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Determinants of access to improved drinking water and sanitation in India: evidence from India Human Development Survey-II (IHDS)

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ABSTRACT

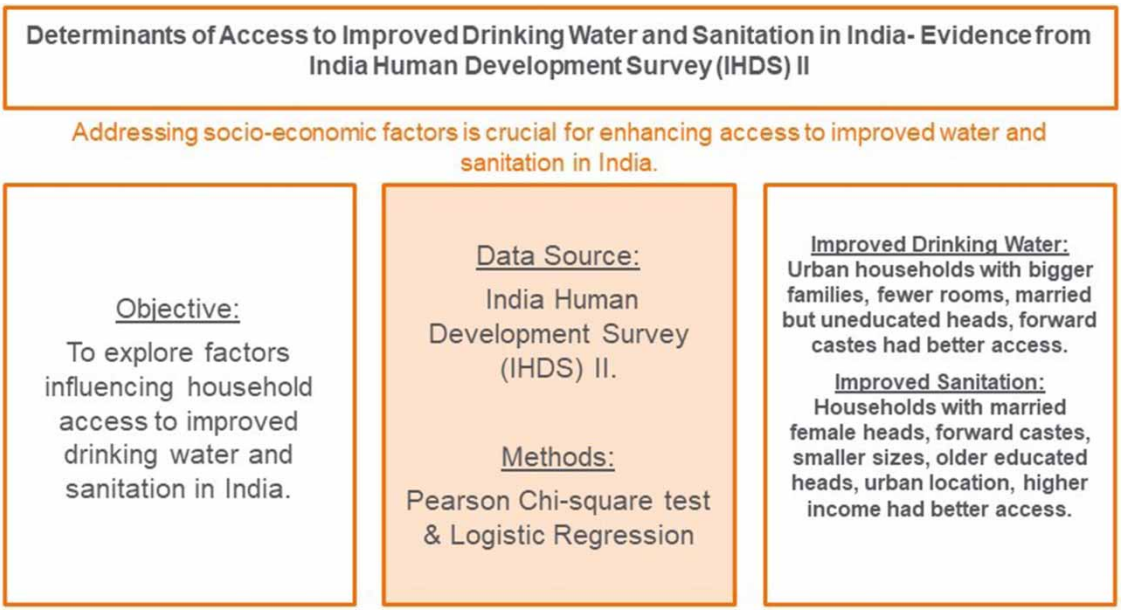
Access to improved drinking water and sanitation has been declared a fundamental right by the UN General Assembly. However, around 25 and 50% of the global population lacked access to safely managed drinking water and improved sanitation in 2020, respectively. India, the second most populous country in the world, has around 3.7 and 31% of its population without access to improved drinking water and sanitation, respectively. This paper explores the factors determining a household's access to improved drinking water and sanitation in India, using India Human Development Survey (IHDS) II data. The results indicate that urban households with bigger family sizes, with fewer rooms, married but uneducated household heads, belonging to forward castes, were more likely to have access to improved drinking water. Similarly, households with married female heads, belonging to forward castes, small household sizes, older aged heads with primary education, from Non-EAG (Empowered Action Group) states, located in urban areas, earning higher incomes and having more rooms were more likely to have access to improved sanitation. Findings suggest subsidized improved water and sanitation services and an increase in public investment to make these facilities affordable for poor rural households.

Key words: Access, Drinking water, Health, IHDS-II, Improved sanitation, India

HIGHLIGHTS

- A considerable share of the global population remains deprived of safe drinking water and sanitation.
- There is an urgent need to understand the factors influencing their access as any policy intervention aiming to improve sanitation and drinking water problem must first identify the population at risk.
- Studies on the determinants of access to improved drinking water and sanitation in the Indian context are limited.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Improved drinking water and sanitation access are crucial to public health and sustainable development. Acknowledging the importance of clean drinking water and sanitation, the UN General Assembly declared it as a fundamental human right in 2010 (United Nations, 2010). It also significantly impacts a household's socio-economic status, living standards, and life expectancy. However, it remains a major developmental challenge, especially in developing countries. In 2020, around 25 and 50% of the global population lacked safely managed drinking water and sanitation. Furthermore, approximately 6% of the world's population still defecated in the open in 2020, whereas 2.3 billion people lacked basic handwashing facilities in the same year (WHO/UNICEF JMP, 2021). Furthermore, the World Health Organization (WHO) estimates that around 2 billion people consume water contaminated with human faeces.

Unsafe drinking water and sanitation are the most common causes of sickness and deaths in developing countries (Bartram *et al.*, 2005). It also increases health costs, decreases worker productivity, and drops school enrolment. The lack of access to safe drinking water and improved sanitation is the world's second-largest cause of child deaths (Watkins, 2006). According to the WHO Report 2015, children living with unimproved drinking water and sanitation facilities face mortality risk and nutritional deficiency. Diarrhoeal diseases due to poor sanitation, poor hygiene, or unsafe drinking water were responsible for 9% of the deaths of children under five (UNICEF, 2022). Prüss-Ustün *et al.* (2019) estimated that around 60% of all diarrhoeal deaths and 5.3% of all deaths among under 5-year-old children in 2016 were due to inadequate drinking water, sanitation, and hygiene. On the other hand, adequate access to improved sanitation and safe drinking water can significantly reduce water-borne infections, and diseases like cholera, typhoid, and diarrhoeal deaths (Wolf *et al.*, 2018; Li & Wu, 2019). Adopting good sanitation and hygiene practices is a cost-effective, easy-to-practice, and most effective public health intervention in preventing infectious diseases like diarrhoea, cholera, hepatitis, etc. (Fewtrell *et al.*, 2005).

Recognizing its importance, the governments in developing countries are making serious efforts to meet Sustainable Development Goal 6 (SDGs 6.1 and 6.2) of the United Nations adopted in 2015. SDGs 6.1 and 6.2 aim to ensure access to improved water, sanitation, and hygiene for all by 2030. According to the WHO-UNICEF Joint Monitoring Programme (JMP), an enhanced source of drinking water includes water piped (into the dwelling, yard, or plot), water from a public tap or standpipe, a tubewell or borehole, a protected dug well, a protected spring, and rainwater. Similarly, an improved sanitation facility includes a flush-to-piped sewer system, septic tank, pit latrine, pit latrine with slab, and composting toilet.

India is the world's second most populous country, accounting for 17.76% of the world's population. Out of its total population, around 91 million people do not have access to clean water sources, and more than 746 million people still lack access to safely managed household sanitation facilities (Water.org, 2023). The poor water and sanitation in India have serious health implications, resulting in cholera, dysentery, and typhoid diseases. A study by Mallick *et al*. (2020) finds that poor sanitation and unsafe water are responsible for most of the diarrhoeal deaths in India. Nevertheless, the Indian government has undertaken several measures to address these issues. The Swachh Bharat Abhiyan (Clean India Mission), launched in 2014, aims to eliminate open defecation and promote cleanliness and hygiene. The programme has led to the construction of millions of toilets in rural areas and reduced open defecation. Despite India being declared Open Defecation Free in 2019, the NFHS Report 2019–2021 showed that 19% of households do not use any toilet facility and still defecate in the open. Open defecation is still prevalent in India due to religious beliefs, untouchability, casteism, illiteracy, and lack of proper toilet infrastructure. The Jal Jeevan Mission,[1] launched in 2019, aims to provide access to piped water to all households by 2024. The programme has set an ambitious target of delivering 55 litres of water per person per day, focusing on water-stressed areas and marginalized communities. Besides them, several non-governmental organizations and private sector entities have also taken up the cause of improving water and sanitation in India. However, the problem of ensuring access to improved drinking water and sanitation remains a significant challenge in India.

It is to be noted that any policy intervention aiming to improve sanitation and drinking water problems must first identify the population at risk of inadequate water and sanitation services. Therefore, there is an urgent need to understand the essential factors influencing access to safe water and improved sanitation. Globally, many studies have explored determinants of access to safe drinking water and sanitation (Adams *et al*., 2016; Abubakar, 2019; Behera & Sethi, 2020; Adil *et al*., 2021; Dongzagla, 2022; Rahut *et al*., 2022). However, studies on the determinants of access to improved drinking water and sanitation in the Indian context are limited. Existing studies are limited to state-level analysis (Tiwari & Nayak, 2013), urban households (Poonia & Punia, 2019), and rural households (De, 2018). Therefore, this study extends the analysis to the national level to address this literature gap and add to the burgeoning scholarship on the socioeconomic determinants of access to safe water and sanitation.

2. LITERATURE REVIEW

Several studies have highlighted the determinants of households' choice of drinking water and sanitation. Abubakar (2019) demonstrated that gender and education of household head, household wealth, place of residence, geopolitical zone, access to electricity, water collection time, and number of rooms in the house are positively significant predictors of access to drinking water. Similar findings were reported by Mulenga *et al*.

[1] Jal Jeevan Mission is a national-level programme launched by the Government of India in 2019 to provide safe and adequate drinking water to all rural households in the country by 2024. The mission is a part of the larger goal to ensure access to clean water, improve public health, and promote sustainable development in rural areas. As on 24 July 2023, around 194,660,082 rural households have been covered.

(2017) who used data collected from a survey of 5,558 households from the 2013/2014 Zambia Demographic and Household Sanitation dataset. They discovered that household wealth, gender, region, and locality of residence were major determinants of better water and sanitation. Using a large survey dataset of 11,619 households in Ghana, Adams *et al.* (2016) revealed that urban areas have better access to safe drinking water and sanitation. Supporting this study, Angoua *et al.* (2018) found that rural households with lower incomes and lower levels of education were less likely to access improved water and sanitation facilities. In Ethiopia, Gebremichael *et al.* (2021) identified several significant variables, including access to water sources, water quality, sanitation facilities, and hygiene perceptions. They found that access to improved water sources and sanitation facilities was limited, with a high reliance on unimproved sources and open defecation.

In the case of Bhutan, Rahut *et al.* (2015) identified several significant variables, including the water source type, the distance to the source, household income, and education level. Using primary data collected from a survey of 600 urban households in Nepal, Behera & Sethi (2020) recorded that households' access to drinking water was significantly influenced by household income, distance to the water source, and the presence of a water point in the neighbourhood. Adil *et al.* (2021) examined the determinants of improved drinking water and sanitation in Pakistan. They discovered that household exposure to media, household head's educational attainment, household wealth, and ethnicity were important predictors. Along with these factors, social norms and place of residence were important predictors of improved sanitation practices. In line with this finding, Singh (2009) reported that the marginalized and the lower-caste households in India are deprived and prevented from accessing improved drinking water sources. In some communities, even the concept of shared toilets is often considered impure (Dwipayanti *et al.*, 2019). Similarly, a regional study conducted by Tiwari & Nayak (2013) in India discovered that factors like caste, household income, education level, and location significantly affected access to improved water and sanitation. They discovered significant disparities based on income and caste.

The review highlights socioeconomic and demographic predictors including household size, age, gender, education, income, wealth, location, marital status, region and caste, and social norms as important predictors of access to clean drinking water and improved sanitation. However, it indicates that the critical determinants are still unknown as the findings of the studies are contradictory and inconsistent. For instance, studies by Dongzagla (2022) and Mulenga *et al.* (2017) show a significantly strong correlation between access to improved water and income, while Yang *et al.* (2013) have not found it to be a significant predictor. Although studies have been conducted globally to identify the determinants, studies exclusively focused on India are limited. Furthermore, existing studies focus separately on urban or rural areas, necessitating a nationwide study. Many of them have used smaller sample sizes collected from the primary survey.

3. MATERIALS AND METHODS

IHDS is a nationally representative survey in India jointly administered by researchers from the University of Maryland and the National Council of Applied Economic Research (NCAER), New Delhi. It is a multi-topic survey that collected information on income, consumption, employment, education, and health. So far, two survey waves have been conducted: IHDS-I in 2004–2005 and IHDS-II in 2011–2012. The present study has used data from IHDS-II (2011–2012) as the most recent round. The IHDS-II selected and surveyed 42,152 households using stratified random sampling. It provided information on 27,579 rural and 14,573 urban households across 35 states and union territories of India.

The IHDS dataset is considered one of the most extensive and comprehensive datasets available for studying various aspects of human development in India. It represents the country's rural and urban populations adequately such that the findings can be generalized to the broader Indian population. It is a longitudinal survey that provides data from the same households and individuals at multiple points in time allowing researchers to

track changes over time and study the dynamics of various human development indicators. It provides detailed socioeconomic data, enabling researchers to explore relationships between different variables and gain insights into the factors influencing human development outcomes. This extensive coverage allows for in-depth analysis of multiple dimensions of human development.

3.1. Measures

The India Human Development Survey-II (IHDS) dataset provides information on types of household drinking water sources and toilet facilities. Sources of drinking water include (i) piped (public supply), (ii) tubewell, (iii) hand pump, (iv) open well, (v) covered well, (vi) river, canal, and streams, (vii) pond, (viii) tanker truck, (ix) rainwater, (x) bottled water, and (xi) others. Similarly, toilet facilities are of four broad types: (i) no facility belonging to the household (or open fields), (ii) traditional pit latrine, and (iii) semi-flush (septic tank) latrine. The present study has used two primary outcomes as the two significant dependent variables: 'source of drinking water' and 'type of toilet used'. Based on the WHO-UNICEF JMP categorization, the dependent variables were dichotomized into improved sources (1) and unimproved sources (0). Improved drinking water sources included piped (public supply), tubewell, hand pump, covered well, and rainwater. On the other hand, unimproved sources had open wells, unprotected springs and surface water (like rivers, canals, and streams), ponds, tanker truck bottled water, and others. Similarly, sanitation was also dichotomized into (1) improved sanitation and unimproved sanitation (0). Improved sanitation facilities included flush and semi-flush toilets or latrines with septic tanks, whereas unimproved sanitation comprised no facility in households (including open fields) and traditional pit latrines.

Various theoretically relevant socioeconomic explanatory variables were included in the analysis, such as gender, age, education, marital status, religion, caste category, number of household members, and total annual household income. Place of residence (urban/rural) and Empowered Action Group (EAG)[2] status were included to examine the regional effects. EAG states comprise Bihar, Chhattisgarh, Rajasthan, Uttarakhand, Assam, Odisha, Madhya Pradesh, and Uttar Pradesh. These states together account for about 46% of the country's population and 61% of the poor (Chandramouli, 2011). EAG is considered the group of the most backward and deprived states.

3.2. Data analysis

Analyses were based on weighted data to account for the complexity of the survey design. First, descriptive statistics (frequency and percentage) were generated for all dependent and independent variables. Then, the Pearson Chi-square test was used to test whether there is a statistically significant relationship between the dependent variables (i.e., drinking water source and sanitation type) and household socioeconomic, demographic, and geographic factors. Lastly binary logistic regressions were used to identify the key determinants of household drinking water source and sanitation type since the outcome variables were binary, as found in similar studies (Adams *et al*., 2016; Abubakar, 2019; Dongzagla, 2022). The results were presented as tables and summary statistics in odds ratios and *p*-values. The analyses were conducted using Stata 14 statistical software.

[2] The Empowered Action Group (EAG) are eight socioeconomically backward states of India including Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttaranchal, and Uttar Pradesh. They face various developmental challenges, including poverty, healthcare, education, infrastructure, and economic growth. They are disadvantaged in almost all socioeconomic indicators. Around 45% of the Indian population lives in these states. These states were identified by the Government of India to receive special attention and focused developmental efforts.

4. RESULTS AND DISCUSSION

Access to improved drinking water and sanitation were the dependent variables in two binary logistic regressions. Binary logistic regressions were used to identify the determinants of access to improved drinking water and improved sanitation. Table 1 reports the descriptive statistics of the dependent and explanatory variables employed in the present analysis.

Our descriptive statistics in Table 1 show that approximately 87.6% of the respondents used water from improved sources, while 12.4% used non-improved sources. About 60% of the respondents were without access to improved sanitation facilities, while 40% used improved sanitation facilities. About 86% of the households were headed by males. Households were evenly distributed across the income category, with 62.47% below one lakh category and more than 10 lakhs only 0.7%. Most respondents were married (84.2%), and almost 25% were educated at a minimum of secondary school level; the remaining 35% had at least primary education.

4.1. Association between households' socioeconomic and demographic factors (independent variables) and sources of drinking water and sanitation facilities (dependent variables)

The associations between households' sources of drinking water and sanitation facilities (dependent variables), gender of the household head, family size, and age of the household head, marital status of the household head, region educational attainment, and household income (independent variables) are presented in Table 2.

Improved water coverage among female-headed households (87.7%) was similar to male-headed households (87.6%). Conversely, improved sanitation coverage among male-headed households (40.5%) was slightly higher than among female-headed households (39.6%). Whereas the association between the gender of the household head and access to improved drinking water was statistically significant ($p < 0.1$), it was not significant for access to improved sanitation. As expected, households where the heads lacked education (87.2%) had lower access to improved sources of drinking water as compared to those with secondary education (88.5%) and graduate and above (91.1%). Surprisingly, households with heads with primary education (86.54%) had lower access than households with heads without education. The association between HH's educational level and household access to improved water was statistically significant ($\chi^2_{(3)} = 62.9$, $p = 0.001$). The observed Chi-square distribution is larger than expected by 62, thus signifying a significant difference in household drinking water source and educational level of the household head. A similar association was observed between improved sanitation coverage and the educational level of HH. Households with higher educational levels had increased access to improved sanitation facilities. Households with heads that had no formal education had lower access to improved sanitation (22.1%) as compared to households with heads who completed primary (38.2%), secondary (56.2%), and graduate and above (72.8%) education. Table 2 indicates a significant positive relationship between the educational level of the household head and access to improved sanitation ($\chi^2_{(3)} = 4{,}400$, $p = 0.001$). The Chi-square value indicates that the observed distribution is larger than expected by 4,400, thus signifying a vast difference among various educational groups in access to improved sanitation. Thus, the likelihood of using improved sanitation increases with the educational level. The results also depict heavy reliance on unimproved sources of sanitation by households headed by uneducated persons (78%), followed by those with primary (61.8%), secondary/higher secondary (43.8%), and graduation and above (27. 2%). These figures suggest that the difference between education levels substantially impacts access to improved sanitation.

We find a statistically significant relationship between income levels and access to improved drinking water ($\chi^2_{(3)} = 32.4$, $p = 0.001$) and sanitation ($\chi^2_{(3)} = 4{,}900$, $p = 0.001$). Households in the highest income bracket of above 10 lakhs had higher improved sanitation coverage (79.7%) as compared to households with lower incomes: 5–10 lakhs (69.2%), 2–5 lakhs (52.7%), and less than or equal to 1 lakh (28.1%). Similarly, households with the highest incomes had higher access to improved drinking water (86.9%) than households with a total annual

Table 1 | Descriptive statistics sanitation and drinking water ($N = 41,902$).

Variables	Categories	Frequency	Percentage
Source of drinking water	Unimproved	5,210	12.41
	Improved	36,785	87.59
	Total	41,995	100
Sanitation facility	Unimproved	25,049	59.67
	Improved	16,929	40.33
	Total	41,978	100
Gender of HH head	Male	36,114	85.77
	Female	5,994	14.23
	Total	42,108	100
Caste	General/Open/Brahmin	11,857	28.19
	OBC	17,056	40.55
	SC/ST/Others	13,153	31.27
	Total	42,066	100
Family size	Small	11,504	27.29
	Medium	22,946	54.44
	Big	7,702	18.27
	Total	42,152	100
Age of HH head	Below 30	3,121	7.41
	30–39	6,962	16.53
	40–49	11,393	27.06
	50–59	9,655	22.93
	60 and above	10,977	26.07
	Total	42,108	100
Marital status HH head	Married	35,455	84.2
	Never married	439	1.04
	Widowed/Separated/Divorced	6,214	14.76
	Total	42,108	100
Education of HH head	Illiterate	13,422	31.9
	Primary	14,808	35.19
	Secondary/Higher Secondary	10,477	24.9
	Graduate and above	3,371	8.01
	Total	42,078	100
EAG status	EAG	15,904	37.73
	Non-EAG	26,248	62.27
	Total	42,152	100
Place of residence	Rural	27,579	65.43
	Urban	14,573	34.57
	Total	42,152	100
Income	Less than or equal to 1,00,000	26,331	62.47
	Rs. 100,001–Rs. 200,000	8,924	21.17
	Rs. 200,001–Rs. 500,000	5,546	13.16
	Rs. 500,001–Rs. 1,000,000	1,055	2.5
	More than Rs. 10,00,000	296	0.7
	Total	42,152	100
No. of rooms	Less than or equal to 2	23,149	55.17

(*Continued.*)

Table 1 | Continued

Variables	Categories	Frequency	Percentage
	3–5 rooms	16,279	38.8
	More than 5 rooms	2,532	6.03
	Total	41,960	100

Source: IHDS-II (2011–2012).

income of 5–10 lakhs (90.1%), 2–5 lakhs (89.2%), and less than or equal to 1 lakh (86.9%). Quite unexpectedly, households in the highest annual income bracket (above 10 lakhs) had lower coverage of improved drinking water (87.8%) than those with lower income levels.

Coverage of improved drinking water was the highest (90.1%) among the households belonging to forward castes (General/Open/Brahmin). Households from reserved caste categories such as OBC (86.5%) and SC/ST/Others (86.8%) had less access to improved drinking water. Similarly, households from forward castes also had the highest level of access to improved sanitation (54.5%). In contrast, only 27.8% of the SC/ST/Others households and 40% of the OBC households used improved sanitation. A significant statistical difference is found between caste category and household's access to improved drinking water ($\chi^2_{(2)} = 92.23$, $p = 0.001$) and sanitation ($\chi^2_{(2)} = 1.8$, $p = 0.001$) were statistically significant.

Households headed by a never-married person had lower access to improved drinking water (85.2%) than households headed by a married person (87.5%) or a widowed/separated/divorced person (88.3%). In contrast, households with heads who were never married had slightly higher access to improved sanitation (43.9%) than households with heads who were married (40.5%), widowed/divorced/separated (39.1%). The association between marital status and households' access to improved drinking water ($\chi^2_{(2)} = 5.76$, $p = 0.057$) and sanitation ($\chi^2_{(2)} = 6.6$, $p = 0.037$) was statistically significant.

The association between the age of the household head and the level of access to improved sanitation ($\chi^2_{(2)} = 533.41$, $p = 0.000$) was statistically significant but was otherwise with the improved drinking water ($\chi^2_{(2)} = 4.76$, $p = 0.313$). Coverage of improved drinking water ranged between 86.7 and 88% for all age groups, and a slight disparity was observed across age groups. However, the results indicate a wide disparity in improved sanitation coverage across age groups. Households from the age group 50–59 years had the highest coverage (45.3%), followed by the age groups above 60 (43.4%), 40–49 years (40.6%), 30–39 years (35.1%), and below 30 years (24.8%). Household size was significantly related to access to improved drinking water ($\chi^2_{(2)} = 4.83$, $p = 0.089$) and sanitation ($\chi^2_{(2)} = 33.01$, $p = 0.000$) in India. Table 2 indicates that the difference between big, medium, and small family sizes does not substantially matter in the level of access to improved drinking water. However, medium-sized households (41.6%) have higher levels of access to improved sanitation compared to small (38.9%) and big (38.7%) households.

Table 2 presents a statistically significant difference in access to improved drinking water ($\chi^2_{(1)} = 48.394$, $p = 0.000$) and sanitation ($\chi^2_{(1)} = 2{,}000$, $p = 0.000$) between EAG states and Non-EAG states. The results indicate that households in Non-EAG states (88.5%) had higher coverage of improved drinking water than EAG states (86.2%). The results also reveal a wide disparity between the households in EAG states (26.5%) and Non-EAG states (48.8%) regarding access to improved sanitation facilities.

4.2. Determinants of access to improved drinking water and sanitation

The logistic regression results in Table 3 report the key determinants of a household having access to improved water and sanitation. The significant determinants of access to improved drinking water are caste category, household size, marital status, educational level, place of residence, and the number of rooms.

Table 2 | Bivariate analysis of variables modelling access to improved water and sanitation ($N = 14,315$).

	Source of drinking water		Source of sanitation	
Variables	**Unimproved**	**Improved**	**Unimproved**	**Improved**
Gender				
Male	4,470(12.4%)	31,514(87.6%)	21,418(59.6%)	14,550(40.5%)
Female	737(12.3%)	52,309(87.7%)	3,604(60.4%)	2,362(39.6%)
Pearson Chi-square statistics	$\chi^2 = 0.0237$; df = 1; $p = 0.087$*		$\chi^2 = 1.578$; df = 1; $p = 0.209$	
Caste				
General/Open/Brahmin	1,170(9.9%)	10,650(90.1%)	5,375(45.5%)	6,437(54.5%)
OBC	2,298(13.5%)	14,681(86.5%)	10,179(60%)	6,793(40%)
SC/ST/Others	1,733(13.2%)	11,377(86.8%)	9,464(72.2%)	3,644(27.8%)
Pearson Chi-square statistics	$\chi^2 = 96.228$; df = 2; $p = 0.000$***		$\chi^2 = 1.800$; df = 2; $p = 0.000$***	
Family				
Small	1,480(13%)	9,952(87%)	6,979(61.1%)	4,447(38.9%)
Medium	2,773(12.1%)	20,110(87.9%)	13,361(58.4%)	9,511(41.6%)
Big	957(12.5%)	6,723(87.5%)	4,709(61.3%)	2,971(38.7%)
Pearson Chi-square statistics	$\chi^2 = 4.835$; df = 2; $p = 0.089$*		$\chi^2 = 33.013$; df = 2; $p = 0.000$***	
Age				
Below 30 years	414(13.3%)	2,691(86.7%)	2,333(75.2%)	768(24.8)
30–39 years	870(12.5%)	6,067(87.5%)	4,503(64.9%)	2,435 (35.1%)
40–49 years	1,362(12%)	10,003(88%)	6,751(59.4%)	4,615(40.6%)
50–59 years	1,212(12.6%)	8,414(87.4%)	5,260(54.7%)	4,357(45.3%)
Above 60 years	1,349(12.4%)	9,569(87.6%)	6,175(56.6%)	4,737(43.4%)
Pearson Chi-square statistics	$\chi^2 = 4.760$; df = 2; $p = 0.313$		$\chi^2 = 533.414$; df = 2; $p = 0.000$***	
Marital status				
Never married	64(14.8%)	369(85.2%)	243(56.1%)	190(43.9%)
Married	4,422(12.5%)	30,915(87.5%)	21,014(59.5%)	14,305(40.5%)
Widow	721(11.7%)	5,460(88.3%)	3,765(60.9%)	2,417(39.1%)
Pearson Chi-square statistics	$\chi^2 = 5.746$; df = 2; $p = 0.057$*		$\chi^2 = 6.606$; df = 2; $p = 0.037$**	
Education				
Illiterate	1,716(12.8%)	11,646(87.2%)	10,401(77.9%)	2,960(22.1)
Primary	1,988(13.46%)	12,780(86.54%)	9,126(61.83%)	5,634(38.17%)
Secondary/Higher	1,198(11.5%)	9,236(88.5%)	4,570(43.8%)	5,859(56.2%)
Graduate	300(8.9)	3,059(91.1)	912(27.2%)	2,445(72.8%)
Pearson Chi-square statistics	$\chi^2 = 62.997$; df = 3; $p = 0.000$***		$\chi^2 = 4,400$; df = 3; $p = 0.000$***	
EAG status				
EAG	2,198(13.8%)	13,682(86.2%)	11,676(73.5%)	4,202(26.5%)
Non-EAG	3,012(11.5%)	23,103(88.5%)	13,373(51.2%)	12,727(48.8%)
Pearson Chi-square statistics	$\chi^2 = 48.394$; df = 1; $p = 0.000$***		$\chi^2 = 2,000$; df = 1; $p = 0.000$***	

(*Continued.*)

Table 2 | Continued

Variables	Source of drinking water		Source of sanitation	
	Unimproved	Improved	Unimproved	Improved
Place of residence				
Rural	3,965(14.4%)	23,513(85.6%)	20,259(73.8%)	7,204(26.2%)
Urban	1,245(8.6%)	13,272(91.4%)	4,790(33%)	9,725(67%)
Pearson Chi-square statistics	$\chi^2 = 299.497$; df = 1; $p = 0.000$***		$\chi^2 = 6{,}600$; df = 1; $p = 0.000$***	
Income				
Less than or equal to 100,000	3,426(13.1%)	22,798(86.9%)	18,839(71.9%)	7,375(28.1%)
1 lakh–2 lakhs	1,044(11.7%)	7,855(88.3%)	4,204(47.3%)	4,689(52.7%)
2–5 lakhs	600(10.9%)	4,928(89.2%)	1,701(30.8%)	3,827(69.2%)
5–10 lakhs	104(9.9%)	945(90.1)	245(23.4%)	803(76.6)
Above 10 lakhs	36(12.2%)	259(87.8%)	60(20.3)	235(79.7%)
Pearson Chi-square statistics	$\chi^2 = 32.443$; df = 4; $p = 0.000$***		$\chi^2 = 4{,}900$; df = 4; $p = 0.000$***	

Source: IHDS-II (2011–2012).
Percentages are computed as rows.
*$p \leq 0.1$, **$p \leq 0.5$, and ***$p \leq 0.01$.

First, female-headed households are 46% more likely to access improved sanitation facilities than male-headed households. One reason for this could be that in many developing countries, women are responsible for managing water, sanitation, and hygiene. Women could pay more attention to such issues than their male counterparts, especially when women are the household heads. Also, females place more attention on privacy and personal hygiene than males. As a result, they would strive to have their toilets at home for better privacy and reduce infection risk. This finding is consistent with Agbadi *et al.* (2019), Armah *et al.* (2018), Adams *et al.* (2016), and Mulenga *et al.* (2017) but disagrees with the work of Akpakli *et al.* (2018). However, gender did not significantly influence the odds ratio of access to improved drinking water.

Households headed by older persons (more than 30 years) were at least 31% more likely to have access to improved sanitation facilities than the ones headed by younger persons (less than 30 years). Older people could afford more basic services compared to young ones, possibly because of their higher economic status. Also, older household heads are more concerned about their health and try to utilize services that improve their and their family's health and quality of life (Agbadi *et al.*, 2019). It may also be possible that a majority of household heads above 30 years of age might have been working and could afford improved sanitation facilities compared to younger household heads who are at risk of being unemployed. This finding is in line with Dongzagla (2022), Agbadi *et al.* (2019), and Akpakli *et al.* (2018). However, the age category has no statistically significant impact on the odds ratio of using improved drinking water.

The results showed that households with literate heads were more likely to have access to improved sanitation than those with illiterate heads. Also, respondents with primary education were 17% less likely to have access to an improved water source than those with no education at all. Perhaps, household heads with formal education are more informed regarding improved water and sanitation health benefits than uneducated household heads. This is in line with Agbadi *et al.* (2019), Adams *et al.* (2016), and Dongzagla (2022). However, the educational level of the household head has no significant impact on the odds of access to drinking water. Compared to households with heads who were never married, households with married heads were 57%, and widowed/divorced/separated heads were 70% more likely to have access to improved drinking water. This contradicts

Table 3 | Multivariate analysis of variables modelling access to improved water and sanitation ($N = 41{,}902$).

	Improved water source		Improved sanitation	
Explanatory variables	**OR**	**SE**	**OR**	**SE**
Gender of the household head				
Female	0.952	0.082	1.462***	0.098
Caste				
OBC	0.758***	0.039	0.856***	0.032
SC/ST/Others	0.748***	0.043	0.572***	0.024
Family status				
Medium	1.054	0.053	1.002	0.039
Big	1.235***	0.081	0.796***	0.042
Age of household head				
30–39	0.955	0.082	1.167**	0.080
40–49	0.959	0.080	1.314***	0.087
50–59	0.879	0.075	1.529***	0.106
60 and above	0.984	0.085	1.604***	0.113
Marital status of household head				
Never married	0.636**	0.126	1.077	0.157
Widowed/Separated/Divorced	1.082	0.092	0.805***	0.054
Educational status household head				
Primary	0.829***	0.042	1.692***	0.071
Secondary/Higher Secondary	0.993	0.059	2.538***	0.121
Graduate and above	1.156	0.113	3.109***	0.224
EAG states				
Non-EAG states	1.071	0.046	2.382***	0.078
Place of residence				
Urban	1.759***	0.077	4.389***	0.139
Income status of the family				
Rs. 100,001–Rs. 200,000	0.938	0.051	1.573***	0.062
Rs. 200,001–Rs. 500,000	0.954	0.069	2.007***	0.106
Rs. 500,001–Rs. 1,000,000	1.013	0.153	2.297***	0.276
More than Rs. 10,00,000	0.824	0.189	2.646***	0.576
Rooms	0.925***	0.011	1.288***	0.017
Constant	10.231***	0.996	0.045***	0.004

Source: IHDS-II (2011–2012).
**$p \leq 0.5$, and ***$p \leq 0.01$.

the finding of Adams *et al.* (2016). Dongzagla (2022) also contradicts this further, arguing that households with never-married heads are usually small-sized and thus can meet the cost of improved water. On the other hand, households with widowed/divorced/separated heads were 26% less likely to have access to improved sanitation

than those with never-married heads. As compared to forward castes, households from OBC and SC/ST/Others categories were 24 and 25% less likely to have access to improved drinking water, respectively. Similarly, households from OBC and SC/ST/Others categories were 14 and 43% less likely to have access to improved sanitation, respectively.

The household size is also an important determinant used in the analysis. Big households (above 7 members) were 23.5% more likely to have access to improved drinking water than small families. This aligns with Irianti *et al.* (2016) and Adams *et al.* (2016), who found that larger households had higher chances of using improved drinking water sources in Indonesia and Ghana, respectively. However, this is in contrast to a study by Dongzagla (2022) in Ghana, where medium- and big-sized households were less likely to use improved drinking water sources than small households. On the other hand, big households were 21% less likely to have access to improved sanitation, compared to small-sized (1–3 members) households. As the number of family members increases, total household income and wealth may decrease. This eventually declines the household's ability to afford an improved sanitation facility.

Similarly, urban households were 76% more likely to access improved drinking water sources and 339% more likely to have access to improved sanitation facilities than rural households. This suggests urban households are spatially closer to facilities or services, whereas rural households are spatially dispersed. Installing a private facility is expensive in rural areas, whereas these are provided by local government or municipal bodies in urban areas. This depicts the urban–rural disparities in access to improved drinking water and sanitation. This finding aligns with the literature suggesting that urban households have a better chance of having access to improved drinking water and sanitation facilities (Armah *et al.*, 2018; Abubakar, 2019). Also, living in EAG and Non-EAG states slightly differentiates households according to their access to improved sanitation. Households who belong to Non-EAG states were 2.38 times more likely to use improved sanitation. No significant influence of EAG status on the odds of access to drinking water has been observed.

We observed that the income level of households had a statistically significant impact on a household's chances of using improved sanitation facilities. Moving from a lower to a higher-income group increases the likelihood of using improved sanitation. As compared to households with the lowest income level (below Rs. 1 lakh), households with higher income levels, i.e., Rs. 1–2 lakhs, Rs. 2–5 lakhs, Rs. 5–10 lakhs, and above 10 lakhs were 57, 100.7, 130, and 165% more likely to have access to improved sanitation facilities. It implies that access to improved sanitation facilities improves with the rise in income levels, which agrees with several studies (Adams *et al.*, 2016; Dongzagla, 2022). This is expected because higher-income households can pay more for improved sanitation facilities (Abubakar, 2019), even when the local government does not provide it. However, income level did not significantly influence access to improved drinking water. The total number of rooms in the house also significantly determines the odds of using improved drinking water and sanitation. One additional room decreases the odds of using improved drinking water by 0.08% but increases the chances of using improved sanitation by around 29%. The present study found that gender, age, EAG status, and income level have no significant influence on the drinking water source of the household.

5. CONCLUSION AND POLICY IMPLICATIONS

Using the data from India Human Development Survey-II (2011–2012), this study has identified the key determinants of access to improved drinking water and sanitation in India. For access to improved drinking water, caste, household size, marital status, education, place of residence, and the number of rooms were statistically significant predictors. Urban households with larger family sizes (above 7), led by married but uneducated heads from forward castes, were more likely to have access to improved drinking water. Regarding improved sanitation access, all socioeconomic and demographic variables showed a statistically significant association.

Households with female heads who were married, belonging to forward castes, small household sizes (1–3), older aged heads with at least primary education, from Non-EAG states, located in urban areas, earning higher incomes, and having more rooms were more likely to have access to improved sanitation facilities.

The findings of the present study have a few significant implications for water and sanitation policies in India. We found that economically and socially backward households have less probability of having access to safe drinking water and sanitation. Since access to these facilities is necessary to lead a healthy and disease-free life, policies are required to improve the access of these sections of society. Despite several schemes such as the Jal Jeevan Mission, rural households have lower access to safe drinking water. This illustrates the existing disparity between urban and rural areas in terms of access. Thus, rural areas still need more focus.

In India, targeted support is essential for socially marginalized caste households, who often belong to the poorer segments of the population and face lower access to improved amenities. To address caste-based inequalities, allocating dedicated funds for their upliftment is crucial. Existing programmes such as the Jal Jeevan Mission and the Swachh Bharat Mission[3] should prioritize the needs of these marginalized and backward caste households to improve their access to clean drinking water and sanitation.

The impact of household income on access to water and sanitation in India is evident, highlighting the need for government intervention to improve the well-being of the poor. As household income rises, households tend to shift from unimproved to improved water and sanitation sources. Thus, household incomes should be enhanced by creating more employment opportunities in both on- and off-farm sectors to improve the affordability of these facilities thereby enhancing their health and overall well-being. Additionally, stakeholders involved in providing sanitation and drinking water facilities can consider subsidizing the cost of improved services for rural households. Also, innovating low-cost products and technologies to make these facilities more affordable for the poor is a valuable step.

Increased public investment should be directed towards improving education. The importance of water and sanitation should be integrated into the school curriculum. For individuals with little or no education, awareness campaigns using simple language, visuals, and local dialects are crucial to overcome social and cultural barriers. Awareness about the harmful effects of poor sanitation, especially open defecation, is essential. Open defecation is still prevalent in India due to religious beliefs, untouchability, casteism, illiteracy, and lack of proper toilet infrastructure. It should be discouraged and its harmful effects on health should be propagated.

To empower female-headed households, it is essential to address their specific needs and challenges, including privacy, security, and water availability while planning sanitation policies. Presently, schemes like Swachh Bharat Mission and Housing for All 2022[4] prioritize female-headed households for allocation of funds for toilets and houses, respectively. Similarly, other schemes also should prioritize female-headed households.

EAG states with the worst health outcomes in the country should be given high priority in providing improved sanitation facilities. These states require substantial progress in terms of quality infrastructure to enhance access

[3] Swachh Bharat Abhiyan, also known Clean India Mission, is a cleanliness and sanitation campaign launched by the Government of India on 2 October 2014. It aims to achieve the vision of a 'Clean India' by addressing issues related to sanitation and cleanliness, improving waste management practices, eliminating Open Defecation, and promoting hygiene and sanitation across the country.

[4] 'Housing for All by 2022' is a flagship initiative of the Indian government, officially known as the Pradhan Mantri Awas Yojana (PMAY). It was launched in June 2015 with the aim of providing affordable housing to all eligible beneficiaries in urban and rural areas of India by the year 2022. The mission focuses on addressing the housing needs of the economically weaker sections, lower-income groups, and middle-income groups in the country.

to safe drinking water and sanitation. Policy attention is crucial to address the challenges of poor access and affordability in these regions.

Key lessons of this study's findings include the need for formulating and implementing sanitation and water policies with more focus on tackling the internal socioeconomic and regional variations in access to improved water and sanitation facilities, as a significant step towards sustainable goal in India. Additionally, safe water and sanitation need to be provided in public spaces too.

6. LIMITATIONS

The paper acknowledges some limitations. Firstly, it relies on a nationally representative dataset, which offers a broad perspective on the topic but may not be suitable for drawing policy implications at the state or regional level due to its general nature. To gain more context-specific insights and a deeper understanding of the issue for regional-level policies, future studies should use primary data and consider the differences in water sources, demographics, and water use patterns in different regions. Secondly, the paper has not incorporated multivariate household analysis to cluster household types. Future research may conduct such analysis to provide clearer insights that will help decision-makers to identify and prioritize specific target groups to achieve the greatest impact of policy interventions.

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DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories. The raw data is located in the public repository of ICPSR: https://www.icpsr.umich.edu/web/DSDR/studies/36151.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Abubakar, I. R. (2019). Factors influencing household access to drinking water in Nigeria. *Utilities Policy 58*, 40–51. https://doi.org/10.1016/j.jup.2019.03.005.

Adams, E. A., Boateng, G. O. & Amoyaw, J. A. (2016). Socioeconomic and demographic predictors of potable water and sanitation access in Ghana. *Social Indicators Research 126*(2), 673–687. https://doi.org/10.1007/s11205-015-0912-y.

Adil, S., Nadeem, M. & Malik, I. (2021). Exploring the important determinants of access to safe drinking water and improved sanitation in Punjab, Pakistan. *Water Policy 23*(4), 970–984. https://doi.org/10.2166/wp.2021.001.

Agbadi, P., Darkwah, E. & Kenney, P. L. (2019). A multilevel analysis of regressors of access to improved drinking water and sanitation facilities in Ghana. *Journal of Environmental and Public Health 2019*. https://doi.org/10.1155/2019/3983869.

Akpakli, D. E., Manyeh, A. K. & Akpakli, J. K. (2018). Determinants of access to improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health and Demographic Surveillance Site. *BMC Research Notes 1*(1), 473. https://doi.org/10.1186/s13104-018-3572-6.

Angoua, E. L. E., Dongo, K., Templeton, M. R., Zinsstag, J. & Bonfoh, B. (2018). Barriers to access improved water and sanitation in poor peri-urban settlements of Abidjan, Côte d'Ivoire. *PLoS ONE 13*(8), e0202928. https://doi.org/10.1371/journal.pone.0202928.

Armah, F. A., Ekumah, B., Yawson, D. O., Odoi, J. O., Afitiri, A. R. & Nyieku, F. E. (2018). Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon 4*(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931.

Bartram, J., Lewis, K., Lenton, R. & Wright, A. (2005). Focusing on improved water and sanitation for health. *The Lancet 365*(9461), 810–812.

Behera, B. & Sethi, N. (2020). Analysis of household access to drinking water, sanitation, and waste disposal services in urban areas of Nepal. *Utilities Policy 62*, 100996. https://doi.org/10.1016/j.jup.2019.100996.

Chandramouli, C. (2011). *Census of India 2011*. Office of Registrar General & Census Commissioner, India. Available at: https://www.census2011.co.in (Accessed 2 January 2023).

De, I. (2018). Determinants of rural sanitation in India and implications for public policy. *Journal of Water, Sanitation and Hygiene for Development 8*(4), 650–659.

Dongzagla, A. (2022). Socioeconomic and demographic factors affecting urban household access to improved water and sanitation in Ghana. *GeoJournal 87*(6), 4763–4773.

Dwipayanti, N. M. U., Rutherford, S. & Chu, C. (2019). Cultural determinants of sanitation uptake and sustainability: local values and traditional roles in rural Bali, Indonesia. *Journal of Water, Sanitation and Hygiene for Development 9*(3), 438–449. https://doi.org/10.2166/washdev.2019.178.

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L. & Colford, J. M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet Infectious Diseases 5*(1), 42–52.

Gebremichael, S. G., Yismaw, E., Tsegaw, B. D. & Shibeshi, A. D. (2021). Determinants of water source use, quality of water, sanitation and hygiene perceptions among urban households in North-West Ethiopia: a cross-sectional study. *PLoS ONE 16*(4), e0239502. https://doi.org/10.1371/journal.pone.0239502.

Irianti, S., Prasetyoputra, P. & Sasimartoyo, T. P. (2016). Determinants of household drinking-water source in Indonesia: an analysis of the 2007 Indonesian family life survey. *Cogent Medicine 3*(1), 1151143. https://doi.org/10.1080/2331205X.2016.1151143.

Li, P. & Wu, J. (2019). Drinking water quality and public health. *Exposure and Health 11*(2), 73–79.

Mallick, R., Mandal, S. & Chouhan, P. (2020). Impact of sanitation and clean drinking water on the prevalence of diarrhea among the under-five children in India. *Children and Youth Services Review 118*, 105478.

Mulenga, J. N., Bwalya, B. B. & Chishimba, K. K. (2017). Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. *International Journal of Development and Sustainability 6*(8), 746–762.

Poonia, A. & Punia, M. (2019). Associates and determinants of drinking water supply: a case study along urban rural continuum of semi-arid cities in India. *Urban Water Journal 16*(10), 749–755.

Prüss-Ustün, A., Wolf, J., Bartram, J., Clasen, T., Cumming, O., Freeman, M. C. & Johnston, R. (2019). Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: an updated analysis with a focus on low- and middle-income countries. *International Journal of Hygiene and Environmental Health 222*(5), 765–777.

Rahut, D. B., Behera, B. & Ali, A. (2015). Household access to water and choice of treatment methods: empirical evidence from Bhutan. *Water Resources and Rural Development 5*, 1–16. https://doi.org/10.1016/j.wrr.2014.09.003.

Rahut, D. B., Cheng, S., Zhan, Z., Li, H., Bobojonov, I., Singh, A. & Sonobe, T. (2022). WASH facilities prevalence and determinants: evidence from 42 developing countries. *Frontiers in Environmental Science 10*, 1013657. https://doi:10.3389/fenvs.2022.1013657.

Singh, D. (2009). Development of scheduled castes in India-a review. *Journal of Rural Development (Hyderabad) 28*(4), 529–542.

Tiwari, R. & Nayak, S. (2013). Drinking water and sanitation in Uttar Pradesh: a regional analysis. *Journal of Rural Development 32*(1), 61–74.

UNICEF (2022). *Estimates of Child Cause of Death, Diarrhea*. [Data file]. Available at: https://data.unicef.org/topic/child-health/diarrhoeal-disease/ (Accessed July 2022).

United Nations (UN) (2010). Resolution Adopted by the General Assembly. 64/292. The Human Right to Water and Sanitation. A/RES/64/292. New York: United Nations Available at: https://dgvn.de/fileadmin/user_upload/DOKUMENTE/English_Documents/A-Res-64-292.pdf.

Water.org (2023). *India's Water and Sanitation Crisis*. Available at: https://water.org/our-impact/where-wework/india/.

Watkins, K. (2006). Human Development Report 2006-Beyond Scarcity: Power, Poverty and the Global Water Crisis. UNDP Human Development Reports (2006).

WHO/UNICEF JMP (2021). *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years Into the SDGs*. World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF), Geneva.

Wolf, J., Hunter, P. R., Freeman, M. C., Cumming, O., Clasen, T., Bartram, J. & Prüss-Ustün, A. (2018). Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. *Tropical Medicine & International Health 23*(5), 508–525.

Yang, H., Bain, R., Bartram, J., Gundry, S., Pedley, S. & Wright, J. (2013). Water safety and inequality in access to drinking-water between rich and poor households. *Environmental Science & Technology 47*(3), 1222–1230.

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