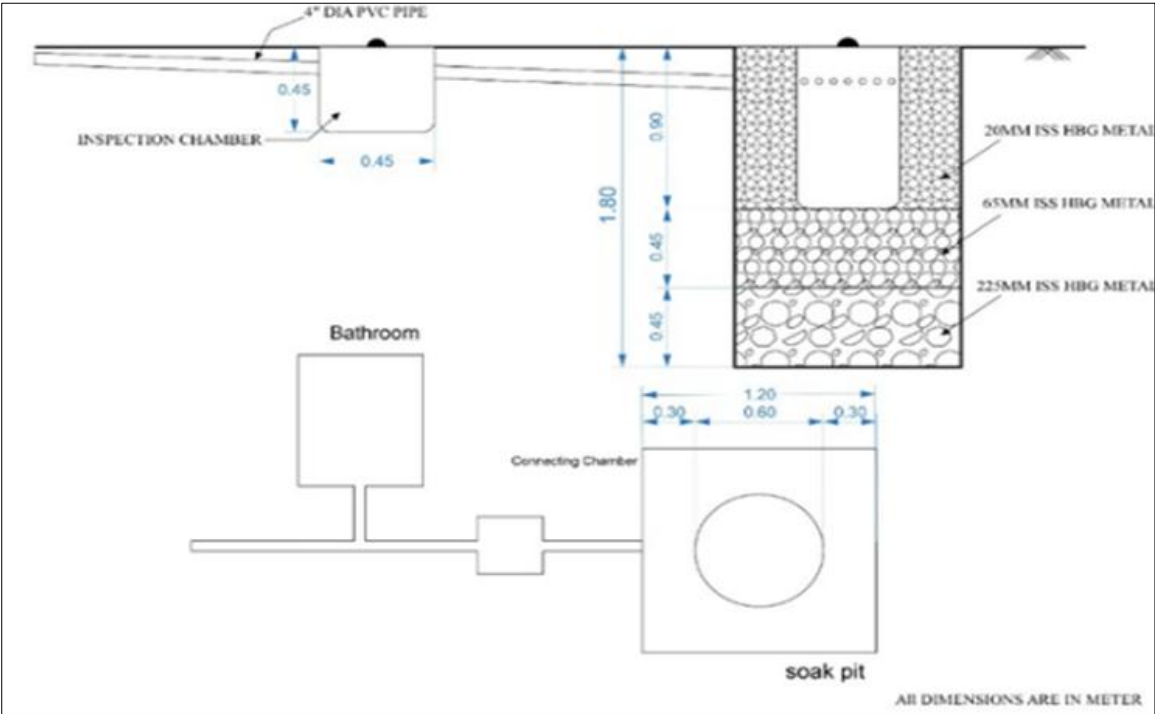


Fig 4: Household soak pit

Locally available materials such as bricks, used plastic drums, and wood can be used to construct the soak pit (Muppidi *et al.*, 2020a) [22]. The technology removes nitrogen and phosphorus, but not to the maximum level compared with other technologies. Also, failures in soak pits were found in most cases, attributed to insufficient maintenance and desludging methods. Inadequately maintained tanks overflow, resulting in direct unhygienic surroundings with groundwater pollution, a significant concern in water-scarce rural areas. The technology has greater adaptability, as it is

easy to construct and requires less operation and maintenance. Rural populations often lack understanding of the environmental and health dangers connected with poorly managed septic systems. This is one of the behavioural barriers that rural communities face. In a study conducted by Kumar and Verma (2021), it was found that educational initiatives aimed at increasing knowledge of sanitation practices increased the general acceptability and maintenance of these systems.

Table 1: Research done on the soak pit in India

S N	Region	Area	Maintanance	Sizes	Capacity	Cost	Material used	References
1.	Mewat (Haryana)	Black & grey water	15 days	1*1*1	270 ltrs/day/HH	-	pebbles, sand and brickbats has been used	(Mondal <i>et al.</i> , 2014) [20]
2.	Chikodi Taluka of Belgaum district, Karnataka	Rural	Periodic	1.5 x 1.2 x 1.5m (HH)1.5 x 1.5 x 1.5m (Institute)	500 (HH)2500 (Institute)		Draught Prone area	(Kulkarni <i>et al.</i> , 2020) [17]
3.	Pyarepur, Tehsil, Qaiser Ganj, Bahraich (Uttar Pradesh)	Domestic WW	Periodic	Septic tank- 10 mtsHouse drain soak pit - 04 mts	--		Due to seepage, infections occur during rainfall and flooding as E. coli is detected in every sample.	(Alam <i>et al.</i> , 2014) [2]

4.	Musunuru Mandal in Andhra Pradesh	Domestic WW	Periodic cleaning every 6 months	1.1.5m*3m*(dia*depth) of soak pit 2.3ft*5ft of drum	-	2000 rupees	Reused plastic drum 1. Plastic drum 2. Brickbats 2.5 ft, 3. sand layer 1.5 ft,	(Muppidi et al., 2020b) [22]
5.	Salwahan gram panchayat, Mandi, Himachal Pradesh	Domestic greywater	Periodic	1 x 1 x 1 metre	-	Around 2000 rupees	gravel, stone and boulders has been used	(Verma, 2020a) [31, 32]
6.	Bogmallo, South Goa, India	Domestic greywater	Requires recharge pits, monitoring	Septic tank: 5×2×2 m VFCW: 2×2×2 m; Disinfection tank: 1×2×2 m; Soak pit: 2 m depth	~1 m ³ wastewater/day	Relatively low-cost	Cement concrete walls, gravel (20–40 mm), sand (0–40 mm), aeration pipes, loose stones, plants	Suresh et al., Nature Environment & Pollution Technology (2023)
7.	Chaliyar River Basin, Kerala, India	Urban	Periodic	Basin area: 2,923 km ² (2,535 km ² in Kerala, 388 km ² in Tamil Nadu); River length: 190 km	Groundwater recharge declined 48.5% (2002–2022); Surface runoff increased 70%	High cost of urban expansion	Concrete, asphalt, interlocking pavers, buildings, roads	Areeparambil & Varghese, Environ Monit Assess (2026)
8.	Fiapre, Sunyani West District (Bono Region, Ghana)	Black & grey water	Periodic cleaning every 6 months	Household pit latrines: ~1–1.5 m diameter, depth 2–3 m	Average household size 4.8 persons	Around 2000 rupees	Lateritic clay and sandy-clay soils; pits often unlined; septic tanks lined with concrete	Journal of Water, Sanitation & Hygiene for Development (Vol 16 No 4, 2026)

2. Materials and Methods

2.1 Study area

Jabalpur is a district in the state that was chosen for the

research based on sanitation coverage criteria, with a Lat and long of 23.1670 and 79.9501, as shown in Figure 5.

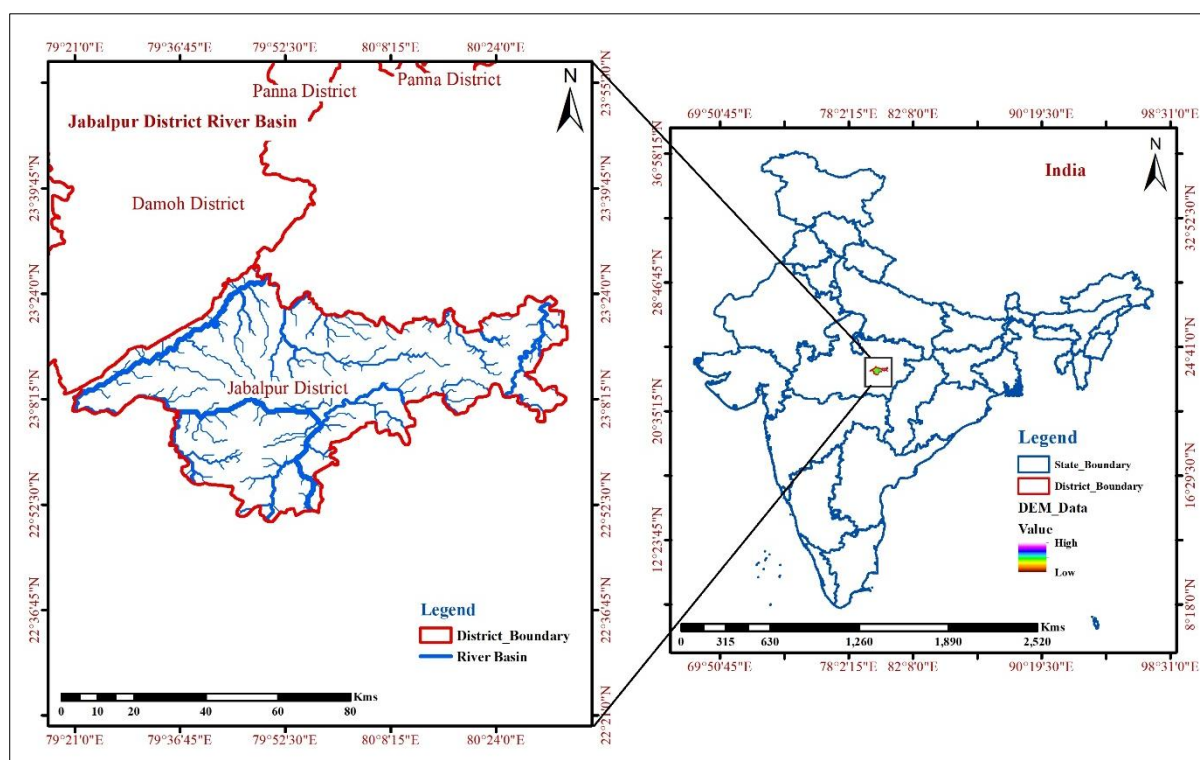


Fig 5: Map of study area

2.2 Data analysis

Villages in Madhya Pradesh (India) faced water scarcity and outbreaks of disease due to the mismanagement of wastewater (Gopi Karelia, 2017). Therefore, it can be

concluded that the proposed approach provides a readily implementable strategy to address water scarcity and improve external environmental conditions. The survey was conducted in 80 households using purposive sampling

methods in the rural area of Jabalpur. The survey was conducted into two parts: one focuses on the basic information of the respondent's family, such as the number of family members, income, education, occupation, Crop, Livestock, health institutional status, etc. and the other part

considered wastewater status and opinions of the respondents on soak pit problems. The first part involved administering the survey to households, and the second part involved collecting data on wastewater treatment technology.

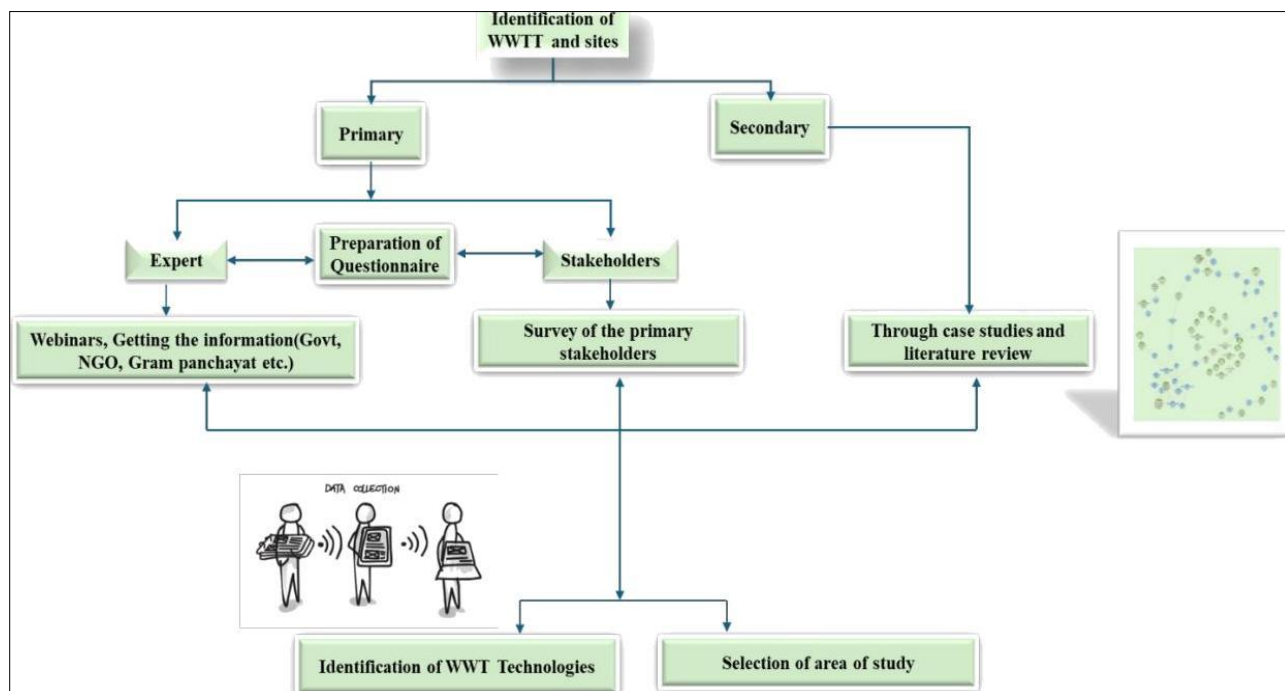


Fig 6: workflow diagram of the study area's wastewater treatment status

To conduct this study, the surveys were performed at the household level in the state's typical rural district, Jabalpur. The houses in the district were surveyed using a structured questionnaire tool and the purposive sampling technique. The

methodology is shown in Figure 6. For the household observation, the sampling strategy was organised concurrently.



Fig 7: Photographs of stakeholders during the surveying process

The respondents were selected based on their convenience and availability, and no inclusion criteria other than their status as villagers were used. Despite the homogeneity of the household types and livelihoods within this population, this method provides an overview of the risks associated with WASH practices in rural households. Five surveyor team members were enlisted in the research team. The survey team conducted household observations by visiting households for approximately 45 minutes, during which they discussed and observed sanitation, water-handling, and wastewater-treatment practices. The approach has been adapted from the ideas of a Joint Monitoring Programme (JMP), in which the WHO/UNICEF developed the questionnaire for water, sanitation, and hygiene. In this study, the questions were taken from the same and reframed/added after input from the locals. The purpose of the JMP is to monitor progress toward the Sustainable Development Goals. The study was conducted between February 2022 to July 2022. The primary focus of the questionnaire was the general household question, resources, locals' behaviour toward the technology, various aspects of the water treatment technology, and health. The information was validated and verified using available NARSS data, open-ended interviews with Jal Nigam staff, and discussions with other stakeholders, including NGOs actively working in these villages.

Results and Discussions

A socio-demographic study was conducted in Jabalpur, Madhya Pradesh, to profile key characteristics that influence sanitation behaviours. The study targeted a sample of 80 rural households, with 52% of respondent's male and 48% female. The average age of the respondents was 42 years, with a standard deviation of 14. The literacy rate was 68%, with males at 78% and females at 58%. Additionally, the study revealed a diverse respondent base: 35% from Scheduled Castes/Tribes, 42% from Other Backwards Classes, and 23% from the general category. Additionally, the distribution of occupations was dominated by agriculture (61%), with daily wage labour (29%), housing primarily consisting of kutchha/semi-pucca (54%), and household sizes averaging 5.2 members. So, if the soak pit has been tried and validated in the above-mentioned places, it can be inferred that it will be a promising technique for semi-urban areas. The soak pit can remove up to 90% of BOD in water (Verma, 2020b) [31, 32]. Enormous and diverse anthropogenic activities rapidly contribute to groundwater contamination across sectors of agriculture, urbanisation, and industry (UNEP, 2003). These findings collectively contextualise the sanitation status findings discussed below.

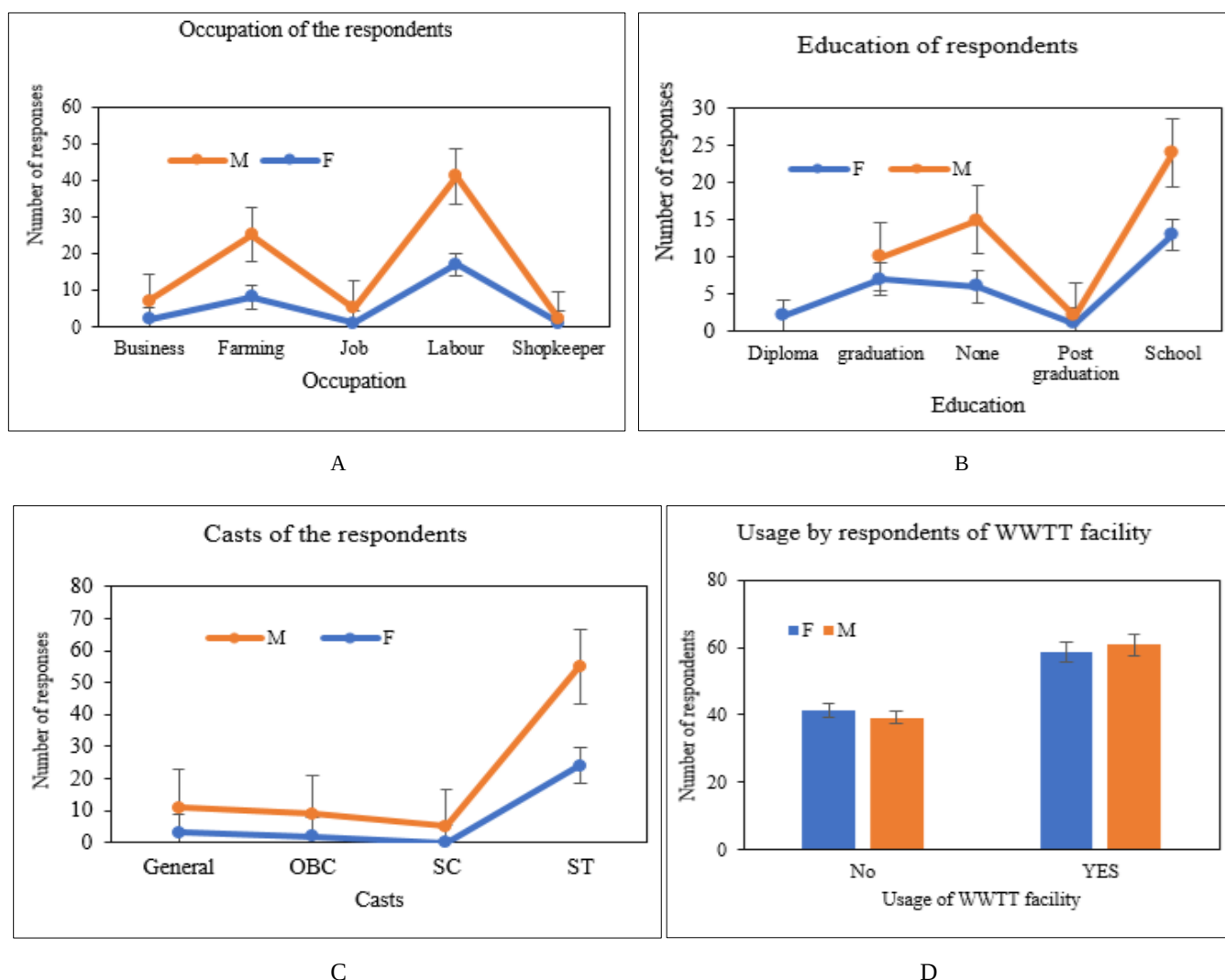


Fig 8: General data of respondents

Impact of soak pit system on water quality:

Inappropriate disposal practices can pollute the soak pit, so there is a need to monitor the source to identify the cause of groundwater pollution (Banerjee, 2011)^[6]. Artificial neural network and genetic programming's are the real time monitoring efficiency tool (Sharma *et al.*, 2018)^[28] according to the model which was in soak pit GP comes out the better promising tool than the ANN it helps in live tracking of effluent comes from soak pit, for comparison of modelling system chemical characteristics of soak pits were taken as pH, TS, TDS, TSS removal efficiency (Sharma *et al.*, 2018)^[28]. Most residences utilise open drains for grey water treatment; however, these can be connected directly to the soak pit for grey water removal, preventing contamination of both surface and groundwater. The soak pit should be away from trees, as their roots could break it (Uddin *et al.*, 2014)

^[30]. The water quality data from ten samples collected from nearby water samples from soak pits reveals that the turbidity ranges from 4 to 10.4 NTU, the pH ranges from 6.81 to 7.68 (mostly neutral), the total dissolved solids (TDS) ranges from 315 to 938 mg/L, the total hardness ranges from 204 to 414 mg/L CaCO₃^[2] and the alkalinity ranges from 232 to 327 mg/L, the calcium ranges from 30.4 to 110.4 mg/L, the magnesium ranges from 16.8 to 37.44 mg/L, and the total hardness ranges from 204 to 414 mg/L CaCO₃^[2]; there are no nitrates or manganese present; total coliform is present in six of the ten samples, the salinity/COD ranges from 0 to 1110 µS/cm, and the electrical conductivity ranges from 469 to 1110 µS/cm. This shows that mismanagement of the soak pits is contaminating the groundwater and is impacting human health.

Table 2: Water testing results of the nearby water sources from the soak pit

SN	Turbidity (NTU)	pH	TDS	Total hardness caco3	calcium	Magnesium	Alkalinity	Fluoride	Iron	Nitrate	Manganese	Total coliform (CFU)	Salinity	COD (mg/l)	EC (us/cm)
1	4.2	7.55	610	300	91.2	17.28	260	0.13	0.4	nil	nil	Absent	Nil	Nil	Nil
2	10.3	7.06	938	414	110.4	33.12	292	0.27	0.2	nil	nil	Present	Nil	Nil	Nil
3	4	7.55	488	304	82.4	23.52	232	0.16	0.3	nil	nil	Present	Nil	Nil	Nil
4	4.6	7.68	671	232	30.4	37.44	268	0.17	0.2	nil	nil	Present	Nil	Nil	Nil
5	7.5	7.21	315	213	56.6	22.6	234	0.12	0.2	nil	nil	Absent	220	6.8	469
6	6.7	6.85	369	204	76.8	16.8	257	0.18	0.2	nil	nil	Present	280	7.4	589
7	8.5	6.91	464	308	54.7	26.7	278	0.12	0.4	nil	nil	Present	340	5.3	691
8	8	6.81	747	303	49.6	24.8	308	0.14	0.3	nil	nil	Absent	560	5.6	1110
9	7	7.09	433	225	43.8	30.1	327	0.2	0.3	nil	nil	Absent	320	7.9	667
10	10.4	6.94	454	256	43.8	32.56	276	0.16	0.4	nil	nil	Present	340	8	709

It has been found that in rural areas of Jabalpur, 36% of soak pits had septic tanks, while the others had kachha pits, which could contaminate groundwater and nearby water sources. It can pose a key threat to groundwater and surface water quality if a soak pit or soakaway system is poorly designed on-site. A study conducted in Jabalpur briefly describes the impact of the soak pit on ground and surface water quality. Only 36% of rural households had septic tanks with soak pits, as shown in Figure 5, which could have severe effects on human and environmental health.

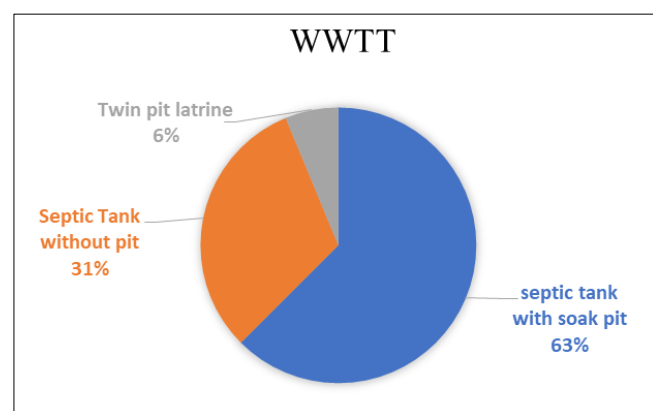


Fig 9: Soak pit availability

Following the examination of waterborne illnesses shown in Figure 9, it has been determined that the regions are also susceptible to these diseases. The infections may arise from various situations; however, in this investigation, the septic tanks were identified as lacking soak pits, leading to wastewater being discharged directly into the ponds or the river. Soak pits can help reduce diseases (malaria, diarrhoea, and other water-borne diseases) when built properly, which

are caused by unhygienic sanitation, stagnant water, or the lack of primary filtration (Ahrens, 2005; Mitchell *et al.*, 2016)^[1, 19]. The design of soak pit vary according to the conditions of soil, input of wastewater, type of wastewater as for grey water only soak pit can work efficiently if it is built according to the soil and wastewater; for black water septic tank and soak pit built together and for flat plateau magic pit (Pit having porous walls that allow water to percolate slowly into ground water) can aid in the treatment of wastewater prior to its final disposal. Soak pits function as barriers between pollutants and groundwater, enhancing the environment and mitigating disease. But in some cases, it creates a huge fuss by contaminating groundwater (Jeje Julius Olatunji Kamar Taiwo Oladepo, 2013b)^[14]. The soak pit is contaminating uncontrolled solid waste dumping sites (Vijay *et al.*, 2011)^[33].

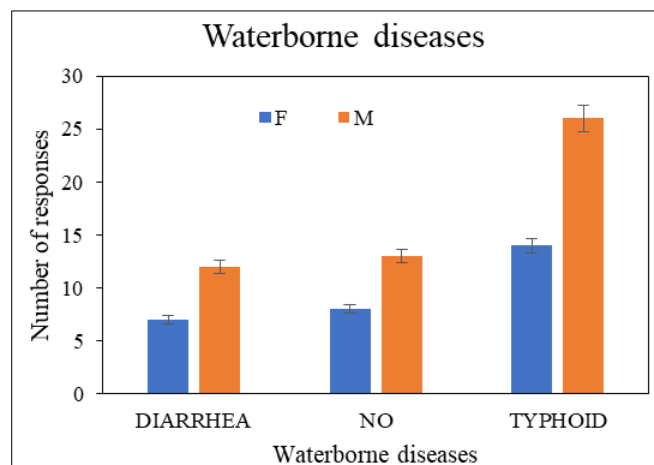


Fig 10: Waterborne diseases of the study area

Conclusion

This research work demonstrates the performance of soak pits in wastewater management. It indicates that they might serve as an economical, decentralised solution for sanitation in rural regions with constrained water resources. Nonetheless, challenges persist due to the absence of site-specific design guidelines that consider India's diverse soil types (such as permeable alluvial and sandy soils versus impermeable black cotton and saline clays) and topographies (including arid deserts, coastal regions, hilly terrains, flat plateaus, and hard rock formations). These deficiencies hinder widespread technology utilisation, since standard pit dimensions are ineffective in rocky or low-percolation regions. This research provides a unique and novel contribution to knowledge by integrating people's perspectives and the realities of sanitation systems in rural settings of a developing country.

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