Research Paper

Health costs and benefits from a pilot rural sanitation intervention in India

David Weis, Guy Hutton and Manish Kumar

ABSTRACT

India hosts two-thirds of the global population defecating in the open and faces a worrying trend of districts declared 'water scarce'. This paper aims to assess the costs and health benefits of sanitation interventions undertaken by the National Rural Drinking Water Security Pilot Project in India between 2012 and 2015. To achieve this goal, a pretest–posttest control group study was undertaken in two study areas located in Karnataka and Uttar Pradesh states. Full software and infrastructure costs were included as well as health endpoints, sourced from primary health centers. In Karnataka, latrine coverage of households increased from 16% to 59% in villages with high level of interventions, and from 7% to 18% in villages with lower levels of intervention. In Uttar Pradesh, coverage increased from 33% to 70% in high intervention villages and from 27% to 39% in the low intervention villages. We found health-related net benefits of USD 13 and USD 10 per person per year and benefit/cost ratios of 2.5 and 5.0 in Karnataka Uttar Pradesh, respectively. Given the positive economic returns on the intervention in culturally heterogeneous sites of southern and northern India, this intervention has potential for bringing significant benefits to the Indian population.

Key words | cost benefit, health, India, sanitation, water

David Weis (corresponding author)
Institute of Environmental Engineering and Management and Institute for Teaching and Educational Research in Health Sciences,
Witten/Herdecke University,
Alfred-Herrhausen-Straße 50, 58448 Witten,
Germany
E-mail: *david.weis@uni-wh.de*

Guy Hutton
United Nations Children's Fund,
Three United Nations Plaza,
New York, NY 10017,
USA

Manish Kumar
National Skill Development Corporation, Block A,
Clarion Collection, Shaheed Jeet Singh Marg,
New Delhi, 110016,
India

David Weis
Guy Hutton
Manish Kumar
For all authors, the work was conducted while at the World Bank,
Water and Sanitation Program (WSP),
HT House, 18-20 Kasturba Gandhi Marg, New Delhi, 110001,
India

INTRODUCTION

Worldwide, 2.3 billion people do not use a basic sanitation facility and of those, 892 million practice open defecation in 2015. India accounts for 25% of those lacking basic sanitation and 45% of those practicing open defecation (JMP 2017).

There is growing scientific literature linking poor water, sanitation and hygiene (WASH) to numerous diseases, such as diarrhea (Wolf *et al.* 2014), soil-transmitted helminth infection (Strunz *et al.* 2014), trachoma (Stocks *et al.* 2014), and schistosomiasis (Prüss-Üstün *et al.* 2008; Clasen *et al.* 2014) nutritional status (Victora *et al.* 2008; Dangour *et al.* 2013; Freeman *et al.* 2017), stunting (Checkley *et al.* 2008), environmental enteropathy (Humphrey 2009; Lin *et al.* 2013), and impaired cognitive development (Bain *et al.* 2014; Clasen *et al.* 2014; Sclar *et al.* 2017). In addition, the cost savings and economic impacts associated with improved WASH have been well established (Hutton 2013).

To improve the WASH situation and generate benefits for its population, in 2011 the Indian Ministry for Drinking Water and Sanitation initiated its 'National Rural Drinking Water Security Pilot Project' (NRDWSPP). It aimed to address the specific needs of the rural inhabitants through a combined set of interventions covering water resource management, agricultural productivity and WASH which supported them with knowledge, finances, infrastructure and management competencies.

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A review of the health economics literature (Hutton & Chase 2016, 2017) revealed few cost–benefit analyses (CBA) have been undertaken in the field of water and sanitation. In general, economic studies have modeled the costs and benefits of a mix of WASH interventions and used generalized unit cost estimates representing state or national level (Hutton 2012; Cronin *et al.* 2014; Hutton *et al.* 2014; Weis *et al.* 2017). This pilot project, on the other hand, provided a unique opportunity to assess the costs and benefits of WASH interventions in specific locations and assess how successful these interventions were. A key question is whether the experiences of the pilot project have implications across India, especially in the light of the more recent sanitation programme of the Government of India – the Swachh Bharat Mission (GoI 2016), initiated in 2014.

The main objective of this study therefore is to investigate what are the costs and benefits of the WASH interventions, to understand their determinants, and assess implications for adopting a similar project design in other districts and states of India. This study presents the detailed results of a health analysis done as part of a more comprehensive cost–benefit study of the NRDWSPP (Weis *et al.* 2017).

METHODS

Study design

The study design follows the pretest-posttest control group of Campbell and Stanley (Campbell *et al.* 1963). In epidemiology, this form of study is also known as controlled before and after study (Cochrane, no date). Here the differentials of two points in time and two scenarios are measured: the situation at the end of the project (factual) is compared with the situation at the start (counterfactual) and high-intervention villages (study group) are compared to low-intervention villages (control group). While the comparison between the two points in time (factual–counterfactual) reveals changes over time, the comparison between the high- and low-intervention villages (study–control) cancels any changes that are not related to the project. Factors that are canceled out through this approach are for example maturation of the individuals, historic tendencies, pretesting and measuring instruments (Campbell *et al.* 1963).

Location and groups

The two locations were selected to represent both different socio-economic contexts and different performance levels of pilots implemented under the differences NRDWSPP, and including both northern and southern states in India. In total, the NRDWP targeted around 2.23 million people located in 15 blocks covering ten states of India. For the present study, six villages were chosen within the Mulbagal Block in Kolar District, Karnataka State in southern India and six villages were chosen in Barauli Ahir Block in Agra District, Uttar Pradesh (UP) State in northern India. The six villages were separated into two groups of three villages each; one group consists of villages where the project intervened with high intensity (study group); the other group only received a limited number of interventions (control group). The control group comprised low-intervention villages instead of no-intervention villages for several reasons. First, the collaborating Non-Governmental Organizations (NGOs) were active in all villages of the block and had established connections with farmers, health practitioners, local political leaders and other key persons. These connections were essential for data collection. Second, the study follows the principle of overestimating costs and underestimating benefits in order to avoid statistical type one errors. Type one error occurs when assuming a hypothesis as true when it is false in reality. Type two error occurs when a hypothesis is labeled false when it is actually true (World Bank 2008). This approach ensures results produced are conservative of the impact and thus adds credibility when making recommendations to policy makers. Third, it was known that villages would implement national programmes (e.g. Swacch Bharat Mission, Mahatma Gandhi National Rural Employment Guarantee Scheme and Integrated Watershed Management Program) and hence would not remain the same as the start year.

For selecting the locations, attention has been paid to comparability between the study and the control group in order to assure that observed changes can be ascribed to the intervention (Boardman *et al.* 2011). In Karnataka, the villages in Mulbagal Block pre-intervention arm were matched for: number of villages, number of households and inhabitants, access to medical services, social status and water availability (see Table S1 in Supplementary Information, available with the online version of this paper). In UP, Barauli Ahir Block was more diverse and hence urbanization level and proximity of villages were included to ascertain the similarity of villages under investigation (see Table S2 in Supplementary Information, available online). Minor differences regarding the population size were unavoidable. However, the presentation of results in per capita terms overcomes this problem. The study period was three years from January 2012 to January 2015.

Interventions

The sanitation part of the intervention adopted the community-led total sanitation (CLTS) (World Bank WSP 2014). It followed a grassroots approach with decisions made at community level to ensure the specific needs of each village were addressed. To minimize the intervention cost while assuring development outcomes, the sanitation technology adopted by most households was the single pit poor-flush latrine, based on community demand and an intention to become open defecation free (ODF). Community mobilizers and regular follow-up of the project team helped ensure actual use of toilets built. Further community mobilization was created through general knowledge-sharing events and through group visits to other locations that successfully implemented new structures and achieved a high level of ODF (AFPRO 2013; MDWS 2013; World Bank WSP 2014). In the analysis, actual usage was assumed if toilets were not used for other purposes (e.g. no evidence of being used for storage), if water and/or soap were available and/or if other signs of usage existed.

The project also aimed to strengthen the management competencies and local accountability through educating communities on how to operate and maintain existing and new infrastructure systems and by encouraging existing Village Water Security Committees (VWSC) to take a leading role in management. Where no traditional VWSC existed, the project helped set up new local management structures. A further structural intervention of the pilot project was the coordination of agencies and funding schemes in order to create sufficient financial support, and avoid duplication of effort and financial support (World Bank WSP 2015a, 2015b).

Health data

Based on the findings of the Economics of Sanitation Initiative (Prüss-Ustün *et al.* 2014; World Bank WSP 2015c), the analysis included twelve water-related morbidity endpoints (diarrhea, helminthes, malnutrition, hepatitis A & E, malaria, chikungunya, dengue, acute lower respiratory infections (ALRI), measles, scabies, trachoma and other related diseases) and six endpoints potentially leading to mortality (diarrhea, helminthes, malnutrition, hepatitis A & E, malaria and other related diseases). Note that chikungunya and dengue were included due to local morbidity patterns in the southern study sites and interventions to improved water storage and environmental management to reduce mosquito breeding. Furthermore, the pathway of effect between poor WASH and measles, respiratory infection and malaria is through malnutrition and the resulting compromise of immunity (chances of contracting disease) and the ability to recover from these diseases (chances of case fatality), especially for children under five years of age (Fishman *et al.* 2004).

In Mulbagal Block the morbidity data were gained through a survey of the Public Health Centers that treated the inhabitants of the study and control villages. Comparing the factual situation of 2015 of the study group to its counterfactual situation in 2012, the dataset showed an improvement in four categories (diarrhea, malnutrition, malaria and dengue) and a worsening in three (helminthes, ALRI and scabies). No data were available for three endpoints (hepatitis, chikungunya and trachoma). The control group in comparison showed a worsening in all categories (Table 1).

In Barauli Ahir, data were only available on the block level. Here, a direct comparison between high and low intervention sites was not possible. A detailed explanation on how the health data has been processed further can be found in the calculation section below.

Impact of the intervention on mortality data could not be ascertained through field surveys, as the study population was too small to deliver reliable results. Instead, we used mortality data available for India (World Bank WSP 2011; Prüss-Ustün *et al.* 2014) and processed it as described below. Regarding the transferability of this data, it could be argued that many studies only investigated the effect of water and sanitation on children below five years of age. However, a meta-analysis of Wolf *et al.* (2014) on health

Table 1 | Morbidity cases collected from public health centers of Eragamuthanahalli, Pethandlahalli and Perumakanahalli village (control group) and Oorkunte, Kothur and Mittur village (study group), authors' investigation

	Control group		Study group	
Disease	**Counter-factual**	**Factual**	**Counter-factual**	**Factual**
Diarrhea	155	175	26	24
Helminthes	245	291	40	60
Malnutrition	29	38	4	3
Hepatitis A & E	10	24		
Malaria	0	0	2	0
Chikungunya	30	32		
Dengue	0	0	2	0
ALRI	85	105	20	22
Measles	41	50	0	0
Scabies	80	90	10	12
Trachoma				
Other	0	0	0	0

impacts of drinking water and sanitation has found great similarities with other age groups. This study therefore follows the conclusion that the estimates derived from children under five can be used for all age groups.

ANALYSIS

Monetizing health effects

For monetizing the health effects we aimed to include all costs and benefits that are directly linked to the interventions of the project (primary effects). Those that only showed indirect links (secondary effects) are unfit for cost–benefit analysis (Boardman *et al.* 2011) and have therefore been excluded.

In general, costs and benefits can occur for the government or for individuals and can be financial (market value exists) or intangible (no market value exists). Costs included were hardware costs for toilet construction and software costs spent for staff, exposure visits and diverse training, equipment to measure the project's progress (such as geo information systems and field surveys) and administrative costs. Due to the short time horizon of the project, some costs that occur after the three-year period such as emptying latrines and replacement of infrastructure were not included. To measure relevant costs, this analysis builds on official Government estimates (MDWS 2015) as well as field observations.

The estimation of benefits required a more elaborated approach, given many of them were intangible in nature (i.e. without direct market values) or were not available from existing data sources. To more fully reflect the societal perspective, this study attempted to capture a broad range of health and non-health impacts of water and sanitation interventions (Hutton 2000). All the benefits except the productive value of higher water quality were measured through the total economic value (TEV) approach (Figure 1). The TEV approach differentiates between who bears the cost (overall society versus the project 'beneficiary' receiving improved water and sanitation services) and the type of benefit (administrative savings, medical care savings, economic savings in production

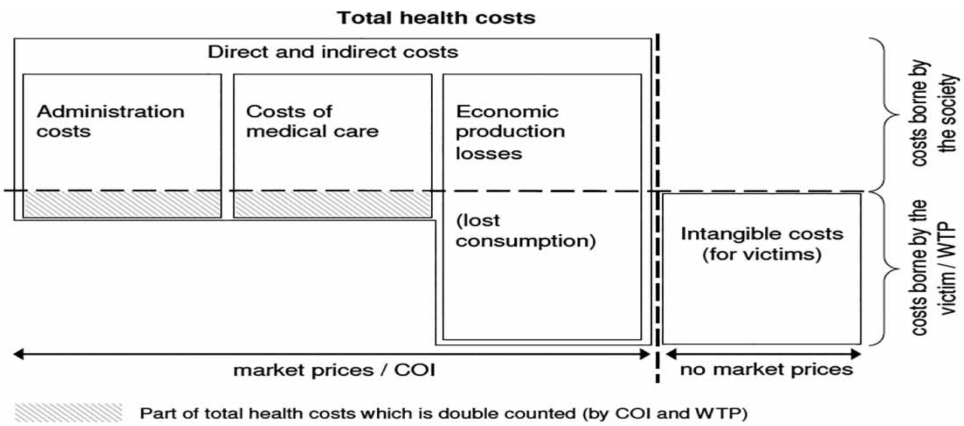

Figure 1 | Economic valuation of total health costs by COI and WTP (WHO 2008).

and consumption, and intangible costs for individuals) (WHO 2008) (Figure 1).

The measurement of the 'costs borne by the society' is possible through finding market prices for the different health services (financial costs). This approach is called cost of illness (COI). The 'costs borne by the victim' are more complex to measure as no market prices exist (intangible costs). Among the available approaches, the human capital approach (HCA) proved to be unsuitable for this analysis as it focuses mainly on financial losses rather than the benefits to individuals which include intangible aspects. The remaining two methods both build on the willingness to pay method (WTP), where people's preferences are measured. The value of a statistical life (VSL) method attaches a monetary value to premature death through observations of risk in real markets (Pearce & Howarth 2000). Attention was paid to avoid double-counting of benefits due to the different valuation methods capturing (part of) the same benefit, such as between the cost of illness and the value of statistical life or between costs paid by patients and costs paid by government (marked grey in Figure 1).

Calculation of costs and benefits

Building on above monetarization, we follow the method described by Cronin et al. (2014) and calculated differentials of: (1) the two points in time (2015 and 2012) and (2) two scenarios (high intervention villages (study group) and low intervention villages (control group)). The net benefits of these two differentials are shown by the upper grey triangle in Figure 2 and are calculated through the following equation:

$$\Delta Net\, Benefit_{f-c} = \Delta Benefit_{f-c} - \Delta Cost_{f-c}$$

where f stands for the factual, in 2015 existing situation, and c for the counterfactual situation, existent in 2012. The Δ indicates that two situations have been compared, namely the high intervention group (study group) and the low intervention group (control group) (Cronin et al. 2014). Such method follows the pretest-posttest control group design of Campbell and Stanley (Campbell et al. 1963). In contrast to studies with only one group and a pre- and

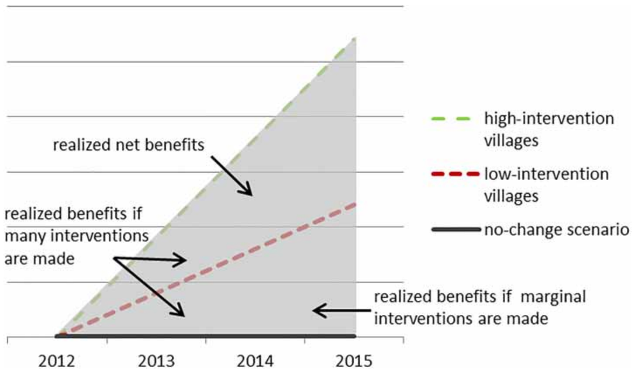

Figure 2 | Concept of the social and economic cost-benefit analysis of sanitation, *source:* authors.

post-test, this study design introduces a control group in order to cancel out effects which might arise from general changes such as implementation of national programmes, underlying historic tendencies, and year-to-year climatic variations (Campbell et al. 1963).

For calculating the morbidity cases of the factual situation f, it is important to bear in mind that not all observed morbidity cases can be attributed to water and sanitation issues. Following the investigation of the Economics of Sanitation Initiative (ESI) (World Bank WSP 2015c), Table 2 shows the attributable fraction, i.e. the proportion of morbidity cases attributable to poor WASH. The health benefit of sanitation alone is assumed to be 28% of cases, taken from meta-analysis (Wolf et al. 2014).

Table 2 | Diseases and attributable fractions, *source:* authors

Disease	Attributable fraction
Diarrhea	88%
Helminthes	100%
Malnutrition	50%
Hepatitis A	88%
Hepatitis E	88%
Malaria	36%
Chikungunya	36%
Dengue	36%
ALRI	34%
Measles	29%
Scabies	50%
Trachoma	100%
Other	35%

Table 3 | Attributable deaths due to poor sanitation (India), numbers from Prüss-Ustün *et al.* (2014) and WSP (2011)

	Attributable deaths due to poor sanitation (India)
Diarrhea	115,404
Malnutrition	37,830
ALRI	53,044
Malaria	2,217
Measles	9,036
Other	33,491

The medical costs saved were based on the illness type, the expected number of outpatient visits and hospital admissions and the level of the health facility. In Mulbagal Block, it was observed that people first pass through the primary health centers before consulting health institutions of higher levels. Hence, the attributable number of cases was spread according to the health facility use and in a last step monetized by the average payment for the corresponding health facility.

Given the lack of mortality data at local level, risk of fatality from each disease was based on national numbers for India, including diarrheal deaths and deaths medicated through poor malnutrition (World Bank WSP 2011; Prüss-Ustün *et al.* 2014) (Table 3). The total mortality from poor sanitation was adjusted to each study area according to the population size, and the assumed reduction from implementing sanitation programmes was 28% (Wolff *et al.* 2014). The generalization of these mortality risks from India to the study areas was assumed correct given the similar coverage of sanitation to national rates. The value for the VSL calculation was taken from a national study of Cropper and colleagues (Cropper *et al.* 2013) which gave a VSL of USD 280,000 (2013 prices), and extrapolated to the study areas based on the average product of the two states to keep internal consistency in the VSL for this study, as it ensures an equal valuation of a life independent from the place of living (Pearce & Howarth 2000).

RESULTS

The results demonstrate that villages receiving high levels of intervention were closer to achieving ODF, measured by the percentage of households having and using a private latrine. High intervention villages more than doubled their coverage from 33% to 70% in the case of Barauli Ahir and from 16% to 59% in Mulbagal Block (Table 4).

Applying the calculations described above and using the model assumptions on health impact of improved sanitation, this increased use of latrines reduces the burden of disease leading to economic benefits. In the study in Mulbagal, the reduced burden of disease is equal to USD 30 per person in high intervention villages, and only USD 7 in low intervention villages. In the case of Barauli Ahir, the health impacts of improved sanitation are valued at USD 15 in high intervention villages, and USD 2.5 in low intervention villages. The incremental benefit of high over low intervention villages is estimated at USD 22 in the Mulbagal case study and USD 12.5 in the Barauli Ahir Block case study (Table 5).

Looking at the project's cost, in the Mulbagal study, USD 9 was spent per resident and in the case of Barauli

Table 4 | Latrine coverage in limited and high intervention villages, *source:* authors

	Limited intervention villages					High intervention villages				
Latrine coverage in Mulbagal Block	**Eragamuthanahalli**	**Pethandlahalli**	**Perumakanahalli**	**Total**	**%**	**Oorkunte**	**Kothur**	**Mittur**	**Total**	**%**
2012/2013	5	15	7	27	7.42	15	15	25	55	15.58
2014/2015	20	27	20	67	18.41	65	60	85	210	59.49
Latrine coverage in Barauli Ahir Block	**Saimari**	**Bad**	**Bisera Kala**	**Total**	**%**	**Rajrai**	**Kakua**	**Bahenta**	**Total**	**%**
2012/2013	181	159	26	366	26.68	80	254	54	388	32.99
2014/2015	236	225	69	530	38.63	252	378	196	826	70.24

Table 5 | Benefits (USD) per capita from reducing the burden of disease, *source:* authors

	Mulbagal Block			Barauli Ahir Block		
Disease	**High intervention**	**Low intervention**	**Benefits**	**High intervention**	**Low intervention**	**Benefits**
Diarrhea	14.04	3.12	10.92	7.32	1.21	6.11
Helminthes	5.86	1.60	4.26	2.75	0.45	2.29
Malnutrition	3.59	0.77	2.82	1.91	0.32	1.59
Hepatitis A & E	0.26	0.07	0.19	0.14	0.02	0.12
Malaria	0.44	0.09	0.35	0.23	0.04	0.19
Chikungunya	0.00	0.02	−0.02	0.00	0.00	0.00
Dengue	0.01	0.00	0.01	0.00	0.00	0.00
ALRI	0.14	0.07	0.07	0.09	0.02	0.08
Measles	0.00	0.02	−0.02	0.00	0.00	0.00
Scabies	0.10	0.09	0.01	0.12	0.02	0.10
Other	4.48	0.93	3.55	2.41	0.40	2.01
Total	28.93	6.78	22.15	14.98	2.48	12.50

Ahir Block USD 3 per resident (Table 6). These costs include the construction of toilets, payments to the support organization, financing of exposure visits and training, as well as the acquisition of measuring equipment (MDWS 2015).

A benefit/cost ratio of 2.5 is found in Mulbagal and of nearly 5 in Barauli Ahir. This means that each dollar invested in Mulbagal creates a value of 2.5 dollars in health savings, in the case of Barauli Ahir Block it even creates a value of 5 dollars in health savings. The net economic benefit, amounts to USD 13 per resident in Mulbagal and USD 10 per resident in Barauli Ahir (Table 7).

Although more net benefits are generated for an average person in Mulbagal, the relative impact of these benefits are very different for the two regions. A plausible reason for this is the high cost difference between the two blocks concerning tap connections. It was one of the NRDWSPPs targets to improve the domestic water supply to increase hand washing and reduce sanitation-related infections. Greater efforts were made in Mulbagal made to install a tap system for the households. Unfortunately, Mulbagal block was hit by a drought in the years of this pilot project and the groundwater table sank drastically. It was hence not possible to use the newly installed infrastructure, and benefits that could have arisen from better water supply to households did not materialize. However, the analysis controlled for the impact of the drought and estimated what the benefits would have been had the taps been used by households.

To test the validity of the above findings, a Monte Carlo sensitivity analysis was undertaken. It showed that roughly 99% of all values for net benefit lies between USD 3 and USD 24 in Mulbagal and between USD 5 and USD 15 in Barauli Ahir (Table 8). Only 0.13% of simulation results surpass this maximum value in Mulbagal, while less than 0.46% of simulation results are less than the minimum value. In

Table 6 | Costs (USD) per capita for different investments, *sources:* MDWS (2015) and authors

Investments	**Mulbagal Costs ($)**	**Barauli Ahir Costs ($)**
Toilet construction	5.49	2.15
Tap connections	3.34	0.00
Support organization	0.10	0.23
Exposure visits	0.05	0.10
Training	0.03	0.06
Measuring equipment	0.06	0.10
Total	9.08	2.65

Table 7 | Benefit/cost ratio and net benefit (USD, per capita), *source:* authors

	Mulbagal	**Barauli Ahir**
Benefit/cost ratio	2.44	4.72
Net benefit ($)	13.07	9.85

Table 8 | Expected values from a Monte Carlo sensitivity analysis, *source:* authors

	Mulbagal ($)	Barauli Ahir ($)
Max 99%	23.91	15.37
Min 99%	3.42	5.12
Average	13.66	10.25
St. Dev.	3.42	1.71

Barauli Ahir, these results are 0.40% and 1.13%, respectively. In Barauli Ahir, the probability of receiving negative values for net benefit is zero while in Mulbagal the probability of a negative net benefit is 0.02%.

CONCLUSION AND IMPLICATIONS

This study has shown the potential health benefits from the NRDWSPP, the economic benefits that can result and the high return on investments. It has been demonstrated that sanitary infrastructure and behavioral interventions led to net benefits per inhabitant of USD 13 in Mulbagal and USD 10 in Barauli Ahir as well as a benefit/cost ratio of 2.5 in Mulbagal and 5.0 in Barauli Ahir.

These results have furthermore been found to be robust to a comprehensive sensitivity analysis using Monte Carlo simulation. A broader analysis has previously shown that the overall societal benefits exceed costs by 10 to 11 times (Barauli Ahir Block vs. Mulbagal Block), when including agricultural, time-saving and environmental effects of water supply and sanitation interventions (Weis *et al.* 2017).

The implications of the high benefit/cost ratios of 2.5 and 5.0, as well as the high net benefits show that the actors involved have achieved benefits for a large part of the rural population in the pilot study sites. It furthermore indicates that the grassroots approach of the pilot project successful in addressing the water and sanitation problems that were present at the rural intervention sites in 2012. We therefore recommend that government and community actors continue to strive for universal sanitation access and usage in those sites.

Given the very different locations and cultural heterogeneity of the two study sites (one in southern and one in northern India), it suggests that the health impacts and returns on investment might be similar across different locations in India. As the pilot project targeted around 2.23 million people (World Bank WSP 2015a, 2015b) and the average net benefits of the two study sites lies between USD 10 and 13 per person, a simplified estimate would suggest that the pilot project created net social health benefits between USD 22 million and USD 29 million. However, for scaling up the pilot approach, a more detailed assessment is needed of the baseline variables in new sites and the potential to benefit.

In summary, the significant benefits associated with sanitation interventions suggest that the Indian Government could increase population welfare through scaling up the pilot project or investing in similar interventions such as the Swacch Bharat Mission.

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