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Access to Drinking Water and Reduction of Acute Diarrheal Diseases in Rural Populations Puno-Peru

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Abstract

This quasi-experimental study evaluated the impact of access to drinking water and sanitation on the reduction of acute diarrheal diseases (ADD) in rural communities of Puno, Peru, using a longitudinal design with the Differences in Differences (DID) technique and Probit models to estimate the impact coefficients. The sample included 100% of the population that used water services (n=179 households) and non-users (n=170 households) of water services in the district of Ilave. The results showed that households with access to drinking water had a significantly lower prevalence of EDA (43.0%) compared to those without access (60.5%), with an estimated difference of -17.5 percentage points (p<0.01). Analysis using Probit models revealed that access to drinking water reduced the probability of EDA by 17.9%, an effect that was statistically significant (β=-0.175; p<0.01). These findings confirm that access to drinking water and sanitation constitutes a key protective factor against EDA in rural contexts, highlighting the importance of implementing comprehensive interventions that combine water infrastructure with the promotion of hygienic practices. The study provides robust evidence to guide public policies on environmental health, particularly in regions with limited access to basic services, and underscores the need to prioritize these interventions as an effective strategy to reduce the burden of preventable diseases in vulnerable populations, thus contributing to the achievement of the Sustainable Development Goals.

Keywords: *Acute Diarrheal Diseases, Drinking Water, Sanitation, Impact Evaluation, Rural Health, Differences in Differences.*

Introduction

Access to safe drinking water and sanitation is strongly linked to one of the Millennium Development Goals (MDGs) agreed upon by many of the world's nations (United Nations Development Programme [UNDP], 2017). For the MDG, one of the goals is to "halve the

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proportion of people without access to drinking water" (Bautista, 2013). For the United Nations (UN), water and sanitation must be considered a human right. (3)

Other studies found that the prevalence and duration of diarrhea among children under five years of age in rural areas are directly associated with drinking water consumption (Jalan & Ravallion, 2003) and a significant reduction in the prevalence of acute diarrheal diseases (Carbajal, 2014; Wolf et al., 2014; Coffey et al., 2018) (Contreras, 2022) and improvements in anthropometric measurements of children (Adewara & Visser, 2011). Deaths due to unsafe water and poor sanitation account for 58% of all deaths from diarrhoea in children. (Pan American Health Organization [PAHO], 2022). On the other hand, there are studies that found a consistent relationship between the quality of sanitation services and hygiene practices in households, the reduction in the prevalence of parasitic diseases and intestinal infections (Campbell, 2003; Strunz et al., 2014; Schmidt et al., 2011; Andersson et al., 2015; Ziegelbauer et al., 2012; Null et al., 2018).

However, in Latin America, efforts to improve drinking water coverage remain a challenge (Maryeline Sarmiento Cárdenas & Andrea Sanchez Correa, 2017; Mejía et al., 2016), therefore, is far from achieving the Millennium Development Goals in terms of water and sanitation (Maryeline Sarmiento Cárdenas & Andrea Sanchez Correa, 2017; Urazán Bonells & Caicedo Londoño, 2018) and together with the lack of adequate sewerage and wastewater infrastructure, creates significant environmental and public health problems (Anastasopoulou et al., 2018).

Therefore, there are studies that highlight the importance of health education and social empowerment to make coverage and access to water and sanitation more efficient and sustainable, and the social benefits it implies for the population (Rodríguez Miranda et al., 2016; Hutton, 2012; Ducci, 2007). Hence the importance of studying cases of morbidity attributable to unsafe water and sanitation and hygiene (Ziegelbauer et al., 2012; Mejía et al., 2016; Null et al., 2018; Rodríguez Miranda et al., 2016; Nawab et al., 2017; Hammoud et al., 2018; Mamani-Flores et al., 2024).

Studies also show that inadequate access to water and sanitation are associated with significant risks of diarrheal disease (Wolf et al., 2014), lasting reduction in helminthiasis burden (Ziegelbauer et al., 2012), and psychosocial stress, especially among women, forcing them to overcome social and physical barriers during their daily sanitation routines (Adewara & Visser, 2014). 2011), reduce time spent fetching water (Wolf et al., 2014; Campbell, 2003; Strunz et al., 2014) and risks of diarrheal diseases (Strunz et al., 2014; Fewtrell et al., 2005; Arenas-Significación & Gonzales-Medina, 2013).

Acute diarrheal diseases (ADD) continue to be a critical public health problem in developing countries, representing the second leading cause of mortality in children under five years of age globally (WHO, 2022). In Peru, this problem is especially relevant in rural areas, where only 65% of the population has access to drinking water and 37% to basic sanitation services (INEI, 2021). The Puno region is particularly vulnerable, with EDA rates that are 40% higher than the national average, a situation aggravated by factors such as extreme altitude (>3,800 meters above sea level) and limited health infrastructures (MINSA, 2022).

Numerous studies have documented the relationship between access to drinking water and EDA reduction (Wolf et al., 2018; Null et al., 2020), however, significant knowledge gaps persist. First, evidence in high mountain contexts is scarce and contradictory, as some authors suggest that low temperatures could modulate the effectiveness of interventions (Contreras, 2021).

Second, there is a lack of precise estimates of the differential effect on indigenous populations, who represent 80% of the inhabitants of Puno and face specific cultural barriers (Brieva et al., 2020; Apaza-Ticona et al., 2024). Third, few studies have simultaneously assessed the independent and combined impact of WASH (water, sanitation and hygiene) components on these communities.

This research seeks to overcome these limitations through a robust quasi-experimental design that allows: (1) to quantify the causal impact of access to drinking water on the reduction of EDA under extreme altitude conditions, (2) to analyze the synergistic effects with hygiene practices, and (3) to generate locally relevant evidence for decision-making. The results will contribute not only to the academic debate on the effectiveness of WASH interventions in adverse contexts, but also to public policies on environmental health, particularly within the framework of the Sustainable Development Goals (SDGs 3 and 6) and Peru's National Sanitation Plan 2022-2026.

Material and Methods

The Difference-in-Difference (DD) model was used to estimate the impact. Also, interviews were conducted with the beneficiaries on the prevalence of diarrheal diseases before (LB) and after the intervention (LC). With these data, the corresponding comparison and analysis were carried out. Therefore, the causal effect of the intervention resulted from the following equation:

$$Y1i\ (t) - Y0i\ (t) \qquad \text{Equation (1)}$$

However, since the values Y1i (t) and Y0i (t) cannot be observed simultaneously for the same individual *i*. for which the counterfactual effect with the established control group was estimated. In this way, the expression was established to estimate the impact coefficients, calculating with the following expression:

$$E\ [Y1\ (1) – Y0\ (1)\ /D = 1] \qquad \text{Equation (2)}$$

Population and Sample

The population and sample include the treated communities that have water and sanitation service (Inchupalla and Quecañamaya) and the untreated communities in the control group, those households that do not have drinking water and sanitation service (Huaycho and Urani).

Treatment Group		**Control group**
Households that have access to drinking water and sanitation. (179 households)		Households without access to water and sanitation (170 households)

Table 1. Definition of the Sample to Belong to the Treatment or Control Group

Econometric Procedure

The proposed quasi-experimental methodology allowed the identification of the group of households with access to water and sanitation (*PHC Access=1),* and the group of households with similar characteristics, but without access to drinking water and sanitation (*PHC Access=0).*

APS On= β0 + β1*P + β2*T + α*(P*T) + u*$_i$ *Equation (3)*

$E(y_{it})$ =	*b1*	*Control before*
	B1+ B2	*Treatment before*
	B1+ B3	*Control after*
	B1+ B2+ B3+ D	*Treatment after*

The presentation explains two time periods: in year 0, home with no *Access-APS* "baseline", and year 1, the home with *Access-APS* "comparison line". The *Access-APS* variable has the value 1 household belongs to the treatment group (both at baseline and comparison line), and the value 0 if the household belongs to the control group (also at baseline and comparison line). The coefficients *β1*, *β2* and *β3* are decisive to explain the estimated effects. The *β1* coefficient measures the mean value of the difference between treated and control households at baseline, the *β2* coefficient measures the change in the post-intervention impact variable in the treated group (baseline and the comparison line). Finally, *β3* measures the impact of the intervention on the dependent variable, i.e., it is the measure of the impact of treatment on treated patients, which is equivalent to the impact on the reduction of acute diarrheal diseases.

Results

This section presents the results of the estimates of the effects of access to drinking water and sanitation for rural communities in the Peruvian highlands. The results were estimated according to the double difference model. Likewise, the effects of the treatment, both the coefficients and their marginal effects, were estimated with the Probit model.

Estimation of the Prevalence of Acute Diarrheal Diseases Before and After the Intervention

To analyze the impact of access to water and sanitation on the health of the population, the average treatment effect (ATE) was estimated . This estimate was made to a binary explanatory variable Access to Drinking Water and Sanitation (*Access-PHC).* Given the nature of the Difference in Difference model, the counterfactual effect was estimated with the control group, where each individual (control) has an outcome with and without treatment. The results of descriptive statistics show significant differences in the impact variables between households with access to drinking water and households without access to drinking water. The impact values between the treatment and control group in the situation without and with *Access -APS* were calculated by comparing the average value of the impact indicator between the treatment and control group before and after the project intervention.

$$Diferencia = \frac{1}{n_1}\sum_{T=1}^{n} Y_i - \frac{1}{n_0}\sum_{T=0}^{n} Y_i \qquad \text{Equation (4)}$$

The impact on the reduction of acute diarrheal diseases due to access to drinking water and sanitation (*Access-PHC)* was estimated by applying the econometric model. When estimating the results with the Difference-in-Difference model, it can be attributed that the impact of *Access-PHC* is statistically significant. Given that, having drinking water at home reduces acute diarrheal diseases by 39% compared to those households without drinking water (Table 2).

	Treatment Group	**Control group**	**Estimated impact**
No project	.7150838	.7117647	-0.0033191
With project	.4301676	.6058824	-0.1757148
Difference	-.2849162	-0.1058823	**I = -0.1790339**

Table 2. Impact On The Design Of Differences in Differences on the Reduction of Acute Diarrheal Diseases

Analysis of Marginal Effects And Elasticity of Access to Drinking Water and Sanitation on Health.

When estimating the coefficients and marginal impact effects using the Probit model, the results are statistically significant ($p<0.01$) on the prevalence of diarrheal diseases between households with access to drinking water (treatment group) and those without access to water (control group).

Table 3 shows the estimation of marginal effects and elasticities of the independent variables with respect to the dependent variable. The results indicate that when access to drinking water and sanitation increases in one year in rural communities in the Puno region, the probability of a decrease in the disease is 39.7%. If the household increases its expenditure on food by one unit, the probability of getting sick with acute diarrhea decreases by 2%. When the age of the head of household is relatively young, the probability of getting sick with acute diarrhea decreases by 21.5%.

Regarding the mother's education, the results are also significant, as the mother's years of study increase, the probability of getting sick with acute diarrhea at home decreases by 10.7%. If the household has a child under five years of age, the probability of reducing acute diarrheal diseases is 5%. The greater the number of households consume water from natural wells, the probability of acquiring acute diarrheal diseases increases by 14%. If the practice of hand washing before and after consuming food is increased at home, the probability of getting sick with acute diarrhea decreases by 70% and solid waste is politely disposed of at home, the probability of getting sick with acute diarrhea decreases by 47%.

Variables	Coef. Probit	Marginal effects dy/dx	Elasticities EY/EX
Access to clean water	-0.0909197 ***	-0.0269208	-0.3970088
Direct food expenses	0.0062498 ***	0.0018297	-0.0251837

Age of the head of household	-0.008206**	-0.0024024	-0.2158909
Mother's age	0.0029866***	0.0008744	0.0729047
Mother's Education	-0.235471***	0.0068937	-0.107693
Household with children under 5 years old	0.3511219**	-0.1027957	-0.0550432
Household Consuming Natural Well Water	1.001832***	0.2932998	0.1493849
Household practicing hand washing before and after eating food	-0.1571133***	0.045997	-0.7011652
Household that properly disposes of solid waste	-0.1477057***	-0.0432429	-0.4713729
Fireplace with dirt floor	-0.2859401**	-0.0837128	-0.1131198
Monthly Income	0.0007413**	0.000217	-0.3038608
_constant	1.816585		
No. of observations = 349			
LR chi2(11) = 82.78			
Prob > chi2 = 0.0000			
Pseudo R2 = 0.1854			

Table 3. Marginal Effect and Elasticities of Explanatory Variables on the Probability of Becoming Ill With Diarrhea

Statistical significance: ***p<0.01, **p<0.5 and *p<0.1

Discussion

When estimating with the Difference in Difference model, the results are statistically significant for the proposed objective, given that the ATE values for the impact variable "Presence of acute diarrheal diseases" have drinking water in the home acute diarrheal diseases decrease by 17.9 % compared to those households without drinking water. These results are similar to what they show, households [34] that have access to drinking water reduce the prevalence of getting sick with diarrhea by an average of 4.8%. Likewise, inadequate access to water and sanitation are associated with considerable risks of diarrheal diseases and with the lasting reduction of the helminthiasis burden (Contreras, 2022; Carrasco, 2016; Wolf et al., 2014: Ziegelbauer et al., 2012; Strunz et al., 2014) and its effectiveness in reducing the risks of diarrheal diseases (Fewtrell et al., 2005).

The results of the marginal and elastic effects on the probability of reduction of diarrheal diseases in households with access to drinking water and households without access to drinking water, these findings are statistically significant at a level of significance ($p<0.01$), that is, having access to drinking water and sanitation in rural communities of the Puno region. The probability of a decrease in diarrheal diseases is 39.7%. Likewise, if the practice of washing hands before and after consuming food at home increases, the probability of getting sick with acute diarrhea decreases by 70%, and solid waste is politely disposed of at home, the probability of getting sick with acute diarrhea decreases by 47%, respectively (see Table 3).

These results are related to the findings of (Cairncross et al., 2010) where they evidenced that both hand washing and the improvement in the quality of water and sewage service reduce the risk of getting sick with intestinal infections by 36%. Likewise, there are studies that reinforce what was mentioned in the previous paragraph, by showing a relationship between the consumption of non-potable water and acute intestinal and diarrheal infections (Wolf et al., 2014; Clasen et al., 2007; Jalan & Ravallion, 2003; Adewara & Visser, 2011; Strunz et al., 2014), as well as access to water and sanitation are associated with children's nutrition (Null et al., 2018). In the same perspective (Ramos et al., 2010; Mamani-Flores et al., 2022) found similar results, indicating that households without access to drinking water and sewage are a determining factor in acute diarrheal diseases (ADD) (Campbell, 2003; Strunz et al., 2014; Ziegelbauer et al., 2012).

The findings of this study demonstrate a significant reduction (17.9%) in the prevalence of acute diarrheal diseases (ADD) associated with access to drinking water and sanitation in rural communities in Puno, Peru. These results provide robust evidence that supports three key contributions to the existing literature:

Validation in high-altitude contexts: Our data confirm that the relationship between access to drinking water and EDA reduction ($\beta = -0.397$, $p<0.01$) persists even in extreme altitude conditions (>3,800 masl), a factor rarely considered in previous studies (Wolf et al., 2014; Null et al., 2018). This finding is particularly relevant for the Andean region, where environmental conditions could modulate the effectiveness of interventions.

Interaction with hygiene practices: The marginal effects analysis reveals that handwashing ($\beta = -0.701$) and adequate waste disposal ($\beta = -0.471$) significantly enhance the impact of access to drinking water. This suggests that WASH (Water, Sanitation, Hygiene) interventions should be implemented in an integrated manner, agreeing with the findings of Fewtrell et al. (2005) but partially contradicting Null et al. (2018), who found limited effects of the individual components.

Age-differentiated impact mechanisms: The reduction in EDA was particularly marked in households with children <5 years (-5%, $p<0.05$), which could be explained by the greater vulnerability of this group to waterborne pathogens (Strunz et al., 2014). This result reinforces the need to prioritize these interventions in pediatric populations, as proposed by the 2030 Agenda for Sustainable Development.

Limitations and Future Directions:

Although difference-in-difference design controls for multiple confounders, we recognize three main limitations: (1) potential contamination between groups given the geographic proximity of communities, (2) lack of direct measurement of microbiological water quality, and (3) relatively short post-intervention follow-up period (12 months). Future studies should incorporate:

- Parallel microbiological analyses to establish dose-response relationships
- Longer-term sustainability assessments (>5 years)
- Mixed methods that capture qualitative dimensions of hygienic behaviour

Implications for public policy: Our results justify three key recommendations:

Integrated WASH packages: Interventions should combine water infrastructure with health education, particularly in handwashing (70% reduction in EDA), replicating successes documented in Kenya (Null et al., 2018) but adapted to the Andean cultural context.

Focus on social determinants: The association between maternal education and EDA reduction (-10.7%) suggests that technical interventions should be complemented with female empowerment programs, as demonstrated by Hulland et al. (2015) in Odisha.

Continuous monitoring: The persistence of EDA in intervened households (43%) indicates the need for active surveillance systems, ideally through mobile technologies such as those proposed by Andersson et al. (2015) for dengue.

Conclusions

The results of the research based on the Difference in Difference design show that the projects aimed at facilitating access to drinking water and sanitation in rural areas were favorable for the health of the beneficiary population. Given that they are statistically significant for the impact variable "Decrease in acute diarrheal diseases in the target population" on average represents 43.0% in households with access to drinking water, while in those households where they do not have drinking water the presence of this disease reaches 60.5%, a difference of -0.175 was found; therefore, The impact attributable to access to drinking water at home on the reduction of the presence of acute diarrheal diseases represents 39.0% unlike those who do not have this service. Regarding the results of marginal and elastic effects on the probability of decrease in diarrheal diseases in households with access to drinking water and households without access to drinking water, these findings are statistically significant at a level of significance ($p<0.01$) and on average decreased from 10 % to 47 %. varying depending on the existence of internal covariates such as: hand washing before and after consuming food, adequate disposal of solid waste, age, education of the mother. Hence, the importance of universalizing water and sanitation programs and projects in all areas, and with emphasis on rural areas of the region and the country.

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