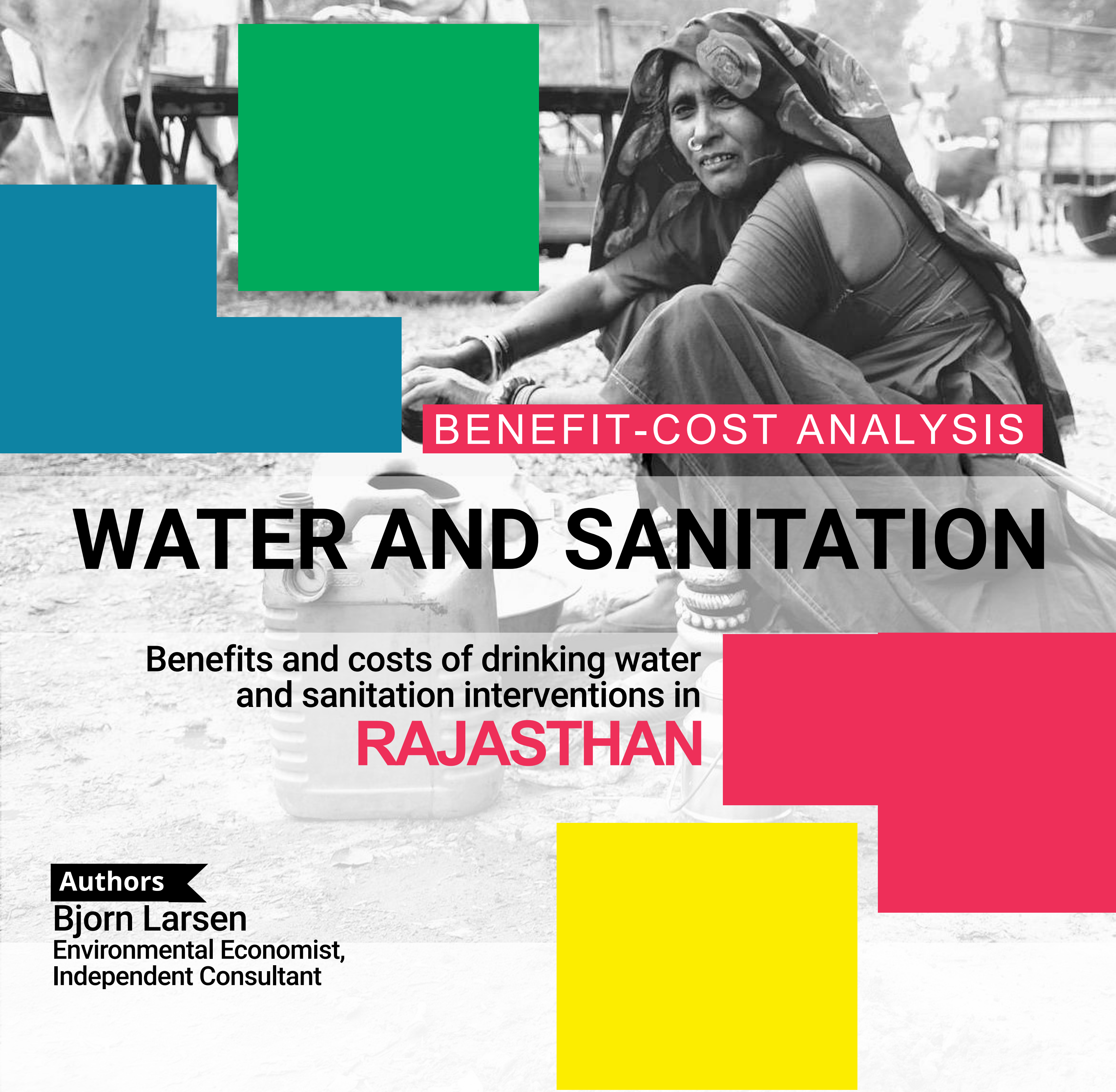

BENEFIT-COST ANALYSIS

WATER AND SANITATION

Benefits and costs of drinking water and sanitation interventions in RAJASTHAN

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RAJASTHAN PRIORITIES
AN INDIA CONSENSUS PRIORITIZATION PROJECT

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This work has been produced as a part of the Rajasthan Priorities project under the larger, India Consensus project.

This project is undertaken in partnership with Tata Trusts.

TATA TRUSTS

Benefits and Costs of Drinking Water and Sanitation Interventions in Rajasthan

Rajasthan Priorities
An India Consensus Prioritization Project

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Working paper as of May 25,, 2018

Academic Abstract

This paper evaluates the benefits and costs of four household drinking water and sanitation interventions. The interventions were selected on the basis of coverage rates and behavioral dimensions in the state. Benefits and costs are presented as a ratio of annualized benefits and annualized costs (benefit-cost ratios) over the expected useful life of each intervention.

Benefit-cost ratios (BCRs) are found to be the largest for improved rural sanitation (8.1-9.7) and improved urban water supply (9.5-14.0), followed by improved urban sanitation (6.7-7.6), household point-of-use (POU) treatment of drinking water (7.9-8.4) and improved rural water supply (4.6-6.9). A behavioral change campaign (BCC) promoting the use of existing sanitation by all household members has the lowest BCR (2.2-2.3).

These BCRs reflect benefits estimated using a value of statistical life (VSL) for averted deaths, a monetary value of time savings at 50-100% of wage rates, the cost-of-illness (COI) approach for averted illness, and annual discount rates of 3-8%. BCRs with averted years of life lost to mortality (YLL) and illness (YLD), valued at 3 times GDP per capita, is also presented in the report. The latter BCRs are somewhat lower than the former, especially at higher discount rates.

The quality of evidence associated with the estimated benefits and costs of the interventions range from “medium” to “medium-strong”. The BCC campaign is, however, supported by only “limited” quality of evidence.

Policy Abstract

The Problem

Diarrheal disease caused nearly 1.7 million deaths globally in 2016. Nearly 0.8 million of these deaths occurred in India of which 90% were due to unsafe drinking water, sanitation and hygiene according to estimates by the Global Burden of Disease 2016 (GBD 2016).[1]

In Rajasthan over 47 thousand deaths were caused by diarrheal disease and intestinal infections (mainly typhoid and paratyphoid) in 2016, constituting 8.7% of all deaths in the state according to GBD 2016, thus remaining a major cause of concern in relation to drinking water and sanitation.

Over 85% of households in Rajasthan had access to an improved drinking water source in 2015-16, up from 82% in 2005-06 according to the National Family Health Survey IV (IIPS, 2017).[2]

Improved drinking water sources are generally considered having a lesser risk of pathogen contamination than unimproved sources (e.g., shallow dug wells, unprotected springs, open surface water). Water from improved sources are, however, not necessarily safe to drink (Pruss-Ustun et al, 2014). Nevertheless, only 6% of households practiced point-of-use (POU) treatment of their drinking water in 2005-06, mainly by filtering, according to the National Family Health Survey III (IIPS, 2008).[3] Moreover, as much as a quarter of the rural population[4] in Rajasthan has more than 30 minutes round-trip to their drinking water source, particularly affecting women and children who often perform the task of fetching drinking water.[5]

About 52% of households in Rajasthan had a sanitary toilet facility in 2015 according to the Swachhta Status Report 2016 (MSPI/GOI, 2017). Moreover, 45% of households had access to

[1] http://www.healthdata.org/
[2] The Joint Monitoring Programme for Water Supply and Sanitation (JMP) of WHO/UNICEF classifies household drinking water sources and sanitation facilities into improved and unimproved sources/facilities.
[3] The figures for 2015-16 from the NFHS 4 were not yet publicly available at the time of this paper.
[4] Practically no urban households have a 30 minutes round-trip to their drinking water source.
[5] 34% of the rural population had more than a 30 minutes round-trip to their drinking water source in 2005-06 (NFHS 3). The figures for 2015-16 from the NFHS 4 were not yet publicly available at the time of this paper.

an improved non-shared sanitation facility in 2015-16 according to the National Family Health Survey IV.[6] Thus about 7% of households shared a sanitation facility with other households in 2015.

The Swachhta Status Report 2016 also reveals that 4.5% of persons with a sanitary toilet facility continued to practice open defecation (OD). Additionally, 48% of households had no sanitation facility and practiced OD in 2015 (MSPI/GOV, 2017). A substantial drive by the government for household sanitation and eradication of OD has, however, reduced this figure quite substantially since 2015.

Based on the household drinking water and sanitation situation in the state, four interventions are evaluated in this paper in terms of their benefits and costs:

1) Improved drinking water source within 30 minutes round-trip from household dwelling.
2) Household POU treatment of drinking water with a filtering device.
3) Non-shared, improved sanitation facility.
4) Household members full use of existing sanitation facilities.

Benefits and costs are presented as a ratio of annualized benefits and annualized costs (benefit-cost ratios (BCRs)) over the expected useful life of each intervention.

It should be noted that a comparison of benefits and costs of these four interventions does not imply that the interventions are mutually exclusive. Indeed they can all contribute towards reducing the disease burden from inadequate drinking water and sanitation. However, a ranking of the interventions in terms of high to low benefit-cost ratios (BCRs) provide valuable information as to setting priorities when facing limited resources.

[6] The Joint Monitoring Programme (JMP) of WHO/UNICEF classifies household sanitation into improved and unimproved facilities.

Intervention 1: Improved drinking water source

Overview

The most common type of improved drinking water source is piped water to dwelling in urban areas and tubewell/borehole/hand pump in rural areas (NSS 71, 2014). Thus the intervention is:

i) Piped water to dwelling for urban households without an improved drinking water source.

ii) Tubewell/borehole for rural households without an improved drinking water source or that have more than 30 minutes round-trip to their drinking water source.

Implementation Considerations

An implementation consideration in rural areas is the location of an improved drinking water source relative to household dwelling. A household may continue to use an unimproved source if this source is closer to the dwelling than the improved source. Providing an improved drinking water source within 30 minutes round-trip may also have cost implications if households are sparsely distributed.

Costs and Benefits

Costs

Annualized cost of improved drinking water supply is estimated in the range of Rs. 1,233 – 1,753 per household. This includes initial capital cost of piped water supply or tubewell/borehole and annual operations and maintenance cost (O&M). About 3.6 million households are expected to benefit from this intervention with total annualized cost of Rs. 4.4-6.3 billion.

Benefits

The quantified benefits of the intervention are the value of health improvements and productivity benefits. The largest benefits are avoided mortality and productivity benefits in terms of time savings from water source closer to dwelling. Total annual benefits are Rs. 23-33 billion, depending on valuation method applied. The value of averted deaths accounts for 29-44% of total benefits. Health care cost savings account about 3%. Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 7-9%. And productivity benefits in terms of time savings account for well over half of total benefits in rural areas.

Intervention 2: Household point-of-use treatment of drinking water

Overview

Only a little over 6% of households in Rajasthan practiced appropriate methods of point-of-use (POU) treatment of drinking water a decade ago, compared to over 20% nationwide in India according to the NFHS 3 (2005-06). POU treatment by appropriate methods is likely to have increased somewhat, postulated at 10% currently. Given that water filter was the most common method in Rajasthan, the intervention assessed in this paper is a behavioral change campaign (BCC) that promotes household POU treatment of drinking water with water filter.

Implementation Considerations

A challenge with a BCC program is decisions as to its intensity, which affects both cost and the rate of behavioral change. Thus emphasis ought to be placed on identifying and testing a design that gives a desired behavioral response at an acceptable cost.

Costs and Benefits

Costs

The main household costs of POU treatment of drinking water is the water filter (Rs. 2,000), parts replacement (Rs. 500 per year), and cost of time spent on filtering water (Rs. 440 per year). For scenarios that make 1.5-3.0 million households start POU treatment by filtering of drinking water, the total annualized cost is Rs. 2.1-4.4 billion. Additionally, a BCC program is estimated to cost in the range of Rs. 0.1-1.8 billion annualized, depending on intensity or level of effort, prompting 1.5-3.0 million households to start POU treatment.

Benefits

The total value of the health and productivity benefits of the intervention is estimated at Rs. 10 – 40 billion, depending on valuation method applied and household response to the promotion program. Health care cost savings account for 8-12% of total benefits. Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for 12-20% of total benefits. The value of averted deaths accounts for the remaining benefits.

Intervention 3: Improved sanitation

Overview

The government has been/is undertaking a substantial drive for household sanitation and eradication of open defecation (OD) with a subsidy of up to Rs 12,000 to eligible households. Most households opt for a flush/pour-flush system with a single- or twin-pit. This is therefore the intervention assessed in this paper. A target of 95% household coverage with improved, non-shared sanitation is applied. The government may, however, aim for 100% coverage. The difference has no/negligible effect on the benefit-cost ratios (BCRs), unless the cost of reaching the last 5% of households escalates.

Implementation Considerations

A consideration is the 4.5% of people that continue to practice OD even after construction of a sanitation facility, according to the Swachhta Status Report 2016 (MSPI/GOI, 2017). A sanitation drive may therefore be accompanied by a sanitation use campaign.

Costs and Benefits

Costs

Costs of household sanitation include initial capital cost, periodic emptying of pit or septic tank, annual operations and maintenance (O&M) cost, cost or time for cleaning of sanitation facility, and cost of sanitation promotion programs by the government. An initial capital cost of Rs. 20,000 is applied. This is for the toilet, installation, and construction of superstructure (base, building). Emptying the pit every five years costs around Rs. 1,500. Annual O&M is assumed to be 5% of initial capital cost. Cleaning of sanitation facility is assumed to be 10 minutes per day. Sanitation program cost of Rs. 600 per household (5% of government sanitation budget) that currently do not have improved, non-shared sanitation is assumed to cover promotion of household sanitation, proper designs, and promotion of household members' full use of the facility.

Annualized average rural and urban cost per household is estimated at roughly Rs. 5,550 – 8,200 and total annualized cost of intervention is estimated at Rs. 41–44 billion based on total intervention beneficiaries of 7.2 million households.

Benefits

The total value of the health and productivity benefits of the intervention is estimated at Rs. 228 – 383 billion, depending on valuation method applied. Health care cost savings account for 3-4% of total benefits. Productivity benefits in terms of time savings account for 43-61% of total benefits. Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 6-9% of total benefits. The value of averted deaths accounts for 26-48%.

Intervention 4: Promotion of the use of sanitation facilities

Overview

The Swachhta Status Report 2016 found that 4.5% of household members continue to practice OD after construction of sanitation facility. Faced with a situation of OD among households with sanitation facility, the intervention is a behavioral change campaign (BCC) that promotes the consistent use of existing sanitation facilities.

Implementation Considerations

A challenge with a BCC program is decisions as to its intensity, which affects both cost and the rate of behavioral change. Thus emphasis ought to be placed on identifying and testing a design that gives a desired behavioral response at an acceptable cost.

Costs and Benefits

Costs

Annualized BCC program cost per household ranges from Rs. 11 for the "low" intensity program to Rs. 181 for the "high" intensity program. The program is directed at all households that currently have a sanitary toilet facility as reported by the Swachhta Status Report 2016 (MSPI/GOI, 2017). Thus total annualized program cost is in the range of Rs. 90 - 1,441 million.

As previously stated, some household members do not use their sanitation facility and continue to practice OD. The NSS 69 (2012) finds several reasons for this: i) no toilet superstructure; ii) lack of cleanliness/insufficient water; iii) malfunctioning of the latrine; iv) personal preferences; and v) other reasons. The two most important reasons in Rajasthan were personal preferences (36%) and lack of cleanliness/insufficient water (17%).

Personal preferences for OD imply that these household members perceive some benefits of continuing OD, or cost of giving up their old practice of OD. The magnitude of this cost is unknown. It is therefore in this paper assumed to be (at least) as large as the value of time spent on OD. Moreover, that lack of cleanliness/insufficient water was reported as the second main reason for not using the toilet facility prompts the inclusion of cost of cleaning of toilet facility (or value of time spent on cleaning).

Total cost of intervention is therefore estimated at roughly Rs. 640 – 2,600 million, depending on intensity or level of effort of the promotion program and household member response rates. The cost includes program cost, cost associated with personal preferences, and cost or time used on cleaning toilet facilities.

Benefits

The total value of the health and productivity benefits of the intervention is estimated at Rs. 1.5 – 3.9 billion. Health care cost savings account for about 2% of total benefits. Productivity benefits in terms of time savings account for 65-80% of total benefits. Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 5-6% of total benefits. The value of averted deaths accounts for the remaining benefits.

BCR Table

The benefit-cost ratios (BCRs) are found to be the largest for improved rural sanitation and improved urban drinking water supply, followed by improved urban sanitation, household point-of-use (POU) treatment of drinking water and improved rural water supply. A behavioral change campaign (BCC) promoting the use of existing sanitation by all household members has the lowest BCR.

The quality of evidence associated with three of these interventions range from "medium" to "medium-strong". The BCC intervention is supported by only "limited" quality of evidence.

Table 1a. Summary of the benefits and costs and interventions (Rs million annualized), VSL approach for mortality benefits and Cost of Illness approach for valuing morbidity benefits

	Interventions	Benefit	Cost	BCR	Quality of Evidence
1a	Improved drinking water supply - urban	5,634	486	**11.6**	Medium
1b	Improved drinking water supply - rural	26,477	4,645	**5.7**	Medium
2	BCC promotion of household POU treatment of drinking water*	30,009	3,638	**8.2**	Medium-Strong
3a	Improved sanitation - urban	40,243	5,552	**7.2**	Medium-Strong
3b	Improved sanitation - rural	327,901	36,234	**9.0**	Medium-Strong
4	BCC promotion of use of existing sanitation facilities*	2,789	1,251	**2.2**	Limited

Notes: All figures assume a 5% discount rate, and use VSL for valuation of mortality benefits and cost-of-illness (COI) for valuation of morbidity benefits. * "Mid" scenario. Source: Author.

Table 1b. Summary of the benefits and costs and interventions (Rs million annualized), YLL approach to valuing mortality benefits; YLD approach to measuring morbidity benefits

	Interventions	Benefit	Cost	BCR	Quality of Evidence
1a	Improved drinking water supply - urban	2,650	486	**5.5**	Medium
1b	Improved drinking water supply - rural	20,977	4,645	**4.5**	Medium
2	BCC promotion of household POU treatment of drinking water*	14,707	3,638	**4.0**	Medium-Strong
3a	Improved sanitation - urban	26,518	5,552	**4.8**	Medium-Strong
3b	Improved sanitation - rural	239,607	36,234	**6.6**	Medium-Strong
4	BCC promotion of use of existing sanitation facilities*	2,315	1,251	**1.9**	Limited

Notes: All figures assume a 5% discount rate, and use an approach that values discounted Years of Life Lost (YLLs) at 3x SGDP per capita for valuation of mortality benefits and values Years Lost to Disability (YLDs) also at 3x SGDP per capita for morbidity benefits. * "Mid" scenario. Source: Author.

1. Introduction

1.1 Context and interventions

Diarrheal disease caused nearly 1.7 million deaths globally in 2016. Nearly 0.8 million of these deaths occurred in India of which 90% were due to unsafe drinking water, sanitation and hygiene according to estimates by the Global Burden of Disease 2016 (GBD 2016).

In Rajasthan over 47 thousand deaths were caused by diarrheal disease and intestinal infections (mainly typhoid and paratyphoid) in 2016, constituting 8.7% of all deaths in the state according to GBD 2016, thus remaining a major cause of concern in relation to drinking water and sanitation.

Based on the household drinking water and sanitation situation in the state, four interventions are evaluated in this paper in terms of their benefits and costs:

1) Improved drinking water source within 30 minutes round-trip from household dwelling.
2) Household POU treatment of drinking water with a filtering device.
3) Non-shared, improved sanitation facility.
4) Household members full use of existing sanitation facilities.

Benefits and costs are presented as a ratio of annualized benefits and annualized costs (benefit-cost ratios (BCRs)) over the expected useful life of each intervention. BCRs are presented using discount rates of 3%, 5% and 8%.

It should be noted that a comparison of benefits and costs of these four interventions does not imply that the interventions are mutually exclusive. Indeed they can all contribute towards reducing the disease burden from inadequate drinking water and sanitation. However, a ranking of the interventions in terms of high to low benefit-cost ratios (BCRs) provide valuable information as to setting priorities when facing limited resources.

1.2 Common data

Many of the data utilized in this paper are common to the four interventions. These data are discussed in this section.

Data on household access to drinking water and sanitation, and household point-of-use (POU) treatment of drinking water are mainly from the National Family Health Surveys (NFHS) 4 (2015-16) and 3 (2005-06), and the National Sample Surveys (NSS) 71 (2014) and 69 (2012). These surveys provide state level data for Rajasthan. State level data on the use of existing sanitation facilities are from the Swachhta Status Report 2016 (MSPI/GOI, 2017). This report also provides state level data on household sanitation coverage and open defecation (OD) rates in 2015.

Assessed benefits of the interventions are health improvements and productivity benefits. Health improvements are averted cases of diarrheal and intestinal infectious disease (typhoid and paratyphoid) and associated mortality. Included are also averted cases of infectious disease mortality among young children from a reduction in the effect of repeated diarrheal infections on child underweight and associated mortality. The methodology for estimating health improvements of the interventions are provided in Annex 1.

Other health benefits, such as reduction in intestinal nematode infections, are not included in the assessment, as these health effects are relatively minor in terms of total disease burden compared to mortality and morbidity from diarrheal disease and intestinal infections (typhoid, paratyphoid).

However, fluoride contamination of drinking water is widespread in Rajasthan. Over 6,000 habitations (out of a total of over 121,000 habitations) are affected. More than 4.5 million people live in these habitations, or about 6% of the state's population.[7] This health issue is not directly assessed in this paper, but some types of water filters remove as much as 90% of fluoride from drinking water according to the Fluoride Action Network. These filters are

[7] https://www.hindustantimes.com/jaipur/groundwater-report-rings-fluoride-alarm-in-rajasthan/story-T5SIA99uHK5q4qw6mBIvUI.html

reverse osmosis, deionizers, and activated alumina.[8] Groundwater in Rajasthan is also often high in total dissolved solids (TDS) that pose an additional water supply problem.

The baseline health data used for the estimation of health improvements are from the Global Burden of Disease 2016 (GBD 2016) for the state of Rajasthan.[9]

Averted mortality is valued using two alternative methods:

(i) Value of statistical life at 72 times GDP per capita in Rajasthan, based on methodology developed by the World Bank (2016);
(ii) Years of life lost (YLL) to premature mortality discounted at 3%, 5%, and 8% and valued at 3 times GDP per capita in Rajasthan.

Reduced morbidity or incidence of illness is also valued using two alternative methods:

(i) Cost-of-illness (COI) approach that includes averted health care expenditure and productivity benefits in terms of averted lost work days;
(ii) Years lived with disability (YLDs) valued at 3 times GDP per capita in Rajasthan, where YLD is years or fraction of a year with illness or injury multiplied by a disability weight.

Productivity benefits are time savings and averted loss of work days and care giving associated with illness. Time savings are valued at 50% of average wage rates. Averted lost work days among the working population are valued at average wage rates. Averted days of care giving are valued at 50% of average wage rates. Average wage rates are estimated from GDP per capita and labor force participation rates in Rajasthan, and labor income share of GDP for India. Urban and rural wage differentials are estimated from wage differentials reported in the National Sample Survey 68 (NSS 68). Male/female wage differentials are estimated from the NSS 68 and the Labor and Employment Survey 2015-16.

[8] http://fluoridealert.org/content/top_ten/
[9] https://vizhub.healthdata.org/gbd-compare/india

Table 1.1 Basic data for Rajasthan

	Rajasthan	Remark
Population, 2017	77,124,923	
Baseline mortality, cases in 2016	53,719	Diarrhea, intestinal infectious diseases, indirect effect on infectious disease mortality
Baseline YLDs, 2016	112,679	Diarrhea, intestinal infectious diseases
GDP per capita, 2017 Rs	95,284	
VSL to GDP per capita ratio	72	Method in World Bank and IHME (2016)
VSL, 2017 Rs	6,860,482	Product of GDP per capita and VSL to GDP per capita ratio
Average daily wage rate, 2017 Rs	469	Based on GDP per capita in 2017
Average daily wage rate, Urban, 2017 Rs	738	Based on urban/rural differentials reported in NSS 68
Average daily wage rate, Rural, 2017 Rs	369	Based on urban/rural differentials reported in NSS 68

Costs of interventions are unique to each intervention and discussed in the intervention sections.

1.3 Literature review

The main literature utilized in this paper pertains to the assessment of health benefits of interventions. Wolf et al (2014) present a meta-analysis of relative risks (RRs) of disease and mortality associated with various types of household drinking water and sanitation in low- and middle-income countries globally. Although diarrheal disease and intestinal infections are caused by many factors, the RRs provide the health benefits of improved drinking water supply and sanitation (relative to unimproved drinking water supply and unimproved or no sanitation) as well as the health benefits of household point-of-use (POU) treatment of drinking water from various sources. The RRs associated with each intervention is applied to the baseline diarrheal and intestinal infectious disease burden to estimate health benefits. There is no need for baseline disease burden data for drinking water supply and sanitation separately.

The meta-analysis by Wolf et al include studies of 20 comparisons of alternative drinking water supplies, 48 comparisons of POU treatment vs. no POU treatment, and 12 comparisons of improved vs. unimproved sanitation. These studies were included in the meta-analysis from a review and assessment of a larger set of studies. Pruss-Ustun et al (2014) utilize the RRs in Wolf et al and provide a framework and methodology for estimating preventable disease burden from inadequate drinking water and sanitation. Olofin et al (2013) provide a methodology for estimating child mortality associated with poor nutritional status of children, and Fewtrell et al (2007) provide guidance on the magnitude of effect of diarrheal disease in early childhood on children's nutritional status (annex 1).

For improved sanitation, the RR from a study of rural households in India by Andres et al (2014) is utilized. This study assessed both the direct health benefit of improved sanitation to the household as well as the external health benefit to the community of high sanitation coverage rates. The study was also utilized by a recent report on costs and benefits of sanitation in India by UNICEF (UNICEF, 2018).

Sufficient research evidence of recent origin and high quality of the magnitude of RRs in Rajasthan or even in India is not available for the other interventions. Results from the global meta-analysis by Wolf et al, as well as Olofin et al/Fewtrell et al, are therefore applied to Rajasthan. This can only provide an indication, rather than a precise estimate, of the health benefits one may expect from the four interventions assessed in this paper because the health benefits depend critically on location specific factors such as natural, physical, socio-economic and behavioral factors. A sensitivity analysis of the RRs that determine the estimated magnitude of health benefits is therefore warranted. As is reported in each intervention section, the benefit-cost ratios (BCRs) of interventions are not very sensitive to changes in the RRs for some of the interventions (because of the presence of substantial non-health benefits) while for others they are.

The magnitude of health benefits of interventions is also influenced by the quality and access to public health services and medical care, as well as home management of (diarrheal) infections. These factors influence in particular case fatality rates of (diarrheal) infections. However, this is reflected in the baseline health data used for estimating the health benefits of interventions.

1.4 Household drinking water and sanitation situation

Over 85% of households in Rajasthan had access to an improved drinking water source in 2015-16, up from 82% in 2005-06 according to the National Family Health Survey 4 (NFHS 4). This is defined in the NFHS 4 as piped water into dwelling/yard/plot, public tap/standpipe, tube well or borehole, protected dug well, protected spring, rainwater, and community reverse-osmosis (RO) plant.

Improved drinking water sources are generally considered having a lesser risk of pathogen contamination than unimproved sources (e.g., shallow dug wells, unprotected springs, open surface water). Water from improved sources are, however, not necessarily safe to drink (Pruss-Ustun et al, 2014). Nevertheless, only 6% of households practiced point-of-use (POU) treatment of their drinking water in 2005-06, mainly by filtering (NFHS 3). Moreover, as much as a quarter of the rural population in Rajasthan has more than 30 minutes round-trip to their drinking water source, particularly affecting women and children who often perform the task of fetching drinking water.

About 52% of households in Rajasthan had a sanitary toilet facility in 2015 according to the Swachhta Status Report 2016 (MSPI/GOI, 2017). Moreover, 45% of households had access to an improved non-shared sanitation facility in 2015-16 according to the National Family Health Survey IV. Thus about 7% of households shared a sanitation facility with other households in 2015. An improved sanitation facility is defined in the NFHS 4 as flush/pour-flush toilets to piped sewer system, septic tank, or pit latrine; ventilated improved pit (VIP)/biogas latrine; pit latrine with slab; twin pit/composting toilet; which facility is not shared with any other household.

The Swachhta Status Report 2016 also reveals that 4.5% of persons with a sanitary toilet facility continued to practice open defecation (OD). Additionally, 48% of households had no sanitation facility and practiced OD in 2015 (MSPI/GOV, 2017). A substantial drive by the government for household sanitation and eradication of OD has, however, reduced this figure quite substantially since 2015.

2. Improved drinking water source

2.1 Description of intervention

Rajasthan is a heterogeneous state with varying geo-hydrological and climatic conditions, with seasonality playing a crucial role in ensuring water security. About 92% of urban households in Rajasthan had an improved drinking water source in 2015-16, but only 83% did so in rural areas of the state (NFHS 4, 2015-16). Moreover, a substantial share of households in rural areas has more than 30 minutes round-trip to their drinking water source.

Households in the state have access to a variety of types of drinking water sources, including about one-third of rural households having tap water. However, the most common type of improved drinking water source is piped water to dwelling in urban areas and tubewell/borehole/hand pump in rural areas (NSS 71, 2014). Thus the intervention is:

i) Piped water to dwelling for urban households without an improved drinking water source.

ii) Tubewell/borehole for rural households without an improved drinking water source or that have more than 30 minutes round-trip to their drinking water source.

Health benefits are estimated for urban and rural households that currently rely on unimproved drinking water sources. For rural households, time savings benefits are estimated for households that currently have more than 30 minutes to drinking water source, whether this source is improved or unimproved. Distant unimproved sources may not be contaminated by pathogens or other pollutants, but there is risk of pathogen contamination during extraction, transportation and storage of water prior to drinking.

Two important drinking water supply dimensions in Rajasthan are, however, not addressed in this paper. That is fluoride contamination and total dissolved solids (TDS) in groundwater that pose an additional water supply problems. Some types of household water filters can, however, effectively deal with these problems (see next intervention).

2.2 Calculation of Costs and Benefits

Most of the data used for the calculation of costs and benefits of the improved drinking water intervention are presented in section 1.2. Remaining data are presented below.

2.2.1 Costs

Costs of improved drinking water supply include initial capital cost, and annual operations and maintenance (O&M) cost. No promotion program is needed as the intervention is here considered public works.

An initial capital cost of Rs. 15,000 is applied with annual O&M cost at 1.5% of initial capital cost. Annualized cost per household is estimated at Rs. 1,429 (table 2.1) and total annualized cost of intervention is estimated at Rs. 5.1 billion (table 2.2) based on total intervention beneficiaries of 3.6 million households (see next section).

Table 2.1. Cost of improved drinking water supply (Rs per household)

Capital cost	15,000
Useful life (years)	20
Annualized capital cost	1,204
O&M (1.5% of capital cost per year)	225
Total annualized intervention cost	**1,429**

Note: Discount rate: 5%.

Table 2.2. Total annualized cost of intervention, Rs million

	Urban	Rural	Total
Beneficiary households (000)	340	3,251	3,591
Total annualized cost, Rs million	**486**	**4,645**	**5,131**

Note: Discount rate: 5%. Source: Estimates by author.

2.2.2 Benefits

For the estimation of health benefits of the intervention, the population or households of Rajasthan are distributed in four categories of drinking water supply according to current cover (Pre-intervention) and the expected distribution after the implementation of the intervention (Post-intervention) (table 2.3). Cover is based on NFHS 4 (2015-16) while time to drinking water source is based on projections from NFHS 3 (2005-06). While the current percent of households having more than 30 minute round-trip to drinking water source is uncertain, the pre- and post-intervention population distribution has minimal effect on the benefit-cost ratios (BCRs) of the intervention and only on total benefits and costs of the intervention.

The risk (RR) of illness and mortality associated with the use of an improved drinking water source (i.e., the intervention) is 0.77 for urban households (piped water) and 0.89 for rural households (tubewell/borehole) *relative* to unimproved sources (see Annex 1). This means that the disease reduction from the intervention is 23% and 11% for urban and rural households respectively who currently rely on unimproved drinking water sources.

Table 2.3. Population distribution by type of drinking water supply in Rajasthan

Pre-intervention	Urban	Rural	Total	RR Urban	RR Rural
Improved drinking water; access < 30 min	92%	71%	76%	0.77	0.89
Improved drinking water; access > 30 min	0%	13%	9%	0.77	0.89
Unimproved drinking water; access < 30 min	8%	4%	5%	1.0	1.0
Unimproved drinking water; access > 30 min	0%	13%	9%	1.0	1.0
Post-intervention					
Improved drinking water; access < 30 min	100%	100%	100.0%	0.77	0.89
Improved drinking water; access > 30 min	0%	0%	0.0%	0.77	0.89
Unimproved drinking water; access < 30 min	0%	0%	0.0%	1.0	1.0
Unimproved drinking water; access > 30 min	0%	0%	0.0%	1.0	1.0

Source: Author.

The intervention would benefit about 3.6 million households. The Potential Impact Fraction (PIF) formula is applied to the data in table 2.3 to estimate health benefits (see Annex 1), with estimated cases of nearly 1,100 deaths and 2.2 million cases of diarrheal illness averted per year (table 2.4).

Table 2.4. Health benefits of intervention

	Urban	Rural	Total
Beneficiary households (000)	340	3,251	3,591
Averted deaths per year	335	752	1,087
Averted YLDs per year	702	1,578	2,280
Averted cases of diarrhea per year (000)	683	1,536	2,219

Source: Estimates by author.

The total annualized value of the health and productivity benefits of the intervention is estimated at Rs. 25 – 32 billion, depending on valuation method used for valuation of deaths averted, i.e., VSL or YLL at 3 times GDP per capita (table 2.5). The value of averted deaths accounts for 29-44% of total benefits. Health care cost savings, accounting for about 3% of total benefits, are estimated based on a diarrheal disease treatment rate of 30% and a treatment cost of Rs. 1,333 per case.

Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 7-9% of total benefits. A loss of two work days are assumed to be averted per case of diarrhea averted among the working population, valued at average wage rates. Caregiving for children is valued at 50% of wage rates per day of child illness.

Productivity benefits in terms of time savings account for well over half of total benefits in rural areas. Time savings are 30 minutes per household per day for those who would receive drinking water supply in the proximity of their home. These time savings are valued at 50% of average female wage rates.

Table 2.5. Value of benefits of intervention, Rs million per year

	Urban	Rural	Total
Value of deaths averted			
Valuation method: VSL	4,315	9,697	14,012
Valuation method: YLL=3*GDP per capita	2,273	5,108	7,381
Health care cost savings	289	601	890
Productivity benefits (averted lost work days)	1,030	1,157	2,187
Productivity benefits (time savings)	0	15,021	15,021
Total benefits			
VSL	**5,634**	**26,477**	**32,110**
YLL=3*GDP per capita	**3,592**	**21,888**	**25,480**

Note: Discount rate: 5%. Source: Estimates by author.

An alternative valuation of health benefits is presented in table 2.6. Averted mortality is valued as in table 2.5. Reduced morbidity in terms of averted YLDs is, however, valued at 3 times GDP per capita instead of health care cost savings and averted lost work days and caregiving. This gives 6-7% lower total benefits.

Table 2.6. Alternative value of benefits of intervention, Rs million per year

	Urban	Rural	Total
Value of deaths averted			
Valuation method: VSL	4,315	9,697	14,012
Valuation method: YLL=3*GDP per capita	2,273	5,108	7,381
Value of YLD averted	377	848	1,225
Productivity benefits (time savings)	0	15,021	15,021
Total benefits			
VSL	**4,692**	**25,566**	**30,258**
YLL=3*GDP per capita	**2,650**	**20,977**	**23,627**

Note: Discount rate: 5%. Source: Estimates by author.

2.2.3 Benefit-cost ratios

A comparison of benefits and costs, and benefit-cost ratios (BCRs) are presented in four tables. All tables use either VSL or the value of YLL at 3 times GDP per capita for valuation of averted deaths. All tables also include the value of time savings. The two first tables use the cost-of-illness (COI) approach, i.e., health care cost savings and productivity benefits, to value the benefits of averted illness. The two last tables use valuation of YLDs as discussed above.

Benefits and costs are larger in rural than urban areas as most of the beneficiaries are rural. BCRs are, however, larger for urban households than for rural households. This is because the percentage disease reduction from piped water supply for urban households (23%) is larger than the reduction from tubewell/borehole for rural households (11%).

BCRs using health care savings and productivity benefits are in the range of 3.4-14.0 (tables 2.7a-b). They are somewhat larger using VSL than valuation of YLL.

BCRs using YLD are in the range of 3.2-11.6 (tables 2.7c-d). They are again somewhat larger using VSL than valuation of YLL.

Table 2.7a. Benefits and costs of intervention, Rs million per year and BCRs

VSL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban	5,850	419	**14.0**	5,634	486	**11.6**	5,634	596	**9.5**
Rural	27,517	4,010	**6.9**	26,477	4,645	**5.7**	26,477	5,699	**4.6**

Source: Estimates by author.

Table 2.7b. Benefits and costs of intervention, Rs million per year and BCRs

YLL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban	4,539	419	**10.8**	3,592	486	**7.4**	2,818	596	**4.7**
Rural	24,571	4,010	**6.1**	21,888	4,645	**4.7**	19,387	5,699	**3.4**

Source: Estimates by author.

Table 2.7c. Benefits and costs of intervention, Rs million per year and BCRs

VSL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban	4,880	419	**11.6**	4,692	486	**9.7**	4,433	596	**7.4**
Rural	26,592	4,010	**6.6**	25,566	4,645	**5.5**	24,155	5,699	**4.2**

Source: Estimates by author.

Table 2.7d. Benefits and costs of intervention, Rs million per year and BCRs

YLL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban	3,569	419	**8.5**	2,650	486	**5.5**	1,915	596	**3.2**
Rural	23,646	4,010	**5.9**	20,977	4,645	**4.5**	18,496	5,699	**3.2**

Source: Estimates by author.

2.3 Assessment of Quality of Evidence

The dimensions that most importantly affect the estimated benefits and costs of the intervention are presented in table 2.8. Quantified health benefits of the intervention are proportional to the baseline health data. These data are most likely of medium-strong quality. The relative risk (RR) of disease and mortality reductions from improved drinking water supply vs. unimproved is based on a meta-analysis of 20 studies (Wolf et al, 2014). This meta-analysis found an overall RR that is quite consistent with previous meta-analyses (e.g., Waddington et al, 2009). The value of statistical life (VSL) used for valuation of mortality benefits is from a benefit-transfer function developed by the World Bank (World Bank, 2016). The function is based on meta-analysis of VSL studies from mostly high- and medium-income countries and other available evidence of VSL by country income level. Productivity benefits in terms of time savings account for about 50% of total benefits. The time savings are based on limited evidence as studies of these savings are very limited.

In terms of cost of intervention, capital cost and O&M is a rough estimate.

Table 2.8. Quality of evidence

	Quality of evidence
Benefits of intervention:	
Baseline health data	Medium-Strong
Relative risks (RR) for health benefits	Medium-Strong
Valuation of mortality	Medium-Strong
Productivity benefits (time savings)	Medium-Strong
Cost of intervention:	
Capital and O&M	Limited-Medium
Total evidence	**Medium**

Source: Author.

2.4 Sensitivity Analysis

An analysis is carried out as to the sensitivity of the BCRs to some of the dimensions in table 2.8: i) the magnitude of the relative risks (RRs); ii) the productivity benefits (time savings); and iii) capital cost of intervention. The analysis assesses a 50% change in these parameters in the direction of lowering the BCRs. The sensitivity analysis is relative to the base case of using VSL for mortality and cost-of-illness (COI) for morbidity benefits, and a discount rate of 5%.

The results are presented in table 2.9:

i) The sensitivity of the BCR in urban areas is more or less proportional to the change in RR while the BCR is quite insensitive in rural areas. This is because the benefits are urban areas are entirely health benefits, while time savings is a large part of benefits in rural areas.

ii) A change in time savings from 30 min to 15 minutes per household per day has no effect on the BCR in urban areas as there are no time savings. The effect on the BCR in rural areas is relatively modest as time savings is only part of total benefits.

iii) An increase in the capital cost of intervention from Rs. 15,000 to Rs. 22,500 reduces the BCR by one-third in both urban and rural areas.

Table 2.9 BCR sensitivity analysis

		Urban	Rural
	Base case BCR	**11.6**	**5.7**
i)	BCR with 50% change in RR (urban RR=0.885; rural RR=0.945)	5.1	4.4
ii)	BCR with 50% change in time savings (15 min per household per day)	11.6	4.1
iii)	BCR with 50% higher capital cost of intervention (Rs. 22.500 per household)	7.7	3.8

Source: Estimates by author.

3. Household point-of-use treatment of drinking water

3.1 Description of intervention

Only a little over 6% of households in Rajasthan practiced appropriate methods of point-of-use (POU) treatment of drinking water a decade ago, compared to over 20% nationwide in India according to the NFHS 3 (2005-06). The main appropriate method in Rajasthan was the use of a water filter while boiling was most common nationwide. However, nearly 45% of households in Rajasthan strained drinking water through a cloth, but this is not considered an appropriate method.

Recent data on POU treatment from the NFHS 4 (2015-16) were not publicly available at the time of writing this paper. POU treatment by appropriate methods is likely to have increased somewhat, postulated at 10% currently.

Given the low rate of POU treatment by appropriate methods, and that water filter was the most common method in Rajasthan, the intervention assessed in this paper is a behavioral change campaign (BCC) that promotes household POU treatment of drinking water with water filter. Such a BCC program needs to include an assessment of the reasons for the low rate of POU treatment of drinking water in Rajasthan so that obstacles can be overcome. It also needs to raise awareness of health benefits, as well as ensure that households properly maintain the filter devices and replace necessary parts at regular intervals.

As previously mentioned, groundwater in many districts in Rajasthan is affected by fluorides and/or total dissolved solids (TDS). Some water filters can effectively deal with these problems. Reverse osmosis, deionizers, and activated alumina type water filters can remove as much as 90% of fluoride from drinking water according to the Fluoride Action Network.[10] Reverse osmosis water filters, among some other types of filters, can remove most of TDS.

3.2 Literature Review

The challenge with an assessment of the benefits and costs of a BCC that promotes POU treatment of drinking water is the determination of the effectiveness of the campaign and the cost of the campaign in relation to its effectiveness. Three handwashing (HW) programs can shed some light on this. These programs achieved behavioral change rates of 10% to 18% of targeted households. Costs per household of the program that achieved 18% behavioral change is multiple times higher than the program that achieved 10%, demonstrating the rapidly rising marginal program cost in relation to behavioral change rates (table 3.1).

"Low", "mid" and "high" intensity promotion programs of 10%, 15% and 20% behavioral change rate is applied in this paper to the BCC for promotion of POU treatment of drinking water, with costs in table 3.1 adjusted for annual inflation to 2017.

Table 3.1. Cost of behavioral change promotion

	Guatemala	Thailand	Burkino Faso
Behavioral change (% of target population)	10%	16%	18%
Program Cost per Target Household (US $)	0.35	1.2	5.0
Program Cost per Household with Behavioral Change (US $)	3.6	7.4	27.9

Source: Derived from Saade et al (2001), Pinfold and Horan (1996), and Borghi et al (2002).

3.3 Calculation of Costs and Benefits

Most of the data used for the calculation of costs and benefits of the BCC intervention for POU treatment are presented in section 1.2. Remaining data are presented below.

[10] http://fluoridealert.org/content/top_ten/

3.3.1 Costs

An average water filter for POU of drinking water costs about Rs. 2,000 based on an online market review.[11] Parts replacement may be around Rs. 500 per year. There is also a cost of time spent on filtering water, here 2 minutes per household per day valued at 50% of wage rates. These costs are applicable to around 1.5-3.0 million households expected to start POU of drinking water as a result of BCC promotion program (table 3.2).

Table 3.2. Cost of POU treatment of drinking water

	Low	Mid	High
Households starting POU of drinking water (000)	1,523	2,285	3,046
Cost of water filter (Rs per household)	2000	2000	2000
Useful life (years)	5	5	5
Annualized capital cost (Rs per household)	462	462	462
Parts replacement (1 time per year), Rs per household	500	500	500
Cost of time spent on water filtering (Rs/household/year)	430	430	430
Sub-total annualized cost, Rs million (all households)	**2,120**	**3,180**	**4,241**

Note: Discount rate: 5%. Source: Author.

The BCC program promoting POU treatment of drinking water is undertaken once over the assumed 5 years of useful life of the water filter. Costs are according to table 3.1 and adjusted for annual inflation. The program is directed at all households (table 3.3). The cost of the BCC program is only substantial in comparison with the private costs in table 3.2 for the "high" intensity program.

Table 3.3. Cost of BCC program

	Low	Mid	High
Program promotion cost per household (US$)	0.35	1.20	5.00
Program promotion cost per household (US$), 2017	0.5	2.0	7.4
Program promotion cost per household (Rs)	30	130	480
Annualized program promotion cost per HH (Rs)	6.9	30	111
Households targeted by POU promotion (000)	15,230	15,230	15,230
Total annualized program promotion cost (Rs million)	**106**	**457**	**1,689**

Note: Discount rate: 5%. Source: Author.

5.3.2 Benefits

For the estimation of health benefits of the intervention, the population or households of Rajasthan are distributed in two categories of household currently practicing and not practicing POU treatment of drinking water (Pre-intervention) and the expected distribution after the implementation of the intervention (Post-intervention) (table 3.4). While the

[11] https://www.amazon.in/Water-Filters-Purifiers/b?ie=UTF8&node=1380262031

current POU treatment rate is uncertain, the pre-intervention population distribution has minimal effect on the benefit-cost ratios (BCRs) of the intervention and only on total benefits and costs of the intervention.

The relative risk (RR) of illness and mortality are weighted average RR for POU treatment of piped drinking water in urban and other improved drinking water sources in rural (Pruss-Ustun et al, 2014). The RR means that the disease reduction from POU treatment is 35%. The BCC intervention effectiveness is discussed above, ranging from 10% to 20%.

Table 3.4. Population distribution by household POU treatment of drinking water in Rajasthan

	Low	Mid	High	RR
Pre-intervention				
POU treatment (appropriate method)	10%	10%	10%	**0.65**
Not appropriate or no treatment	90%	90%	90%	**1.0**
BBC Water Filter promotion effectiveness (% behavioral change rate)	**10%**	**15%**	**20%**	
Post-intervention				
POU treatment (appropriate method)	20%	25%	30%	**0.65**
Not appropriate or no treatment	80%	75%	70%	**1.0**

Source: Author.

The intervention would make 1.5-3.0 million households start POU treatment of drinking water. The Potential Impact Fraction (PIF) formula is applied to the data in table 3.4 to estimate health benefits (see Annex 1), with estimated cases of about 1,900-3,900 deaths and 3.9-7.9 million cases of diarrheal illness averted per year (table 3.5).

Table 3.5. Health benefits of intervention

	Low	Mid	High
Households starting POU of drinking water (000)	1,523	2,285	3,046
Averted deaths per year	1,929	2,894	3,858
Averted YLDs per year	4,046	6,070	8,093
Averted cases of diarrhea per year (000)	3,939	5,908	7,877

Source: Estimates by author.

The total annualized value of the health and productivity benefits of the intervention is estimated at Rs. 12 – 40 billion (table 3.6). The value of averted deaths accounts for 68-80% of total benefits. Health care cost savings, accounting for 8-12% of total benefits, are estimated based on a diarrheal disease treatment rate of 30% and a treatment cost of Rs. 1,285 per case.

Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for 12-20% of total benefits. A loss of two work days are assumed to be averted per case of diarrhea averted among the working population, valued at average wage rates. Caregiving for children is valued at 50% of wage rates per day of child illness.

Table 3.6. Value of benefits of intervention, Rs million per year

	Low	Medium	High
Value of deaths averted			
VSL	15,964	23,946	31,929
YLL=3*GDP per capita	8,410	12,615	16,819
Health care cost savings	1,518	2,277	3,037
Productivity benefits (averted lost work days and caregiving)	2,422	3,633	4,843
Total benefits			
VSL	**19,904**	**29,856**	**39,809**
YLL=3*GDP per capita	**12,350**	**18,525**	**24,699**

Note: Discount rate: 5%. Source: Estimates by author.

An alternative valuation of health benefits is presented in table 3.7. Averted mortality is valued as in table 3.6. Reduced morbidity in terms of averted YLDs is, however, valued at 3 times GDP per capita instead of health care cost savings and averted lost work days and caregiving. This gives 11-13% lower total benefits.

Table 3.7. Alternative value of benefits of intervention, Rs million per year

	Low	Medium	High
Value of deaths averted			
VSL	15,964	23,946	31,929
YLL=3*GDP per capita	8,410	12,615	16,819
Value of YLD averted	1,395	2,093	2,790
Total benefits			
VSL	**17,360**	**26,039**	**34,719**
YLL=3*GDP per capita	**9,805**	**14,707**	**19,610**

Note: Discount rate: 5%. Source: Estimates by author.

3.3.3 Benefit-cost ratios

A comparison of benefits and costs, and benefit-cost ratios (BCRs) are presented in four tables, as for the previous interventions. All tables use either VSL or the value of YLL at 3 times GDP per capita for valuation of averted deaths. The two first tables use the cost-of-illness (COI) approach, i.e., health care cost savings and productivity benefits, to value the benefits of averted illness. The two last tables use valuation of YLDs as discussed above.

BCRs using health care savings and productivity benefits are in the range of 3.2-9.1 (tables 3.8a-b). They are larger using VSL than valuation of YLL, especially at higher discount rates.

BCRs using YLD are in the range of 2.4-8.0 (tables 3.8c-d). They are again somewhat larger using VSL than valuation of YLL.

The BCRs are declining with increased intensity (from "low" to "high") of the BCC program, because of rising unit costs of achieving behavioral change.

Table 3.8a. Benefits and costs of intervention, Rs million per year and BCRs

VSL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	19,950	2,183	**9.1**	19,904	2,226	**8.9**	19,837	2,292	**8.7**
Mid	29,926	3,558	**8.4**	29,856	3,638	**8.2**	29,755	3,762	**7.9**
High	39,901	5,763	**6.9**	39,809	5,929	**6.7**	39,674	6,185	**6.4**

Source: Estimates by author.

Table 3.8b. Benefits and costs of intervention, Rs million per year and BCRs

YLL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	15,276	2,183	**7.0**	12,350	2,226	**5.5**	10,013	2,292	**4.4**
Mid	22,914	3,558	**6.4**	18,525	3,638	**5.1**	15,019	3,762	**4.0**
High	30,552	5,763	**5.3**	24,699	5,929	**4.2**	20,025	6,185	**3.2**

Source: Estimates by author.

Table 3.8c. Benefits and costs of intervention, Rs million per year and BCRs

VSL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	17,403	2,183	**8.0**	17,360	2,226	**7.8**	17,296	2,292	**7.5**
Mid	26,104	3,558	**7.3**	26,039	3,638	**7.2**	25,944	3,762	**6.9**
High	34,806	5,763	**6.0**	34,719	5,929	**5.9**	34,592	6,185	**5.6**

Source: Estimates by author.

Table 3.8d. Benefits and costs of intervention, Rs million per year and BCRs

YLL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	12,729	2,183	**5.8**	9,805	2,226	**4.4**	7,472	2,292	**3.3**
Mid	19,093	3,558	**5.4**	14,707	3,638	**4.0**	11,208	3,762	**3.0**
High	25,457	5,763	**4.4**	19,610	5,929	**3.3**	14,944	6,185	**2.4**

Source: Estimates by author.

3.4 Assessment of Quality of Evidence

The dimensions that most importantly affect the estimated benefits and costs of the intervention are presented in table 3.9. The quality of evidence of the baseline health data and valuation of mortality is discussed before. The relative risk (RR) of disease and mortality reductions from POU treatment of drinking water is based on a meta-analysis of 48 studies (Wolf et al, 2014).

In terms of cost of intervention, the cost of water filter and maintenance is by far the largest cost component and has medium-strong evidence.

Table 3.9. Quality of evidence

	Quality of evidence
Benefits of intervention:	
Baseline health data	Medium-Strong
Relative risks (RR) for health benefits	Medium-Strong
Valuation of mortality	Medium-Strong
Cost of intervention:	
Cost of water filter and maintenance	Medium-Strong
Total evidence	**Medium-Strong**

Source: Author.

3.5 Sensitivity Analysis

An analysis is carried out as to the sensitivity of the BCRs to two of the dimensions in table 3.9: i) the magnitude of the relative risks (RRs); and ii) cost of intervention. The analysis assesses a 50% change in these parameters in the direction of lowering the BCRs. The sensitivity analysis is relative to the base case of using VSL for mortality and cost-of-illness (COI) for morbidity benefits, and a discount rate of 5%.

The results are presented in table 3.10:

i) The sensitivity of the BCR is proportional to the change in RR. This is because the benefits are entirely health benefits.

ii) An increase of 50% in each of the components of the cost of intervention separately reduces the BCR only somewhat. A simultaneous increase in the cost of all components reduces the BCR by one-third.

Table 3.10. BCR sensitivity analysis

		Mid-case
	Base case BCR	**8.2**
i)	BCR with 50% change in RR (RR=0.825)	4.1
ii)	BCR with 50% higher cost of water filter (Rs. 3,000 per household)	7.2
	BCR with 50% higher cost of parts replacement (Rs. 750 per year per household)	7.1
	BCR with 50% higher cost of time spent on treatment (3 minutes per household per day)	7.2
	BCR with 50% higher program promotion cost	7.7
	BCR with 50% higher cost of all cost components	5.5

Source: Estimates by author.

4. Improved sanitation

4.1 Description of intervention

About 52% of households in Rajasthan had a sanitary toilet facility in 2015 according to the Swachhta Status Report 2016 (MSPI/GOI, 2017). Moreover, 45% of households had access to an improved non-shared sanitation facility in 2015-16 according to the National Family Health Survey IV.[12] Thus about 7% of households shared a sanitation facility with other households in 2015. An improved non-shared sanitation facility is defined in the NFHS 4 as flush/pour-flush toilets to piped sewer system, septic tank, or pit latrine; ventilated improved pit (VIP)/biogas latrine; pit latrine with slab; twin pit/composting toilet; which facility is not shared with any other household.

The Swachhta Status Report 2016 also reveals that 4.5% of persons with a sanitary toilet facility continued to practice open defecation (OD). Additionally, 48% of households had no sanitation facility and practiced OD in 2015 (MSPI/GOV, 2017). A substantial drive by the government for household sanitation and eradication of OD has, however, reduced this figure quite substantially since 2015. Nevertheless, sanitation programs inevitably encounter challenges of quality of construction, choice of appropriate sanitation technology, and achieving sustained OD free communities.

[12] The Joint Monitoring Programme (JMP) of WHO/UNICEF classifies household sanitation into improved and unimproved facilities

The most common household sanitation facility in Rajasthan is a flush/pour-flush toilet in both urban and rural areas. The Government of India is promoting household sanitation facilities with a monetary incentive up to Rs 12,000 to eligible households. Most households opt for a flush/pour-flush system with a single- or twin-pit. This is therefore the intervention assessed in this paper, with the aim of reaching 95% household coverage with improved, non-shared sanitation. The government may, however, aim for 100% coverage. The difference has no/negligible effect on the benefit-cost ratios (BCRs), unless the cost of reaching the last 5% of households escalates.

Institutional sanitation (sanitation facilities at pre-schools, schools, health facilities, etc.), albeit important, is not assessed in this paper.

4.2 Calculation of Costs and Benefits

Most of the data used for the calculation of costs and benefits of the sanitation intervention are presented in section 1.2. Remaining data are presented below.

4.2.1 Costs

Costs of household sanitation include initial capital cost of the sanitation facility, periodic emptying of pit or septic tank, regular cleaning of the facility, annual operations and maintenance (O&M) cost, and cost of sanitation promotion programs by the government.

An initial capital cost of Rs. 20,000 is applied. This is for the toilet, installation, and construction of superstructure (base, building). This is the cost reported in a recent survey of over 10,000 households in 12 states conducted by UNICEF in 2017 (UNICEF, 2018), reflecting the cost paid by households and cost paid by the government among the poorest two quintiles of households, which are the households that are most likely to still not have improved sanitation. The cost may be higher or lower for some households. The impact of this on the benefit-cost ratios (BCR) is assessed in the sensitivity analysis.

Each of the government recommended twin-pits is 4-feet deep and 3-4 feet wide and takes an average household about 5 years to fill. Once one is full, the second pit is put into use while the fecal matter in the first pit breaks down. Emptying the pit costs around Rs 1,500.[13] Cleaning of the sanitation facility is assumed to take 10 minutes per day, with time valued at 50% of urban and rural wage rates.[14] Sanitation program cost of Rs. 600 per household (5% of government sanitation budget) that currently do not have improved non-shared sanitation is assumed to cover promotion of household sanitation, proper designs, and promotion of household members full use of the facility.

Annualized cost per rural and urban household is estimated at Rs. 5,553 – 8,182 (table 4.1) and total annualized cost of intervention is estimated at nearly Rs. 42 billion (table 4.2) based on total intervention beneficiaries of 7.2 million households (see next section). Cost of cleaning constitutes more than half of the cost for urban households and nearly half of the cost for rural households.

Table 4.1. Cost of household sanitation (Rs per household)

	Urban	Rural	Remark
Capital cost	20,000	20,000	Initial cost
Emptying of pit	1,500	1,500	Once per 5 years
Cost of cleaning per year	5,258	2,629	10 minutes per household per day
O&M cost	1,000	1,000	5% of capital cost per year
Program cost	600	600	Once per household
Annualized cost, Rs	**8,182**	**5,553**	Per household

Note: Discount rate: 5%. Source: The author.

Table 4.2. Total annualized cost of intervention, Rs million

	Urban	Rural	Total
Beneficiary households (000)	679	6,525	7,203
Total annualized cost, Rs million	**5,552**	**36,234**	**41,786**

Note: Discount rate: 5%. Source: Estimates by author.

4.2.2 Benefits

For the estimation of health benefits of the intervention, the population or households of Rajasthan are distributed in four categories of household sanitation according to current sanitation cover (Pre-intervention) and the expected distribution after the implementation of the intervention which aims to reduce the population with shared and unimproved or no sanitation to 5% in both urban and rural areas (Post-intervention) (table 4.3). Cover is based

[13] ttps://scroll.in/article/759201/swachh-bharat-in-rajasthan-a-village-shows-why-open-defecation-is-ending-only-on-paper

[14] 10 minutes per day is here considered sufficient in order to reap the diarrheal risk reduction applied in this paper. Households may, however, spend more time on cleaning for aesthetic and status benefits that are not captured in this paper. In the survey by UNICEF in July-August 2017, households report an average cleaning time of the sanitation facility of about 30 minutes per day.

on the Swachhta Status Report 2016 (MSPI/GOI, 2017) and NFHS 4 (2015-16) for Rajasthan. Non-use of existing facilities is based on the Swachhta Status Report 2016. While the current sanitation cover and non-use of existing facilities is uncertain in light of the government's drive to increase coverage, the pre- and post-intervention population distribution has minimal effect on the benefit-cost ratios (BCRs) of the intervention and only on total benefits and costs of the intervention.

The risk (RR) of illness and mortality associated with the use of an improved, non-shared sanitation facility (i.e., the intervention) is 0.53 *relative* to unimproved or no sanitation facility. This includes the direct health benefit to the household adopting improved sanitation and the external health benefit to the community, as estimated by Andres et al (2014) (see Annex 1). The RR associated with the use of shared sanitation facilities is here assumed to be 0.77. Thus disease reduction from the intervention is 47% and 23%, respectively.

Table 4.3. Population distribution by type of household sanitation in Rajasthan

Pre-intervention	Urban	Rural	Total	RR
Have improved non-shared sanitation and using it	71.5%	33.4%	42.6%	**0.53**
Have improved non-shared sanitation BUT not using it	1.0%	2.2%	2.4%	**1.0**
Shared sanitation	17.8%	2.4%	7.2%	**0.77**
Other unimproved or no sanitation	9.7%	62.0%	47.8%	**1.0**
Post-intervention				
Intervention target (access rate of improved non-shared sanitation)	95%	95%	95%	
Have improved non-shared sanitation and using it	94.0%	89.5%	90.7%	**0.53**
Have improved non-shared sanitation BUT not using it	1.0%	5.5%	4.3%	**1.0**
Shared sanitation	0.9%	0.1%	0.4%	**0.77**
Other unimproved on no sanitation	4.1%	4.9%	4.6%	**1.0**

Source: Author.

The intervention would benefit about 7.2 million households. The Potential Impact Fraction (PIF) formula is applied to the data in table 4.3 to estimate health benefits (see Annex 1), with estimated cases of over 13,600 deaths and nearly 28 million cases of diarrheal illness averted per year (table 4.4).

Table 4.4. Health benefits of intervention

	Urban	Rural	Total
Beneficiary households (000)	679	6,525	7,203
Averted deaths per year	1,540	12,077	13,617
Averted YLDs per year	3,230	25,332	28,562
Averted cases of diarrhea per year (000)	3,143	24,657	27,800

Source: Estimates by author.

The total value of the health and productivity benefits of the intervention is estimated at Rs. 285 – 368 billion, depending on method of valuation of deaths averted (table 4.5). The value of averted deaths accounts for 32-48% of total benefits. Health care cost savings, accounting for 3-4% of total benefits, are estimated based on a diarrheal disease treatment rate of 30% and a treatment cost of Rs. 1,333 per case.

Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 6-8% of total benefits. A loss of two work days are assumed to be averted per case of diarrhea averted among the working population, valued at average wage rates. Caregiving for children is valued at 50% of wage rates per day of child illness.

Productivity benefits in terms of time savings account for 43-56% of total benefits. Time savings are 20 minutes per household member per day for those who no longer would practice open defecation (OD) and 3 minutes per household member per day for those no longer with a shared sanitation facility. These time savings are valued at 50% of wage rates for all beneficiaries 5+ years of age. In the recent survey by UNICEF household members reported that they on average spend 40 minutes per day on OD (UNICEF, 2018). This may, however, include time spent on co-activities that household members may undertake. Thus, to be conservative, only 20 minutes are accounted as time savings of ending OD in this paper. This is also the average time spent on OD reported by households in 6 East Asian countries according to the Economics of Sanitation Initiative (ESI) by the Water and Sanitation Program, World Bank.[15]

[15] https://www.wsp.org/content/economic-impacts-sanitation

Table 4.5. Value of benefits of intervention, Rs million per year

	Urban	Rural	Total
Deaths averted			
VSL	19,847	155,683	175,530
YLL=3*GDP per capita	10,455	82,011	92,466
Health care cost savings	1,330	9,649	10,979
Productivity benefits (averted lost work days)	4,737	18,580	23,317
Productivity benefits (time savings)	14,328	143,990	158,318
Total benefits, Rs million			
VSL	**40,243**	**327,901**	**368,143**
YLL=3*GDP per capita	**30,850**	**254,229**	**285,079**

Note: Discount rate: 5%. Source: Estimates by author.

An alternative valuation of health benefits is presented in table 4.6. Averted mortality is valued as in table 4.5. Reduced morbidity in terms of averted YLDs is, however, valued at 3 times GDP per capita instead of health care cost savings and averted lost work days and caregiving. This gives slightly lower total benefits.

Table 4.6. Alternative value of benefits of intervention, Rs million per year

	Urban	Rural	Total
Deaths averted			
VSL	19,847	155,683	175,530
YLL=3*GDP per capita	10,455	82,011	92,466
Value of YLD averted	1,735	13,606	15,341
Productivity benefits (time savings)	14,328	143,990	158,318
Total benefits, Rs million			
VSL	**35,910**	**313,279**	**349,189**
YLL=3*GDP per capita	**26,518**	**239,607**	**266,125**

Note: Discount rate: 5%. Source: Estimates by author.

4.2.3 Benefit-cost ratios

A comparison of benefits and costs, and benefit-cost ratios (BCRs) are presented in four tables. All tables use either VSL or the value of YLL at 3 times GDP per capita for valuation of averted deaths. All tables also include the value of time savings. The two first tables use the cost-of-illness (COI) approach, i.e., health care cost savings and productivity benefits, to value the benefits of averted illness. The two last tables use valuation of YLDs as discussed above.

Benefits and costs are larger in rural than urban areas as most of the beneficiaries are rural. BCRs using health care savings and productivity benefits are in the range of 4.7-9.7 (tables 4.7a-b). They are somewhat larger using VSL than valuation of YLL. They are also somewhat larger for rural households than for urban households.

BCRs using YLD are in the range of 4.0-9.2 (tables 4.7c-d). They are again somewhat larger using VSL than valuation of YLL, and larger for rural households than for urban households.

Table 4.7a. Benefits and costs of intervention, Rs million per year and BCRs

VSL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban sanitation	41,812	5,521	**7.6**	40,243	5,552	**7.2**	38,084	5,647	**6.7**
Rural sanitation	340,703	35,243	**9.7**	327,901	36,234	**9.0**	310,293	38,089	**8.1**

Source: Estimates by author.

Table 4.7b. Benefits and costs of intervention, Rs million per year and BCRs

YLL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban sanitation	35,782	5,521	**6.5**	30,850	5,552	**5.6**	26,502	5,647	**4.7**
Rural sanitation	293,407	35,243	**8.3**	254,229	36,234	**7.0**	219,444	38,089	**5.8**

Source: Estimates by author.

Table 4.7c. Benefits and costs of intervention, Rs million per year and BCRs

VSL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban sanitation	37,351	5,521	**6.8**	35,910	5,552	**6.5**	33,928	5,647	**6.0**
Rural sanitation	325,849	35,243	**9.2**	313,279	36,234	**8.6**	295,989	38,089	**7.8**

Source: Estimates by author.

Table 4.7d. Benefits and costs of intervention, Rs million per year and BCRs

YLL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Urban sanitation	31,321	5,521	**5.7**	26,518	5,552	**4.8**	22,346	5,647	**4.0**
Rural sanitation	278,554	35,243	**7.9**	239,607	36,234	**6.6**	205,139	38,089	**5.4**

Source: Estimates by author.

4.3 Assessment of Quality of Evidence

The dimensions that most importantly affect the estimated benefits and costs of the intervention are presented in table 4.8. The quality of evidence of the baseline health data and valuation of mortality is discussed before. The relative risk (RR) of disease and mortality reductions from improved sanitation vs. unimproved sanitation is based on one study of Indian households. The time savings from ending OD are conservative compared to UNICEF (2018) and similar to evidence from other Asian countries.

In terms of cost of intervention, capital cost is based on recent experience of the government sanitation promotion program. Time needed on cleaning of sanitation facility to reap the heslth benefits estimated in this paper is uncertain.

Table 4.8. Quality of evidence

	Quality of evidence
Benefits of intervention:	
Baseline health data	Medium-Strong
Relative risks (RR) for health benefits	Medium
Valuation of mortality	Medium-Strong
Productivity benefits (time savings)	Medium-Strong
Cost of intervention:	
Capital cost	Medium-Strong
Cleaning of sanitation facility	Medium
Total evidence	**Medium-Strong**

Source: Author.

4.4 Sensitivity Analysis

An analysis is carried out as to the sensitivity of the BCRs to some of the dimensions in table 4.8: i) the magnitude of the relative risks (RRs); ii) the productivity benefits (time savings); and iii) cost of two intervention cost components. The analysis assesses a 50% change in these parameters in the direction of lowering the BCRs. The sensitivity analysis is relative to the base case of using VSL for mortality and cost-of-illness (COI) for morbidity benefits, and a discount rate of 5%.

The results are presented in table 4.9:

i) The BCRs decline with 30-40% with the change in RR. This large change in the BCRs is because health benefits are a major share of total benefits.

ii) A change in time savings from 20 min to 10 minutes per person per day decreases the BCRs by no more than 15-20%.

iii) An increase in the capital cost of intervention from Rs. 20,000 to Rs. 30,000 reduces the BCR by 15-20%. A higher cleaning cost of 20 minutes per day reduces the BCRs by 30-40% due to the high cost of cleaning relative to total cost.

A sensitivity analysis is also undertaken with respect to sanitation coverage rates. If the rural population with a sanitary toilet is 70-80% today instead of 38% in 2015 (i.e., improved non-shared and shared in table 4.3), the BCR changes only minimally. Thus the actual coverage rate has no significant effect on the BCR.

Table 4.9 BCR sensitivity analysis

		Urban	Rural
	Base case BCR	**7.2**	**9.0**
i)	BCR with 50% change in RR (RRs=0.76 and 0.88)	4.4	6.3
ii)	BCR with 50% change in time savings (10 min per person per day)	6.3	7.1
iii)	BCR with 50% higher capital cost of intervention (Rs. 30,000 per household)	6.3	7.3
	BCR with 50% higher cleaning cost (20 minutes per day)	4.4	6.1

Source: Estimates by author.

5. Promotion of the use of sanitation facilities

5.1 Description of intervention

The construction of a household sanitation facility does not necessarily mean that all household members will use the new facility. The Swachhta Status Report 2016 found that 4.5% of household members continue to practice OD after construction of sanitation facility. Non-use is more prevalent in rural areas (6%) than in urban areas (1%).

Faced with a situation of OD among households with sanitation facility, the intervention is a behavioral change campaign (BCC) that promotes the consistent use of existing sanitation facilities.

5.2 Literature Review

The challenge with an assessment of the benefits and costs of a BCC that promotes the use of sanitation is the determination of the effectiveness of the campaign and the cost of the campaign in relation to its effectiveness. Three handwashing (HW) programs can shed some light on this, and are reported in the section on the POU treatment of drinking water intervention.

"Low", "mid" and "high" intensity promotion programs of 10%, 15% and 20% behavioral change rate is applied in this paper to the BCC for promotion of the use of sanitation, with costs in table 5.1 adjusted for annual inflation to 2017.

5.3 Calculation of Costs and Benefits

Most of the data used for the calculation of costs and benefits of the BCC intervention for the use of sanitation facilities are presented in section 1.2. Remaining data are presented below.

5.3.1 Costs

The BCC program promoting the use of existing household sanitation is repeated every 3 years over the useful life of the sanitation facilities. Annualized cost per household ranges from Rs. 11 for the "low" intensity program to Rs. 181 for the "high" intensity. The program is directed at all households that currently have improved sanitation, as precisely which households have members who do not utilize existing facilities is unknown. Thus total annualized cost is in the range of Rs. 90-1,441 million (table 5.1).

Table 5.1. Cost of BCC program promotion intervention

	Low	Mid	High
Useful life of existing sanitation facility (years)	20	20	20
BBC program promotion cost per household (US$)	0.35	1.20	5.00
Program promotion cost per household (US$), 2017	0.5	2.0	7.4
Program promotion cost per household (Rs)	30	130	480
Annualized program promotion cost per household (Rs)	**11**	**49**	**181**
Households targeted by BCC program intervention (million)	7.9	7.9	7.9
Total annualized BCC program promotion cost, Rs Million	**90**	**390**	**1,441**

Note: Discount rate is 5%. BBC program is repeated every 3 years over the useful life of the sanitation facility.

Source: Author.

The NSS 69 (2012) finds several reasons for non-use of existing sanitation facilities: i) no toilet superstructure; ii) lack of cleanliness/insufficient water; iii) malfunctioning of the latrine; iv) personal preferences; and v) other reasons. The two most important reasons in Rajasthan were personal preferences (36%) and lack of cleanliness/insufficient water (17%).

Personal preferences for OD imply that these household members perceive some benefits of continuing OD, or cost of giving up their old practice of OD. The magnitude of this cost is unknown. It is therefore in this paper assumed to be (at least) as large as the value of time spent on OD, i.e., 20 minutes per person per day valued at 50% of average wages. This is applied to the 36% of non-users who state "personal preferences" as reason for not using existing toilet facilities (annualized cost of ending OD in table 5.2).

Moreover, that lack of cleanliness/insufficient water was reported as the second main reason for not using the toilet facility prompts the inclusion of cost of cleaning of toilet facility (or value of time spent on cleaning), i.e., 20 minutes per week valued at 50% of wages. This cost is applied to all households with non-users of existing toilet facilities (annual cost of cleaning toilets in table 5.2).

Total private cost of intervention is therefore estimated at Rs. 573 – 1,148 million, depending on intensity or level of effort of the promotion program and household member response rates. Total private and public (promotion program) cost is therefore Rs. 663 – 2,589.

Table 5.2. Addition cost of intervention (Rs. Million)

	Low	Mid	High
Annualized cost (foregone benefits) of ending OD	436	655	873
Annual cost of cleaning toilets	137	206	275
Total annual cost	**573**	**861**	**1,148**

Note: Discount rate: 5%. Source: Author.

5.3.2 Benefits

For the estimation of health benefits of the intervention, the population or households of Rajasthan are distributed in four categories of household sanitation according to current sanitation cover and use of sanitation (Pre-intervention) and the expected distribution after the implementation of the intervention which aims to reduce the population not using existing sanitation facilities (Post-intervention) (table 5.3). The pre-intervention distribution is the same as for the improved sanitation intervention in the previous section. And again, while the current sanitation cover and non-use of existing facilities is uncertain, the pre-intervention population distribution has minimal effect on the benefit-cost ratios (BCRs) of the intervention and only on total benefits and costs of the intervention.

The risk (RR) of illness and mortality associated with the use of an improved, non-shared sanitation facility (i.e., the intervention) is 0.72 relative to unimproved or no sanitation facility (Wolf et al, 2014) (see Annex 1)[16]. The RR associated with the use of shared sanitation facilities is not reported in Pruss-Ustun et al (2014) or Wolf et al (2014) and is here assumed

[16] This intervention involves a relatively small number of households. The community health benefit estimated in Andres et al (2014) is therefore likely to be minimal. The relative risk in Wolf et al (2014) is therefore applied instead, reflecting primarily the direct health benefit to the household.

to be 0.86. Thus disease reduction from the intervention is 28% and 14%, respectively. The BCC intervention effectiveness is discussed above, ranging from 10% to 20%.

Table 5.3. Population distribution by type of household sanitation in Rajasthan

Pre-intervention	Low	Mid	High	RR
Have improved non-shared sanitation and using it	42.6%	42.6%	42.6%	**0.72**
Have improved non-shared sanitation BUT not using it	2.4%	2.4%	2.4%	**1.0**
Shared sanitation	7.2%	7.2%	7.2%	**0.86**
Other unimproved on no sanitation	47.8%	47.8%	47.8%	**1.0**
BCC intervention effectiveness (% behavioral change rate)	**10.0%**	**15.0%**	**20.0%**	
Post-intervention				
Have improved non-shared sanitation and using it	42.9%	43.0%	43.1%	**0.72**
Have improved non-shared sanitation BUT not using it	2.1%	2.0%	1.9%	**1.0**
Shared sanitation	7.2%	7.2%	7.2%	**0.86**
Other unimproved on no sanitation	47.8%	47.8%	47.8%	**1.0**

Source: Author.

The intervention would end OD among 182-364 thousand household members. The Potential Impact Fraction (PIF) formula is applied to the data in table 5.3 to estimate health benefits (see Annex 1), with estimated cases of 41-81 deaths and about 83-167 thousand cases of diarrheal illness averted per year (table 5.4).

Table 5.4. Health benefits of intervention

	Low	Mid	High
Individuals ending open defecation (000)	182	273	364
Averted deaths per year	41	61	82
Averted YLDs per year	86	128	171
Averted cases of diarrhea per year (000)	83	125	167

Source: Estimates by author.

The total annualized value of the health and productivity benefits of the intervention is estimated at Rs. 1.6 – 3.7 billion (table 5.5). The value of averted deaths accounts for 17-28% of total benefits. Health care cost savings, accounting for 2% of total benefits, are estimated based on a diarrheal disease treatment rate of 30% and a treatment cost of Rs. 1,333 per case.

Productivity benefits in terms of averted lost work days (including caregiving by adults for ill children) account for about 4-5% of total benefits. A loss of two work days are assumed to be averted per case of diarrhea averted among the working population, valued at average wage rates. Caregiving for children is valued at 50% of wage rates per day of child illness.

Productivity benefits in terms of time savings account for 65-75% of total benefits. Time savings are 20 minutes per household member per day for those who no longer would practice open defecation (OD), as in the case of the previous sanitation intervention. These time savings are valued at 50% of wage rates for all beneficiaries regardless of age.

Table 5.5. Value of benefits of intervention, Rs million per year

	Low	Medium	High
Value of deaths averted			
VSL	526	789	1,052
YLL=3*GDP per capita	277	416	554
Health care cost savings	33	50	67
Productivity benefits (averted lost work days)	80	120	160
Productivity benefits (time savings)	1,221	1,831	2,441
Total benefits, Rs million			
VSL	**1,860**	**2,789**	**3,719**
YLL=3*GDP per capita	**1,611**	**2,416**	**3,221**

Note: Discount rate: 5%. Source: Estimates by author.

An alternative valuation of health benefits is presented in table 5.6. Averted mortality is valued as in table 5.5. Reduced morbidity in terms of averted YLDs is, however, valued at 3 times GDP per capita instead of health care cost savings and averted lost work days and caregiving. This gives 4% lower total benefits.

Table 5.6. Alternative value of benefits of intervention, Rs million per year

	Low	Medium	High
Value of deaths averted			
VSL	526	789	1,052
YLL=3*GDP per capita	277	416	554
Value of YLD averted	46	69	92
Productivity benefits (time savings)	1,221	1,831	2,441
Total benefits, Rs million			
VSL	**1,792**	**2,689**	**3,585**
YLL=3*GDP per capita	**1,544**	**2,315**	**3,087**

Note: Discount rate: 5%. Source: Estimates by author.

5.3.3 Benefit-cost ratios

A comparison of benefits and costs, and benefit-cost ratios (BCRs) are presented in four tables, as for the previous interventions. All tables use either VSL or the value of YLL at 3 times GDP per capita for valuation of averted deaths. All tables also include the value of time savings. The two first tables use the cost-of-illness (COI) approach, i.e., health care savings and productivity benefits, to value the benefits of averted illness. The two last tables use valuation of YLDs as discussed above.

The BCRs using health care savings and productivity benefits are in the range of 1.1-2.8 (tables 5.7a-b). They are somewhat larger using VSL than valuation of YLL.

BCRs using YLD are in the range of 1.1-2.7 (tables 5.7c-d). They are again somewhat larger using VSL than valuation of YLL.

Table 5.7a. Benefits and costs of intervention, Rs million per year and BCRs

VSL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	1,933	684	**2.83**	1,860	664	**2.80**	1,759	637	**2.76**
Mid	2,899	1,274	**2.28**	2,789	1,251	**2.23**	2,638	1,222	**2.16**
High	3,866	2,591	**1.49**	3,719	2,589	**1.44**	3,517	2,594	**1.36**

Source: Estimates by author.

Table 5.7b. Benefits and costs of intervention, Rs million per year and BCRs

YLL + health care and productivity	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	1,773	684	**2.59**	1,611	664	**2.43**	1,452	637	**2.28**
Mid	2,660	1,274	**2.09**	2,416	1,251	**1.93**	2,178	1,222	**1.78**
High	3,546	2,591	**1.37**	3,221	2,589	**1.24**	2,903	2,594	**1.12**

Source: Estimates by author.

Table 5.7c. Benefits and costs of intervention, Rs million per year and BCRs

VSL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	1,864	684	**2.72**	1,792	664	**2.70**	1,694	637	**2.66**
Mid	2,797	1,274	**2.20**	2,689	1,251	**2.15**	2,540	1,222	**2.08**
High	3,729	2,591	**1.44**	3,585	2,589	**1.38**	3,387	2,594	**1.31**

Source: Estimates by author.

Table 5.7d. Benefits and costs of intervention, Rs million per year and BCRs

YLL + YLD	3% discount rate			5% discount rate			8% discount rate		
	Benefit	Cost	BCR	Benefit	Cost	BCR	Benefit	Cost	BCR
Low	1,705	684	**2.49**	1,544	664	**2.32**	1,387	637	**2.18**
Mid	2,557	1,274	**2.01**	2,315	1,251	**1.85**	2,080	1,222	**1.70**
High	3,409	2,591	**1.32**	3,087	2,589	**1.19**	2,773	2,594	**1.07**

Source: Estimates by author.

5.4 Assessment of Quality of Evidence

The dimensions that most importantly affect the estimated benefits and costs of the intervention are presented in table 5.8. The quality of evidence of the benefits is discussed before.

In terms of cost of intervention, the cost of ending OD (foregone benefit) is very uncertain with limited evidence. As this is the key parameter driving the BCRs, the overall quality of evidence regarding the intervention is limited.

Table 5.8. Quality of evidence

	Quality of evidence
Benefits of intervention:	
Baseline health data	Medium-Strong
Relative risks (RR) for health benefits	Medium-Strong
Valuation of mortality	Medium-Strong
Productivity benefits (time savings)	Medium-Strong
Cost of intervention:	
Cost of ending OD (foregone benefit)	Limited
Total evidence	**Limited**

Source: Author.

6. Conclusion

This paper has evaluated the benefits and costs of four household drinking water and sanitation interventions. The interventions were selected on the basis of coverage rates and behavioral dimensions in the state. The benefit-cost ratios (BCRs) are found to be the largest for improved urban drinking water supply and improved rural sanitation, followed by improved urban sanitation, household point-of-use (POU) treatment of drinking water and improved rural water supply.

The quality of evidence associated with these interventions range from "medium" to "medium-strong". A behavioral change campaign (BCC) promoting the use of existing sanitation by all household members has a smaller BCR, and supported by only "limited" quality of evidence.

Table 6.1. Summary of the benefits and costs and interventions (Rs million annualized)

	Interventions	Discount	Benefit	Cost	BCR	Quality of Evidence
1a	Improved drinking water supply - urban	3%	5,850	419	**14.0**	Medium
		5%	5,634	486	**11.6**	
		8%	5,634	596	**9.5**	
1b	Improved drinking water supply - rural	3%	27,517	4,010	**6.9**	Medium
		5%	26,477	4,645	**5.7**	
		8%	26,477	5,699	**4.6**	
2	BCC promotion of household POU treatment of drinking water*	3%	30,079	3,558	**8.4**	Medium-Strong
		5%	30,009	3,638	**8.2**	
		8%	29,908	3,762	**7.9**	
3a	Improved sanitation - urban	3%	41,812	5,521	**7.6**	Medium-Strong
		5%	40,243	5,552	**7.2**	
		8%	38,084	5,647	**6.7**	
3b	Improved sanitation - rural	3%	340,703	35,243	**9.7**	Medium-Strong
		5%	327,901	36,234	**9.0**	
		8%	310,293	38,089	**8.1**	
4	BCC promotion of use of existing sanitation facilities*	3%	2,899	1,274	**2.3**	Limited
		5%	2,789	1,251	**2.2**	
		8%	2,638	1,222	**2.2**	

Notes: All figures use VSL for valuation of mortality benefits and cost-of-illness (COI) approach for valuation of morbidity benefits. * "Mid" scenario. Source: Author.

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Annex 1. Health effects of unsafe drinking water and sanitation

Unsafe drinking water and sanitation (WAS) is directly and indirectly affecting population health. Directly, unsafe WAS causes diarrheal infections and other health effects which in turn lead to mortality especially in young children. Indirectly, unsafe WAS contributes to poor nutritional status in young children through the effect of repeated diarrheal infections (World Bank, 2008; Fewtrell et al, 2007; Larsen, 2007).[17] Poor nutritional status in turn increases the risk of child mortality or fatality rate from disease (Fishman et al., 2004; Black et al, 2008; Olofin et al, 2013).

Direct effect

Pruss-Ustun et al (2014), based on a global review, presents a methodology for estimating the diarrheal disease burden from unsafe WAS and the disease burden that can be expected to be prevented from improved WAS. For drinking water, the (preventable) disease burden is estimated relative to unimproved drinking water sources. For POU treatment (filtering or boiling), the (preventable) burden is estimated in relation to type of drinking water supply. For sanitation, a distinction is only made between unimproved and improved sanitation facilities as studies of health risks of other sanitation dimensions are insufficient. The relative risks of disease that are relevant for this paper are presented in tables A1.1-2.

For improved sanitation, however, a study of rural households in India by Andres et al (2014) estimates a relative risk of 0.53 that includes both the direct health benefit of improved sanitation to the household as well as the external health benefit to a community with high sanitation coverage rates.

Table A1.1. Relative risk of diarrheal disease and mortality for drinking water source and POU treatment

Baseline drinking water source	Improved drinking water source other than piped to premise	Basic piped water to premise	POU treatment (filtering or boiling and safe storage)
Unimproved drinking water source	**0.89**	**0.77**	0.55
Improved drinking water source other than piped to premise		0.86	**0.62**
Basic piped water to premise			**0.72**

Source: Pruss-Ustun et al (2014).

Table A1.2. Relative risk of diarrheal disease and mortality for sanitation

Baseline sanitation	Improved sanitation facility
Unimproved sanitation facility	**0.72**

Source: Pruss-Ustun et al (2014); Wolf et al (2014).

Indirect effect

[17] Repeated infections, and especially diarrheal infections, have been found to significantly impair weight gains in young children. Studies documenting and quantifying this effect have been conducted in communities with a wide range of infection loads in a diverse group of countries. World Bank (2008) provides a review of these studies.

Estimating the indirect mortality effects of diarrhea from WAS is here undertaken in two stages. First, the fraction of under-five child mortality attributable to child underweight is estimated. This follows the methodology in Olofin et al (2013). Second, a fraction of under-five child mortality from underweight is attributed to diarrheal infections from WAS in early childhood using the approach in Fewtrell et al (2007).[18]

Estimates of increased risk of cause-specific mortality in children under five years of age with mild, moderate and severe underweight is presented in table A1.3 based on Olofin et al (2013).

Table A1.3. Relative risk of mortality from severe, moderate and mild underweight in children under five

	Severe	Moderate	Mild	None
Diarrhea	11.56	2.86	1.73	1.00
Acute lower respiratory infections (ALRI)	10.10	3.11	1.85	1.00
Measles	7.73	3.12	1.00	1.00
Malaria	1.29	1.65	1.26	1.00

Source: Olofin et al (2013). ALRI is acute lower respiratory infections. Relative risks are in relation to severe, moderate and mild underweight according to the WHO Child Growth Standards.

These relative risk ratios are applied to prevalence rates of child underweight to estimate attributable fractions (AF_j) of mortality by cause, *j*, from child underweight as follows:

$$AF_j = \frac{\sum_{i=1}^{n} P_i (RR_{ji} - 1)}{\sum_{i=1}^{n} P_i (RR_{ji} - 1) + 1} \qquad \text{(A1.1)}$$

where RR_{ji} is relative risk of mortality from cause "*j*" for children in each of the underweight categories, *i*, in table A1.3; and P_i is the underweight prevalence rate.

Annual cases of mortality from child underweight by cause, "*j*" are estimated as follows:

$$M_j = BDB_j * AF_j \qquad \text{(A1.2)}$$

where BDB_j is baseline annual cases of mortality from cause "*j*". Annual cases of under-five child mortality from diarrheal infections in early childhood (W) is then estimated as follows:

$$W = \sum_{j=1}^{j=m} \gamma_j M_j \qquad \text{(A1.3)}$$

[18] An alternative approach to estimating the fraction of mortality attributable to diarrheal infections from WAS is the methodology developed in Larsen (2007) and World Bank (2008). This, however, requires estimation of counterfactual prevalence rates of child underweight (prevalence of underweight in the absence of diarrheal infections) from original survey data of child nutritional status. As the original survey data are often not readily available, the approach in Fewtrell et al is here used instead. The approach in Fewtrell et al gives a somewhat lower estimate of indirect mortality from WAS than the Larsen and World Bank methodology.

where γ_j is the fraction of child underweight mortality (M_j) attributed to diarrheal infections in early childhood. A value γ_j = 0.5 for ALRI, measles, and malaria is applied here based on Fewtrell et al (2007).

Preventable disease burden from interventions

The potential impact fraction (PIF) formula is applied to estimate the preventable disease burden from the drinking water and sanitation interventions evaluated in this paper:

$$PIF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i^{'} RR_i}{\sum_{i=1}^{n} P_i RR_i} \qquad \text{(A1.4)}$$

where P_i is the pre-intervention population distribution by type of drinking water, POU treatment, or sanitation; $P_i^{'}$ is the post-intervention population distribution; and RR_i is the relative risk of disease and mortality in tables A1.1-2.

The preventable disease burden or health benefit (B) of interventions is then:

$$B = PIF * BDB \qquad \text{(A1.5)}$$

where *B* is annual cases of mortality and morbidity prevented, *BDB* is the baseline disease burden or annual cases of diarrheal disease mortality and morbidity in Rajasthan. Included in the *BDB* in this paper is also annual cases of typhoid and paratyphoid mortality and annual cases of mortality (*W*) from the indirect effect discussed above.

Rajasthan is the largest Indian state. It has a diversified economy, with mining, agriculture and tourism. Rajasthan has shown significant progress in improving governance and tackling corruption. However, it continues to face acute social and economic development challenges, and poverty remains widespread. What should local, state and national policymakers, donors, NGOs and businesses focus on first, to improve development and overcome the state's remaining issues? With limited resources and time, it is crucial that priorities are informed by what can be achieved by each rupee spent. To fulfil the state vision of "a healthy, educated, gender sensitive, prosperous and smiling Rajasthan with a well-developed economic infrastructure", Rajasthan needs to focus on the areas where the most can be achieved. It needs to leverage its core competencies to accelerate growth and ensure people achieve higher living standards. Rajasthan Priorities, as part of the larger India Consensus – a partnership between Tata Trusts and the Copenhagen Consensus Center, will work with stakeholders across the state to identify, analyze, and prioritize the best solutions to state challenges. It will commission some of the best economists in India, Rajasthan, and the world to calculate the social, environmental and economic costs and benefits of proposals.

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