Master’s Thesis of Public Health

Impact of Official Development Assistance (ODA) on water, sanitation and hygiene (WASH) coverage and burden of diarrhoeal diseases

공적개발원조(ODA)가 식수 및 위생 공급률과 설사 질병부담에 미치는 영향: 패널 데이터 분석

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Abstract

Impact of Official Development Assistance (ODA) on water, sanitation and hygiene (WASH) coverage and burden of diarrhoeal diseases

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Background: Provision of sufficient drinking water and sanitation facilities have always been one of the main public health challenges. According to the latest WHO and UNICEF reports, approximately 2.3 billion of the world's population still lacked basic sanitation facilities and this result to about 1.1 million diarrhoea-related deaths each year. Diarrhoea is one of the main symptoms for most of the WASH-related diseases (water-borne diseases such as cholera, guinea worm disease, typhoid and dysentery, etc.) caused due to the lack of WASH facilities and the burden of diarrhoeal diseases have been estimated to be about 1.5% of the total global burden of diseases which is similar to that of HIV-AIDS. Although the amount of aid flows to the WASH sector has increased over the decades (since 1973) there have yet been studies assessing if the amount of ODA gross disbursements (WASH sector) channelled from 2004 to 2017 has an impact on improving WASH coverage and if improvement in such WASH coverage has an impact on reducing the burden of diarrhoeal diseases. This study, therefore, aims to assess if the ODA gross disbursement directed towards the WASH sector has an impact on improving

WASH coverage and if improved WASH coverage has an impact on reducing the burden of diarrhoeal diseases.

Methodology: Panel regression analyses (Fixed-effects model) have been conducted to evaluate 1) if increase in the amount of gross WASH ODA disbursement has an impact on improving WASH coverage and 2) if WASH coverage has an impact on reducing the burden of diarrhoeal diseases among 115 WASH ODA recipient countries. WASH coverage, in this study, has been assessed through three indicators which are: 1) proportion (%) of population having access to improved water; 2) proportion (%) of population having access to improved sanitation facilities and 3) proportion (%) of population practising open defecation. Data for WASH coverage indicators have been obtained from the WHO Global Health Observatory (GHO) and for each of the WASH coverage indicators, total, rural and urban populations have been assessed separately to determine if WASH coverage varies with the area of settlement. Data for the amount of gross WASH ODA disbursement were obtained from the Organisation for Economic Cooperation and Development Creditor Reporting System (OECD-CRS) and data for the burden of diarrhoeal diseases were obtained from the Institute for Health Metrics and Evaluation (IHME). Disability-Adjusted Life Years (DALY) rate per 100,000 population has been selected as the measuring unit for the burden of diarrhoeal diseases.

Results: The effect of WASH ODA on WASH coverage was significant among countries belonging to the lower income groups- LICs and LMICs rather than UMICs. The effect of WASH coverage on the burden diarrhoeal diseases, however, was most significant among countries belonging to higher income group- UMICS rather than LICs and LMICs. Results of the analyses conducted among all 115 countries indicated that the effect of WASH ODA was only significant in reducing proportion of the rural population practising open defecation (%). From the analyses conducted according to different income

groups, the effect of WASH ODA was most significant among the LMICs and least significant among the UMICs. All of the WASH coverage indicators (water, sanitation and open defecation rate) for rural population, sanitation coverage and open defecation rate for total population in LMICs improved with increase in the amount of WASH ODA channelled. The effect of WASH ODA on improving water coverage for all populations (total, rural and urban) and sanitation coverage for the urban population among the LICs was also significant. Furthermore, improvement in all of WASH coverage indicators did reduce the burden of diarrhoeal diseases significantly except for water coverage for the rural population and sanitation coverage for the total population among the 115 countries. The effect of WASH coverage on reducing the burden of diarrhoeal diseases was most significant among the UMICs and least significant among the LICs. Improvement in all of the WASH coverage indicators, except water coverage and open defecation rate of the urban population, significantly reduced the burden of diarrhoeal diseases. For both of LICs and LMICs, improvement in the WASH coverage for urban population had a more significant effect on the reduction of burden of diarrhoeal diseases than the rural population. Improvement in all of the WASH coverage indicators for the urban population in LIMCs significantly reduced the burden of diarrhoeal diseases while improvement in sanitation coverage and open defecation rate of the urban population in LICs had significant effect on the reduction of diarrhoeal diseases. Improvement in water coverage for the rural population in LICs; water (total population %) and sanitation (rural population %) also had significant effect on reducing the burden of diarrhoeal diseases.

Discussion and Conclusion: The effect of WASH ODA was most significant among the LMICs rather than LICs and UMICs. One of the plausible explanations for it could be that for the effect of WASH ODA to occur, the recipient country needs to have a certain level of institutional capacity. Countries in the LICs may tend to lack institutional capacity to set targets and achieve them systematically thus, the effect of WASH ODA may have been less

significant. The effect of WASH ODA was not significant among the UMICs, one possible explanation for it might be that WASH facilities in UMICs have reached a saturation point and any further increase in the amount of WASH ODA will not have a direct impact on increasing WASH coverage. UMICs, where the level of economic development tend to be higher than those countries in LICs and LMICs, might not have as compelling ODA effect as those countries with lower levels of economic development. Although the impact of WASH ODA on WASH coverage was not significant among the UMICs, the effect of WASH coverage on reducing the burden of diarrhoeal diseases was most significant in UMICs. This could therefore imply that although increase in the amount of WASH ODA may not directly improve WASH coverage in UMICs, improvement in the WASH coverage significantly reduces the burden of diarrhoeal diseases in UMICs. Moreover, lack of political commitment from the local governments and that comparatively more funds have been channelled towards increasing water coverage than sanitation could some of the main factors hindering further improvement in sanitation coverage. Achieving coverage for water has been perceived to be more 'tangible' and objective (can be measured empirically) while for sanitation coverage it tends to be more 'intangible' – requires involvement of more human resources to maintain sanitation facilities. Likewise, national policies for improvement in the sanitation coverage has yet to be one of the main priorities in most the recipient countries which could be the main factor hindering sustainment and further achievement of WASH coverage in many countries.

Keywords: Water, sanitation and hygiene (WASH), Official Development Assistance (ODA), diarrhoeal diseases, Disability-Adjusted Life Years (DALY), Panel data analysis, Fixed-effects model

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List of Abbreviations

DALY: Disability-Adjusted Life Years

GDP: Gross Domestic Product

GLAAS: Global Analysis and Assessment of Sanitation and Drinking-Water

GNI: Gross National Income

LICs: Low-income countries

LMICs: Lower-middle-income countries

MDGs: Millennium Development Goals

ODA: Official Development Assistance

OECD: Organisation for Economic Co-operation and Development

OECD-CRS: OECD Creditor Reporting System

OECD-DAC: OECD Development Assistance Committee

SDG: Sustainable Development Goal

UMICs: Upper-middle-income countries

UN: United Nations

WASH: Water, Sanitation and Hygiene

WHO: World Health Organisation

YLD: Years Lost due to Disability

YLL: Years of Life Lost

Chapter 1. Introduction

1.1. Background

Provision of sufficient drinking water and sanitation facilities have always been one of the main public health challenges. According to the latest WHO and UNICEF reports, approximately 2.3 billion of the world's population still lacked basic sanitation facilities and this result to about 1.1 million diarrhoea-related deaths each year (WHO, 2017). Diarrhoea is one of the main symptoms for most of the WASH-related diseases (water-borne diseases such as cholera, guinea worm disease, typhoid and dysentery, etc.) caused due to the lack of WASH facilities and the burden of diarrhoeal diseases have been estimated to be about 1.5% of the total global burden of diseases which is similar to that of HIV-AIDS. (Prüss-Ustün et al., 2014; UNICEF, 2016; WHO, 2017).

In 2010, the United Nations General Assembly has recognised having access to proper WASH facilities as basic human rights. The resolution reinforced the member states and development organisations to enhance technical capacity and financial resources for the developing countries in order to “provide safe, clean, accessible, and affordable drinking water and sanitation for all” (UN, 2010). Therefore, there have been continuous global efforts to increase improved water and sanitation coverage where the amount of Official Development Assistance (ODA) channelled towards the WASH sector has increased substantially in line with the Millennium Development Goals (MDGs)

(Winpenny et. al, 2016). Water Supply and Sanitation Collaborative Council (WSSCC) has also launched the Global Sanitation Fund (GSF) in 2008 to prioritise donor funding in order to support existing national mechanisms and projects in the WASH sector. Moreover, according to OECD (2012), aid to the WASH sector has been increasing steadily since 1973. Despite such efforts, however, unsafe drinking water and lack of sanitation facilities still ranked as high as 14th and 19th leading risk factors of global DALY for both sexes in 2015 (Global Burden of Disease Risk Factors Collaborators, 2015; UNICEF, 2016).

Although the amount of aid flows to the WASH sector has increased over the decades, there have yet been studies assessing if the amount of ODA gross disbursements (WASH sector) channelled from 2004 to 2017 has an impact on improving WASH coverage and if improvement in such WASH coverage has an impact on reducing the burden of diarrhoeal diseases. This study, therefore, aims to assess if the ODA gross disbursement directed towards the WASH sector has an impact on improving WASH coverage and if improved WASH coverage has an impact on reducing the burden of diarrhoeal diseases.

1.2. Literature Review

As shown in [Table 1], thus far to author's knowledge, there have been 5 previous studies conducted to assess the impact of WASH ODA on WASH coverage. Botting et. al (2010) analysed the relationship between ODA disbursement per capita and WASH coverage, infant and child mortality. Their results indicated that access to improved water has consistently improved since 2002 (after the establishment of MDGs) while sanitation access were largely non-significant. Furthermore, results suggested that access to sanitation facilities had an effect on reducing infant and child mortality.

Gopalan and Rajan (2016) study assessed whether ODA gross disbursements have been effective in improving the percentage of the population having access to improve the water and sanitation facilities. Results from the Gopalan and Rajan (2016) study suggested that the amount of ODA gross disbursements channelled to the WASH sector was only effective among the lower-middle-income countries (LMICs) rather than low-income countries (LICs) or upper-middle-income countries (UMICs). Their results also indicated that rural areas seem to have experienced greater improvements in terms of water and sanitation coverage than urban areas.

Ndikumana and Pickbourn (2016) investigated whether targeting foreign aid to WASH sector can help achieve the goal of expanding access to WASH services among 29 countries in the sub-Saharan Africa region. They claimed that increase in the amount of WASH ODA was associated with increase in the access to WASH services although the relationship was non-linear.

Wayland (2017), on the other hand, mainly focussed on exploring which were the factors constraining the effectiveness of aid in the context of the WASH sector. The proportion (%) of the population having access to basic drinking water, sanitation facilities and under-five mortality rate per 1000 live births (Under-5 mortality) were the dependent variables and the amount of aid committed to WASH sector was the explanatory variable. In Wayland (2017) study, data for aid commitments have been obtained from the AidData instead of OECD-CRS. Wayland (2017) suggested that factors such as government effectiveness, regulatory quality and having large percentage of rural populations were some of the main factors constraining the effectiveness of aid in the WASH sector.

Last but not the least in Cha et. al (2017) study, which aimed to explore the trends between the performance of ODA and its expansion in the WASH sector, indicated that the inequality of water and sanitation coverage among 103 WASH ODA recipient countries has not been addressed effectively over the past decade. Moreover, Cha et. al (2017)'s results indicated that countries with the least water and sanitation coverage have been persistently receiving far less ODA per capita than those countries with much better water and sanitation coverage. Ultimately, suggesting that ODA for water and sanitation has been poorly targeted. None of the studies, however, has managed to include the proportion (%) of population practising open defecation as part of WASH coverage indicators and none has analysed if WASH coverage has an impact on the reducing the burden of diarrhoeal diseases (DALY rate).

[Table 1] Previous studies conducted on the impact of WASH ODA on WASH coverage and conducted in relation to WASH ODA

Author(s)	Countries of Analysis	Purpose of Study	Study Design	Dependent Variables	Explanatory Variable(s)	Main Findings
Botting et. al (2010)	49 LICs (World Bank classification)	To analyse the relationship between ODA disbursement per capita, improved water and sanitation coverage, and infant and child mortality since the establishment of the MDGs.	1. Country-level analysis (2002-2006)	Data: WHO 1. Proportion (%) of population with access to improved water 2. Proportion (%) of population with access to improved sanitation facilities 3. Infant mortality rate 4. Child mortality rate	Data: OECD-CRS 1. WASH ODA gross disbursements	Access to improved water has consistently improved since 2002 while sanitation access were largely non-significant. Access to sanitation facilities had effect on reducing infant and child mortality.
Gopalan and Rajan (2016)	139 LMICs (World Bank classification)	To assess whether the amount of ODA gross disbursements channelled to the WASH sector has contributed to the improvement in the WASH coverage.	1. Panel Fixed-effects model (2002 – 2012)	Data: WHO 1. Proportion (%) of population with access to improved water 2. Proportion (%) of population with access to improved sanitation facilities	Data: OECD-CRS 1. WASH ODA gross disbursements	Increase in ODA gross disbursements produce strong, positive and significant effect on improved WASH coverage.
Ndikumana and Pickbourn (2016)	29 countries in the sub-Saharan Africa region	To investigate whether targeting foreign aid to WASH sector can help achieve the goal of	1. Panel Fixed-effects model 2. Generalized method of moments (system GMM)	Data: WHO 1. Proportion (%) of population with access to improved drinking water, 2. Proportion (%) of	Data: OECD-CRS 1. WASH ODA gross disbursements	Increase in the amount of WASH ODA is associated with increase in the access to WASH services although the

		expanding access to WASH services.	regressions (1990-2010)	population with access to improved sanitation facilities 3.Ratio of urban access to rural access (water) 4.Ratio of urban access to rural access (sanitation)		relationship is non-linear.
Wayland (2017)	125 ODA recipient countries	To assess which factors constraints the effectiveness of aid in the WASH sector	1. Dynamic Panel Model (DPM) 2. Latent Growth Model (LGM) 3. Panel Instrumental Variable Model (IVM) (1995 – 2004)	Data: WHO 1. Proportion(%) of population with access to improved drinking water, 2. Proportion(%) of population with access to improved sanitation facilities 3. Under-five mortality	Data: AidData 1.AidData commitment (total per capita dollar value of aid from all donors of WASH projects)	Government ineffectiveness, regulatory quality and large rural population constrained the effectiveness of WASH aid.
Cha et.al (2017)	103 ODA recipient countries	To explore trends in the expansion of water and sanitation coverage in developing countries and the performance of ODA.	1. Panel Random-effects model (1990 – 2010)	Data: WHO 1. Proportion(%) of population with access to improved water 2. Proportion(%) of population with access to improved sanitation facilities	Data: OECD-CRS 1. Income level 2. WASH ODA commitment	Countries with the least coverage persistently received far less ODA per capita than those countries with much more extensive water and sanitation coverage, suggesting that ODA for water and sanitation is poorly targeted.

1.3. Purpose of the Study

There have been various studies assessing effectiveness of foreign aid in general, but comparatively few studies have been conducted to assess effectiveness of ODA directed towards the WASH sector (Gopalan and Rajan, 2016). Although the amount of aid flows to the WASH sector has increased over the last few years there have yet been studies assessing if the increase in the ODA gross disbursements (WASH sector) has been effective in improving WASH coverage and if improvement in the WASH coverage will have an impact on reducing the burden of diarrhoeal diseases. Moreover, unlike most of the previous studies where ODA commitments have been examined, this study aim to assess the impact of ODA gross disbursements instead. The main difference between ODA commitments and ODA gross disbursement is that the prior accounts from donors' perspective (how much the donors have committed to donate) while the latter refers to the actual amount of ODA being disbursed each year where it can said to be a more favourable indicator to assess the amount of aid flow from the recipients' perspective.

In this study, the burden of diarrhoeal diseases (Disability-Adjusted Life Years-DALY) is assessed instead of the mortality rate. One of the main reasons for such is that mortality rate by itself is not able to provide a full picture of the whole burden of the diseases borne by the individuals in different populations. DALY, on the other hand, is able to provide an indication of the overall burden of diseases borne by each WASH ODA recipient countries. Disability-Adjusted Life Years (DALY) = YLL (Years of Life Lost) + YLD (Years Lost due to Disability). WHO (2014) stated that DALY measures the gap between the current health status and an ideal health situation (a situation where the entire population lives up to an advanced age, free of disease and disability). DALY also accounts for disabilities that might not result in death but can severely affect one's quality of life.

The main differences between the previous studies mentioned in [Table 1] and this study are that the proportion (%) of total, rural, urban populations practising open defecation have been included as one of the indicators for the WASH coverage. Furthermore, to author's knowledge, this is the first study to assess the impact of WASH coverage on the burden of diarrhoeal diseases (DALY rate) together with the impact of WASH ODA on WASH coverage via panel regression analysis.

1.4. Hypothesis

The objective of this study is to assess if the amount of gross ODA disbursement channelled towards the WASH sector has an impact on improving the WASH coverage and whether improvement in WASH coverage has an impact on reducing the burden of diarrhoeal diseases.

Hence, hypotheses of this study are as follows:

1. The amount of gross ODA disbursement channelled to the WASH sector will have an impact on improving WASH coverage (water, sanitation coverage and proportion (%) of population practising open defecation).

2. Improvement in the WASH coverage will have an impact on reducing the burden of diarrhoeal diseases (DALY rate per 100,000 population).

Chapter 2: Methodology

2.1. Study design

Previous studies which examined the impact of ODA on the WASH sector have used panel data for their analysis. Some of the main advantages of using panel data are that there could be a more accurate inference of model parameters which is probably due to panel data having greater degrees of freedom and sample variability than cross-sectional data which contributes to the efficiency of econometric estimates (Hsiao, 2007). Moreover, with panel data the impact of omitted variables can also be controlled. Panel data contain information on both the intertemporal dynamics and individuality of the entities may allow one to control the effects of missing or unobserved variables (Hsiao, 2007). Thus, in this study country-level panel data have also been used for the analysis.

WASH coverage, in this study, has been assessed through three indicators which are: 1) the proportion (%) of population having access to improved water; 2) proportion (%) of population having access to improved sanitation facilities and 3) proportion (%) of population practising open defecation. For each of the WASH coverage indicators: total, rural and urban populations have also been assessed separately to determine if WASH coverage varies with the area of settlement. Data for WASH coverage have been obtained from the World Health Organisation (WHO) Global Health Observatory (GHO) data from 2004 to 2017, where 2017 being the latest data available. Data for ODA gross disbursements have been obtained from the Organisation for Economic Co-operation and Development (OECD) Creditor Reporting System (CRS) from 2002 to 2017. The ODA gross disbursements have been measured in US dollars, millions, 2017 constant prices.

Out of 157 WASH ODA recipient countries, 39 countries have been excluded from this study due to various missing and unavailability of data. Countries with high population density and GDP per capita (such as China and India) and 3 high-income countries (Chile, Panama and Uruguay) have also been excluded in this study for data accuracy. Therefore, panel data regression (the fixed-effects model) of 115 ODA recipient countries have been conducted and the dependent variables (WASH coverage and burden of diarrhoeal diseases) have been lagged by 2 years as ODA transferred from donors to recipients in a given year may take several months to reach beneficiaries and for its impact to be realised. Moreover, to minimise reverse causality (Wee et. al, 2017).

2.2. Characteristics of the study sample

Out of 157 ODA recipient countries 115 countries were set as the target countries of analysis. Of which, 27 countries belonged to the LICs income group, 41 to the LMICs group, 47 to the UMICs group (please refer to [Appendix A: pg. 66]). Regional wise, 14 countries were from the Europe and Central Asia region, 18 countries from East Asia and Pacific region, 24 countries from Latin America and Caribbean region, 9 countries from the Middle East and North Africa region, 7 countries from South Asia region and lastly 43 countries from sub-Saharan Africa region (please refer to [Appendix B: pg. 68]).

2.3. Method of Analysis

To assess if WASH ODA has an impact on WASH coverage and burden of diarrhoeal diseases, empirical estimations have been estimated as shown in the following pages. Panel regression analyses were conducted using STATA software version 14.1.

2.3.1. Data sources and variables

The dependent variables of this study are 1) WASH coverage and 2) burden of diarrhoeal diseases. The explanatory variable for 1) WASH coverage analyses is the amount of WASH ODA while for the 2) burden of diarrhoeal diseases analyses is the WASH indicators. Considering the importance of having indicators that depict each of the WASH ODA recipient countries' level of development and capacity level of the populations, following three indicators have been included as the control variables of this study: population density, GDP per capita (US$2010) and Human Development Index (HDI). HDI is a composite index which measures a country's average achievements in three aspects- health (life expectancy index), knowledge(education index), and income (Gross National Income index). Since it is also one of the indicators to measure poverty from a multidimensional perspective, it has been included instead of including each separate indicators for health, education and income. Inclusion of HDI as one of the control variables also has an advantage of not excluding those countries with missing or unavailable data. As for example, data for each recipient country's education indicators tend to have many missing values when compared to that of HDI.

Human Development Index (HDI)			
Dimensions	**I.** Long and healthy life	**II.** Knowledge	**III.** A decent standard of living
Indicators	Life expectancy at birth	1. Expected years of schooling 2. Mean years of schooling	GNI per capita (PPP$)
Dimension Index	Life expectancy index	Education index	GNI index

Source: http://hdr.undp.org/en/content/human-development-index-hdi

I. WASH coverage

1) Proportion (%) of population having access to at least basic drinking water services

2) Proportion (%) of population having access to at least basic sanitation facilities

3) Proportion (%) of population practising open defecation

For each of the indicators for water, sanitation and open defecation have been assessed separately.

1. Total percentage (%) of the population

2. Percentage (%) of rural population

3. Percentage (%) of urban population

[Table 2] Description of Variables (WASH coverage)

<table>
<tr><th>Type of Variables</th><th>Variables</th><th>Explanation</th><th>Sources</th></tr>
<tr><td rowspan="9">Dependent variables</td><td>Total percentage (%) of population having access to at least basic drinking water services</td><td rowspan="3">Improved drinking water source includes piped water on premises</td><td rowspan="9">WHO Global Health Observatory (GHO) data</td></tr>
<tr><td>Percentage (%) of rural population having access to at least basic drinking water services</td></tr>
<tr><td>Percentage (%) of urban population having access to at least basic drinking water services</td></tr>
<tr><td>Total percentage (%) of population having access to at least basic sanitation facilities</td><td rowspan="3">Improved sanitation facilities include flush/pour flush</td></tr>
<tr><td>Percentage (%) of rural population having access to at least basic sanitation facilities</td></tr>
<tr><td>Percentage (%) of urban population having access to at least basic sanitation facilities</td></tr>
<tr><td>Total percentage (%) of population practising open defecation</td><td rowspan="3">Open bodies of water, or other open spaces rather than using the toilet to defecate
\</td></tr>
<tr><td>Percentage (%) of rural population practising open defecation</td></tr>
<tr><td>Percentage (%) of urban population practising open defecation</td></tr>
<tr><td>Explanatory variable</td><td>WASH ODA gross disbursements</td><td>Actual amount of ODA funding directed to WASH sector among the recipient countries</td><td>OECD-CRS</td></tr>
</table>

Control variables	Gross Domestic Product per capita (GDP per capita Constant 2010 US$)	GDP per capita is divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	World Bank
	Population density	Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	
	Human Development Index	The Human Development Index (HDI) is a summary composite index that measures a country's average achievements in three basic aspects of human development: health, knowledge, and income.	United Nations Development Programme (UNDP)

Explanation of the variables have been retrieved from the sources mentioned in the table.

Water coverage

Model 1) $Y_{it}^{WT} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 2) $Y_{it}^{WR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 3) $Y_{it}^{WU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Sanitation coverage

Model 4) $Y_{it}^{ST} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 5) $Y_{it}^{SR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 6) $Y_{it}^{SU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Population practising Open defecation

Model 7) $Y_{it}^{OT} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 8) $Y_{it}^{OR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 9) $Y_{it}^{OU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Where,

i = Countries, t = Year, $\alpha_i =$ Country (fixed) effect

$\beta =$ Regression coefficient of explanatory variables

$\gamma =$ Regression coefficient of control variables, $Z =$ Control variables, $\epsilon =$ Error term

Y_{it}^{WT} = Total percentage of population having access to at least basic water services

Y_{it}^{WR} = Percentage of rural population having access to at least basic water services

Y_{it}^{WU} = Percentage of urban population having access to at least basic water services

Y_{it}^{ST} = Total percentage of population having access to at least basic sanitation services

Y_{it}^{SR} = Percentage of rural population having access to at least basic sanitation services

Y_{it}^{SU} = Percentage of urban population having access to at least basic sanitation services

Y_{it}^{OT} = Total percentage of population practising open defecation

Y_{it}^{OR} = Percentage of rural population practising open defecation

Y_{it}^{OU} = Percentage of urban population practising open defecation

II. Burden of diarrhoeal diseases

Dependent Variable: Burden of diarrhoeal diseases (DALY rate per 100,000 population)

Explanatory Variables: WASH coverage indicators

1) Proportion (%) of population having access to at least basic drinking water services

2) Proportion (%) of population having access to at least basic sanitation facilities

3) Proportion (%) of population practising open defecation

For each of the indicators for water, sanitation and open defecation have been assessed separately.

1. Total percentage (%) of the population

2. Percentage (%) of rural population

3. Percentage (%) of urban population

[Table 3] Description of Variables (Burden of diarrhoeal diseases)

Dependent variable	Rate (per 100,000 population) of total burden of diarrhoeal diseases (expressed in DALY)	Burden of diarrhoeal diseases = DALY (= Years of Life Lost (YLL) due to diarrhoeal diseases + Years Lived with Disability (YLD)) caused by diarrhoeal diseases	Institute for Health Metrics and Evaluation (IHME)
Explanatory variables	Total percentage (%) of population having access to at least basic drinking water services	Improved drinking water source includes piped water on premises	WHO Global Health Observatory (GHO) data
	Percentage (%) of rural population having access to at least basic drinking water services		
	Percentage (%) of urban population having access to at least basic drinking water services		
	Total percentage (%) of population having access to at least basic sanitation facilities	Improved sanitation facilities include flush/pour flush	
	Percentage (%) of rural population having access to at least basic sanitation facilities		
	Percentage (%) of urban population having access to at least basic sanitation facilities		
	Total percentage (%) of population practising open defecation	Open bodies of water, or other open spaces rather than using the toilet to defecate	
	Percentage (%) of rural population practising open defecation		
	Percentage (%) of urban population		

	practising open defecation		
Control variables	Gross Domestic Product per capita (GDP per capita Constant 2010 US$)	GDP per capita is divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	World Bank
	Population density	Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	
	Human Development Index	The Human Development Index (HDI) is a summary composite index that measures a country's average achievements in three basic aspects of human development: health, knowledge, and income.	United Nations Development Programme (UNDP)
	WASH ODA gross disbursements	Actual amount of ODA funding directed to WASH sector among the recipient countries	OECD-CRS

Explanation of the variables have been retrieved from the sources mentioned in the table.

Burden of diarrhoeal diseases (DALY rate)

Model 10) $Y_{it}^{DWT} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 11) $Y_{it}^{DWR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 12) $Y_{it}^{DWU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 13) $Y_{it}^{DST} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 14) $Y_{it}^{DSR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 15) $Y_{it}^{DSU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 16) $Y_{it}^{DOT} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 17) $Y_{it}^{DOR} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Model 18) $Y_{it}^{DOU} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \epsilon_{it}$

Where,

i = Countries, t = Year, $\alpha_i =$ Country (fixed) effect

$\beta =$ Regression coefficient of explanatory variables

$\gamma =$ Regression coefficient of control variables, $Z =$ Control variables, $\epsilon =$ Error term

Y_{it}^{DWT}= Burden of diarrhoeal diseases among total population having access to at least basic water services

Y_{it}^{DWR}= Burden of diarrhoeal diseases among rural population having access to at least basic water services

Y_{it}^{DWU}= Burden of diarrhoeal diseases among urban population having access to at least basic water services

Y_{it}^{DST}= Burden of diarrhoeal diseases among total population having access to at least basic sanitation services

Y_{it}^{DSR}= Burden of diarrhoeal diseases among rural population having access to at least basic sanitation services

Y_{it}^{DSU}= Burden of diarrhoeal diseases among urban population having access to at least basic sanitation services

Y_{it}^{DOT}= Burden of diarrhoeal diseases among total population practising open defecation

Y_{it}^{DOR}= Burden of diarrhoeal diseases among rural population practising open defecation

Y_{it}^{DOU}= Burden of diarrhoeal diseases among urban population practising open defecation

2.4. Pearson's Correlation Matrix

Correlation test have been conducted to assess if there were any correlations between the variables and the results are as shown in [Table 4]. The control variables: population density, GDP per capita (US$2010) and Human Development Index (HDI), and amount of WASH ODA mostly had low positive correlations at 0.01 significance level except for population density and GDP per capita (US$2010) where it had a low negative correlation. Variables representing the WASH coverage all had a low positive correlations with the amount of WASH ODA, population density, GDP per capita (US$2010) except for the proportion of populations practising open defecation (%) where there were low but negative correlations. Due to the nature of WASH, where coverage for each sectors (water, sanitation and open defecation rate) are highly interdependent, the correlations amongst each WASH coverage indicators were mostly high. Both water and sanitation coverage had very high correlation with populations practising open defecation (%), but sanitation coverage had higher correlation than that of the water coverage at 0.01 significance level. Moreover, the correlations between the rural populations practising open defecation (%) and urban populations practising open defecation (%) were also very high at 0.01 significance level which indicates that countries with higher proportion of population practising open defecation (%) in the rural areas are more likely to have higher proportion of population practising open defecation (%) in the urban areas.

2.5. Model selection: Fixed-effects vs. Random-effects model

Both Breusch-Pagan Lagrangian Multiplier (LM) and Hausman tests have been conducted to determine the appropriate model of analysis for this study. In all of the LM tests, the p-value was 0.000 (Prob>chi2 = 0.0000) at 0.05 significance level. Therefore, between the Random-effects Regression Model and Pooled OLS Regression Model, Random-effects Regression Model have shown to be the more appropriate model. To determine between the Random-effects Regression Model and Fixed-effects Regression Model, the Hausman test have been performed. In all of the Hausman tests conducted, p-value was 0.000 (Prob>chi2 = 0.0000) at significance level of 0.05. The Fixed-effects Regression Model have, thus, shown to be the most appropriate model to assess the impact of ODA on WASH coverage and burden of diarrhoeal diseases.

[Table 4] Pearson's Correlation Matrix

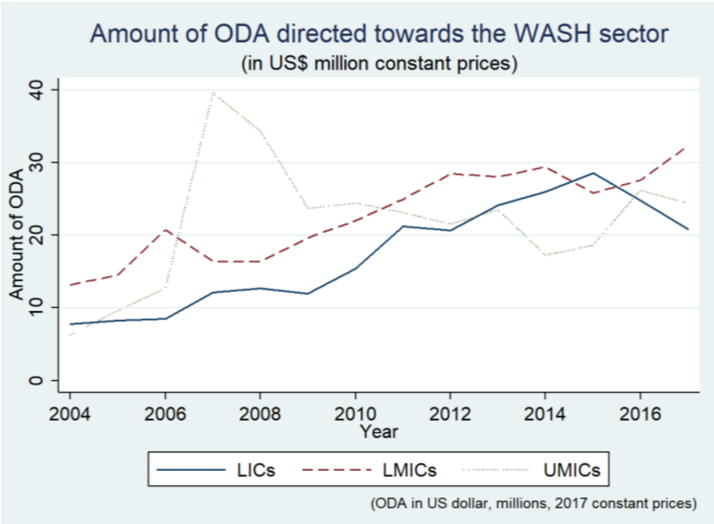
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. WASH ODA (2-year lag)	1.0000												
2. Population Density	0.0212	1.0000											
3. Log [GDP per capita (US$ 2010)]	0.2893**	-0.0647**	1.0000										
4. Human Development Index	0.0860**	0.0454	0.3797**	1.0000									
5. Water coverage (% total population)	0.0630**	0.1991**	0.2324**	0.8350**	1.0000								
6. Water coverage (% rural population)	0.0471	0.2649**	0.1760**	0.7556**	0.9490**	1.0000							
7. Water coverage (% urban population)	0.0949**	0.1336**	0.2884**	0.7772* *	0.8720**	0.7936**	1.0000						
8. Sanitation coverage (% total population)	0.0736**	0.1171**	0.2703**	0.8558**	0.8486**	0.8411**	0.7385*	1.0000					
9. Sanitation coverage (% rural population)	0.0708**	0.1501**	0.2453**	0.8276**	0.8106**	0.8376**	0.7184*	0.9775**	1.0000				
10. Sanitation coverage (% urban population)	0.0800**	0.0503*	0.2818**	0.8051**	0.8017**	0.8054**	0.7155*	0.9575**	0.9098**	1.0000			
11. Open defecation (% total population)	-0.0897**	-0.1873**	-0.2766**	-0.6425**	-0.6365**	-0.5968**	-0.5275*	-0.7427**	-0.7444**	-0.6292**	1.0000		
12. Open defecation (% rural population)	-0.0877**	-0.2101**	-0.2537**	-0.6235**	-0.6019**	-0.6144**	-0.5221**	-0.7284**	-0.7727**	-0.6175**	0.9722**	1.0000	
13. Open defecation (% urban population)	-0.0970**	-0.0818**	-0.3038**	-0.4255**	-0.4169**	-0.4009*	-0.4215**	-0.5527**	-0.5527**	-0.5341**	0.8239**	0.7943**	1.0000

Statistical significance: *<0.05, **<0.01

Chapter 3: Results

3.1. General characteristics of results

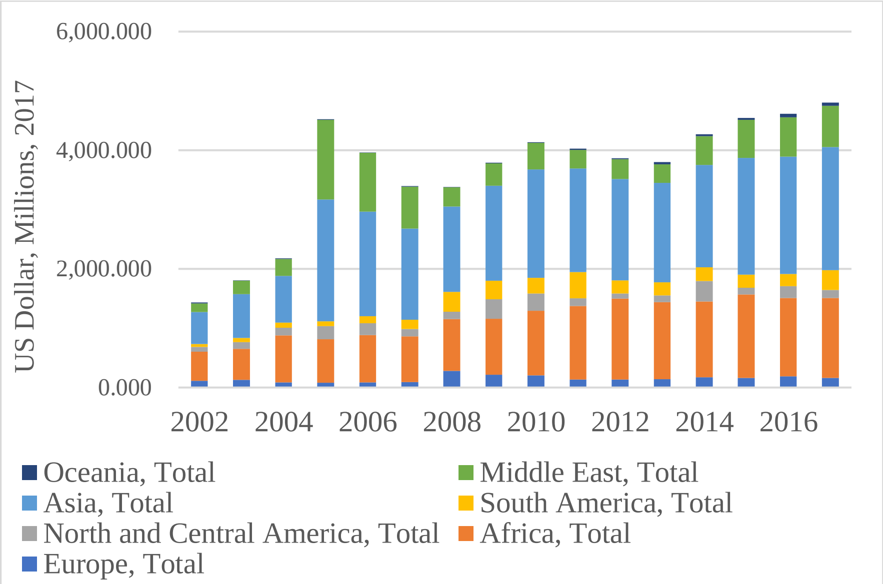
To assess whether the amount of ODA gross disbursement channelled towards the WASH sector from 2002 to 2017 has an impact on the WASH coverage and if WASH coverage has an impact on reducing the burden of diarrhoeal diseases from 2004 to 2017 (dependent variables have been lagged by 2 years), 115 countries of analysis have been categorised according the World Bank Atlas method where countries' economies with GNI per capita less than $995 in 2017 (current US dollars) were classified as the LICs while countries with GNI per capita within the range of $996 and $3,895 were classified as LMICs. UMICs were those with GNI per capita between $3,896 and $12,055 (World Bank, 2018).



[Figure 1] The amount of ODA directed to the WASH sector

[Figure 1] shows how the amount of ODA directed towards the WASH sector varies according to different income groups. Data were obtained from the OECD-CRS where the average amount of ODA directed to the WASH sector from 2004 to 2017 have been aggregated and grouped accordingly- LICs, LMICs, UMICs. With regard to the general trend of the graph, the amount of ODA directed to the WASH sector in all three income groups have increased from 2004 to 2017. There are, however, differences in the overall trend among the three income groups. Both the LICs and LMICs had a steady increase in the amount of ODA channelled to the WASH sector, while the UMICs had a steep increase and a rapid fall in the amount of ODA channelled to the WASH sector from 2006- 2009.

Although there could be many possible complex causes behind such steep rises and falls, some of the possible explanations for such steep rise in 2006 (UMICs) could be due to the Paris Club debt relief operations for Iraq. The amount of ODA channelled to Iraq was unprecedentedly high in 2005 (US$ 107.1 billion) and 2006 (US$ 104.4 billion) perhaps, the sudden fall after 2007 could be due to the debt relief as it was significantly reduced in 2007 (Paris Club operations). OECD has announced the possible reason behind such drastic changes in the amount of ODA could be partly due to the high debt relief in 2006 and reduction in the amount of ODA channelled to Iraq (OECD, 2008).



[Figure 2] Total amount of ODA gross disbursements directed to WASH sector

According to the OECD report, the top five donors in the WASH sector from 2009-10 were (bilateral donors) Japan, Germany, France and institutional donors IDA and EU institutions. They accounted for almost 60 % of all aid to the WASH sector (OECD, 2012). [Figure 2] shows the total amount of ODA gross disbursements directed to the WASH sector by regions. With reference to [Appendix B: pg.68], 14 countries were from the Europe and Central Asia region, 18 countries from the East Asia and Pacific region, 24 countries from the Latin America and the Caribbean region, 9 countries from the Middle East and North Africa region, 7 of the countries from the South Asia region and 43 countries from the sub-Saharan Africa region in this study. Asia received the most amount of WASH ODA followed by Africa, Central and Latin America, the Middle East from 2002 to 2017.

However, when the amount of ODA is assessed on an annual basis, sub-Saharan Africa region had received 25% of total aid to the sector, followed by the South and Central Asia region- 23% (OECD-DAC, 2010). According to the DAC statistics in 2010-11, the absolute amount of ODA channelled towards the WASH sector remained at around US$8.8 billion (current prices) where 4.6% of total DAC bilateral aid (of US$94 billion) and about 11.4% of total multilateral aid (of US$39 billion) were channelled towards the WASH sector. About US$4.5 billion were channelled from multilateral institutions. The amount of WASH ODA increased from 2002 to 2017 where 2017 recorded the highest amount of ODA directed towards WASH.

[Table 5] Sub-categories under WASH sector

DAC code	CRS code	Title	Description
140: I.4. Water Supply and Sanitation, Total	14010	Water sector policy and administrative management	Water sector policy and governance, including legislation, regulation, planning and management, as well as transboundary management of water; institutional capacity development; activities supporting the Integrated Water Resource Management approach.
	14015	Water resources conservation (including data collection)	Collection and usage of quantitative and qualitative data on water resources; creation and sharing of water knowledge; conservation and rehabilitation of inland surface waters (rivers, lakes, etc.), ground water and coastal waters; prevention of water contamination.
	14020	Water supply and sanitation (large systems)	Programs where components according to 14021 and 14022 cannot be identified. When components are known, they should individually be reported under their respective purpose codes: water supply [14021], sanitation [14022], and hygiene [12261].
	14021	Water supply – large systems	Potable water treatment plants; intake works; storage; water supply pumping stations; large-scale transmission/conveyance and distribution systems.
	14022	Sanitation – large systems	Large-scale sewerage including trunk sewers and sewage pumping stations; domestic and industrial wastewater treatment plants.
	14030	Basic drinking water supply and basic sanitation	Programs where components according to 14031 and 14032 cannot be identified. When components are known, they should individually be reported under their respective purpose codes: water supply [14031], sanitation [14032], and hygiene [12261].
	14031	Basic water supply	Rural water supply schemes using hand pumps, spring catchments, gravity-fed systems, rainwater collection and fog harvesting, storage tanks, small distribution systems typically with shared connections/points of use. Urban schemes

			using hand pumps and local neighbourhood networks including those with shared connections.
	14032	Basic sanitation	Latrines, on-site disposal and alternative sanitation systems, including the promotion of household and community investments in the construction of these facilities. (Use code 12261 for activities promoting improved personal hygiene practices.)
	14040	River basins development	Infrastructure focused integrated river basin projects and related institutional activities; river flow control; dams and reservoirs [excluding dams primarily for irrigation (31140) and hydropower (23065) and activities related to river transport (21040)]
	14050	Waste management/disposal	Municipal and industrial solid waste management, including hazardous and toxic waste; collection, disposal and treatment; landfill areas; composting and reuse.
	14081	Education and training in water supply and sanitation	Education and training for sector professionals and service providers.

Explanation of the codes have been retrieved from: http://www.oecd.org/dac/stats/49819385.pdf.

[Table 5] lists out all of the subsectors in the WASH sector. WASH ODA have been channelled to sectors beyond water supply and sanitation facilities where it includes policy and administrative management, data collection, development of river basins, management of waste and disposal, education and training in water supply and sanitation as well.

[Table 6] Descriptive Statistic

Variables	Observations	Mean	Standard Deviation	Min	Max
WASH ODA (2-year lag) (US$, Millions, 2017 Constant Prices)	1,557	21.19	47.84	-2.12	1096.92
Total population using at least basic drinking water services (%)	1,603	77.97	18.71	25	100
Rural population using at least basic drinking water services (%)	1,521	68.40	23.24	12	1000
Urban population using at least basic drinking water services (%)	1,522	90.25	9.17	57	100
Total population using at least basic sanitation facilities (%)	1,602	59.62	30.27	4	100
Rural population using at least basic sanitation facilities (%)	1,521	50.92	32.16	2	100
Urban population using at least basic sanitation facilities (%)	1,522	68.19	26.34	11	100
Total population practising open defecation (%)	1,591	15.30	18.60	0	80
Rural population practising open defecation (%)	1,515	22.97	24.40	0	95
Urban population practising open defecation (%)	1,522	4.87	8.14	0	59
Burden of diarrhoeal diseases (DALY rate per 100,000 population)	1,610	2201	2889	39	20075
Population Density	1,604	121.67	182.78	1.61	1454
Log[GDP per capita (US$ 2010)]	1,601	23.49	2.02	18.81	28.52
Human Development Index	1,610	258.28	124.64	1	470

Descriptive statistics of all 115 countries have been shown below in [Table 6]. The average percentage of total population having access to at least basic water services, among all 115 ODA recipient countries from 2004 to 2017, was 77.97% while it was 68.40% for the rural populations and 90.25% for the urban populations. In the case for sanitation coverage, the total population having access to basic sanitation facilities was about 59.62% while it was 50.92% for the rural population and 68.19% for the urban population. The mean percentage of total population practising open defecation was 15.30%, while it was 22.97% among the rural populations and 4.87% among the urban populations. The average burden of diarrhoeal diseases, calculated in DALY rate (per 100,000 population), suffered by 115 countries was about 2201. With reference to the mean percentage of water and sanitation coverage for all 115 countries, the coverage for water is much higher than that of sanitation coverage. Both water and sanitation coverage were higher among the population living in the urban areas that the rural areas. Population practising open defecation was also significantly lowered among the urban population as compared to the rural population.

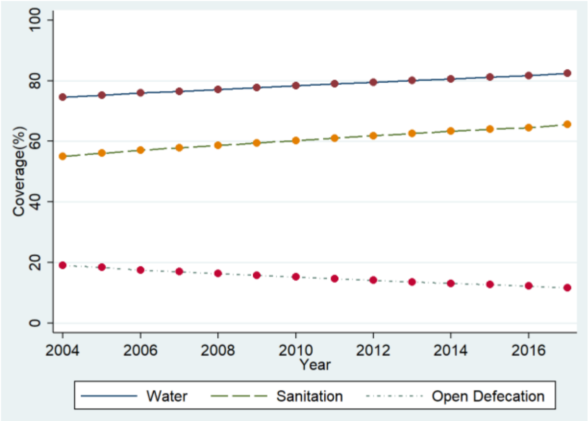
[Table 7] WASH coverage and burden of diarrhoeal diseases (DALY rate) by income groups

	Water (%)			Sanitation (%)			Open Defecation (%)			DALY rate (per 100,000 population)
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	
LICS	44.2	80.5	55.2	20.6	38.8	26.4	39.1	9.2	29.8	5325.0
LMICs	64.9	90.0	75.7	42.5	65.3	52.2	28.2	5.8	18.9	2160.9
UMICs	86.8	96.6	93.1	77.6	89.3	85.2	7.9	1.3	3.7	441.5

As shown in [Table 7], WASH coverage is significantly lower while the burden of diarrhoeal diseases significantly worsened among the LICs when compared to the mean percentage of WASH coverage shown in [Table 5]. Among the LICs, the mean percentage of total population having access to at least basic water services drops to 55.21% and sanitation coverage significantly falls to 26.43%. The burden of diarrhoeal diseases (in DALY rate per 100,000 population) on the other hand almost doubles to 5325. Amongst the LMICs, the percentage of total population having access to at least basic drinking water services increases to about 75.70%. Sanitation coverage also increases to 52.25% while percentage of population practising open defecation decreases to about 18.92%. The burden of diarrhoeal diseases, on the other hand, drops significantly to about 2160 (DALY rate per 100,000 population). The coverage for water and sanitation among the UMICs escalated all the way up to 93.09% and 85.24% respectively. Percentage of total population practising open defecation and the burden of diarrhoeal diseases also reduced significantly to 3.68% and 441.48 (DALY rate per 100,000 population) respectively.

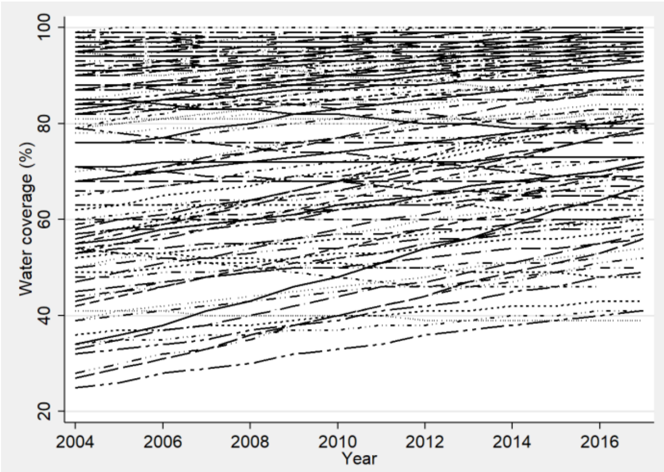
In all of the income groups, urban areas had higher water and sanitation coverage than the rural areas. Among the LMICs, water coverage was 44.2% in the rural areas while it was 80.5% in the urban areas. Sanitation coverage, too, was slightly higher in the urban areas where it was 20.6% in the rural and 38.8% in the urban areas. Population practising open defecation was significantly higher in the rural areas than the urban – 39.1% in the rural and 9.2% in the urban areas. Among the LMICs, water coverage in the rural areas was 64.9% while it was 90% in the urban areas. Sanitation coverage in the rural areas was 42.5% while 65.3% in the urban areas. Population practising open defecation in the rural areas was 28.2% while 5.8% in the urban areas. Countries belonging to the UMICs income group had about 86.8% of water coverage in the rural areas and 96.6% in the urban areas. Sanitation was fairly high in the rural areas where it was 77.6% but higher in the urban areas - 89.3%. Population practising open defecation was comparatively low in the UMICs as to those in LICs and LMICs, where it was 7.9% in the rural areas and 1.3% in the urban areas respectively. All in all, countries belonging to the higher Gross National Income (GNI) per capita, tend to have better WASH coverage and lower burden of diarrhoeal diseases (DALY rate per 100,000 population).

3.2. Graphs: WASH coverage and burden of diarrhoeal diseases

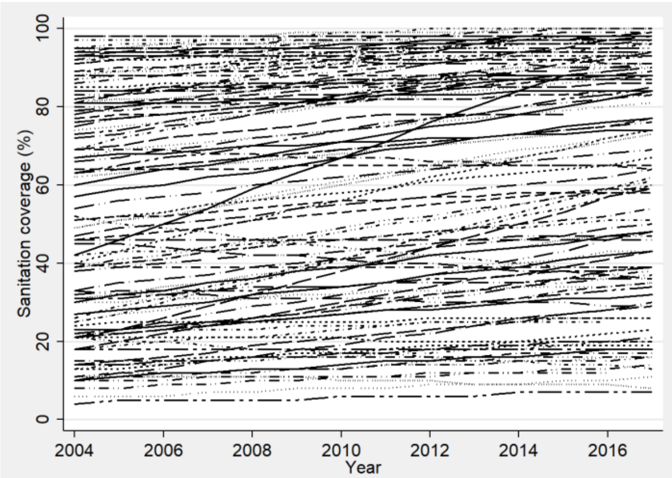


[Figure 3] Overall trend of WASH coverage (%) from 2004 – 2017

[Figure 3] illustrates the overall trend of WASH coverage (%) of all WASH ODA recipient 115 countries from 2004 to 2017. Although the overall percentage change in all of the three indicators were not highly significant, the overall trend for WASH coverage (%) have improved. Both the coverage for water and sanitation are in increasing trend, where the coverage for water was about 10% higher than the coverage for sanitation. The actual percentage change from 2004 to 2017, however, seemed subtle (less than 10%) for both water and sanitation coverage. There was also improvement in the percentage of population practising open defecation where 20% of population practising open defecation in 2004 had reduced to almost half in 2017. All of the three WASH coverage indicators have improved from year 2004 to 2017. The coverage (%) for water was the highest while percentage of the population practising open defecation had the greatest percentage change from 2004 to 2017.



[Figure 4] Water coverage (%) of all 115 countries

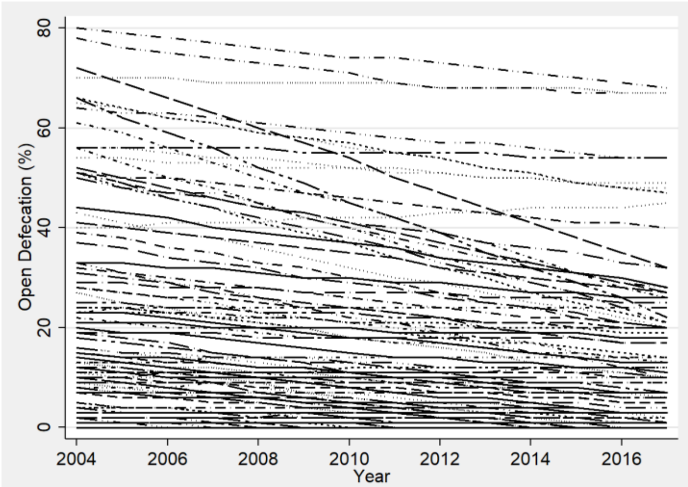


[Figure 5] Sanitation coverage (%) of all 115 countries

Graphs showing the overall trend of WASH coverage and burden of diarrhoeal diseases in each of the 115 WASH ODA recipient countries have been illustrated in [Figure 4], [Figure 5] and [Figure 6]. These figures display how WASH coverage (%) has changed over time in each of the recipient countries- graphs have been overlaid and thus, each line represents a country's WASH coverage from 2004 to 2017.

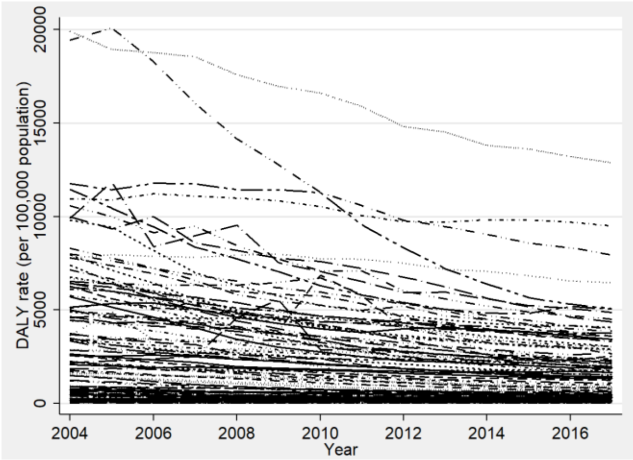
From the start of Millennium Development Goals (MDGs), improving sanitation coverage has always been one of the key challenges (Target 10 of MDG 7) while improvement in the water coverage has been recognised as one of the key progresses. One of the plausible reasons behind such is due to strong demand and considerable political enthusiasm for improving water supplies as it tends to provide more empirical and tangible outcomes as compared to that of improving coverage for sanitation (Cha et. al, 2017). It is highly vital to reduce such gap between water and sanitation coverage as they are both highly interdependent of each other. Likewise, countries with low sanitation coverage are likely to have diminishing effect on their water coverage. According to the 2006 UNDP report, the gap between water and sanitation coverage ranges from 29% in East Asia region to 18% in sub-Saharan Africa region. WASH ODA recipient countries in the South Asia region, access to improved sanitation is less than half of improved water (UNDP, 2006).

Comparing [Figure 4] and [Figure 5], the coverage for water (%) have improved much more significantly than the coverage for sanitation (%). Country with the lowest water coverage (%) was still above 20% in 2004 while in the case for sanitation coverage it was less than 10%. Although the coverage for both water and sanitation (%) have increased over the years, the coverage for water improved at a much faster rate than the coverage for sanitation. Furthermore, as it can be seen in [Figure 5] there were still numerous countries with sanitation coverage (%) below 60%. Although not all countries achieved 60% water coverage, the number of countries having less than 60% water coverage was fewer than that of sanitation.



[Figure 6] Proportion of total population practising open defecation (%) among the 115 countries

As shown in [Figure 6] the percentage of population practising open defecation (%) has decreased over the period of 14 years (2004 – 2017). Majority of the countries had less than 60% of the population practising open defecation. Most of the countries were within the range of 0% to 30% and only a handful of countries experienced a steep fall in the percentage of population practising open defecation from about 70% to 35%. Some of the similarities between sanitation coverage (%) and proportion of population practising open defecation are that the rate of change was subtle and most of the WASH ODA recipient countries remained stagnant without much improvements made. For further illustration, [Figure 10] highlights the percentage change in the proportion of total population practising open defecation (%) in each of the recipient countries.

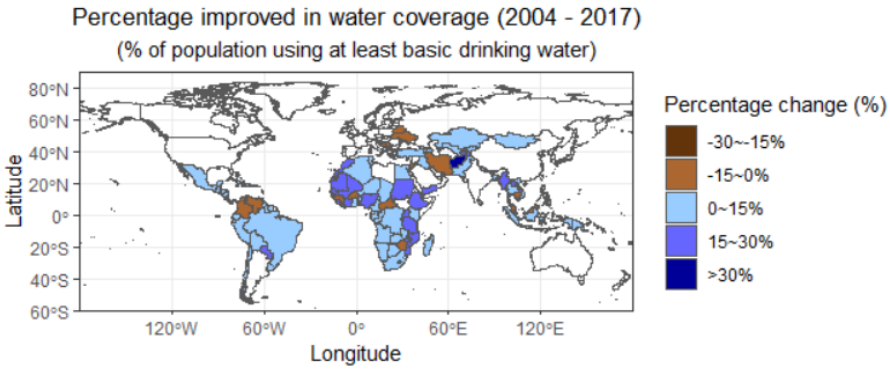


[Figure 7] Burden of diarrhoeal diseases (DALY rate per 100,000 population) among the 115 countries

WHO stated that the total burden of disease linked to water and sanitation accounts for 58 million DALY per year (94% of the diarrhoeal burden of disease) largely from unsafe water, sanitation and hygiene (WHO, 2008). Above [Figure 7] lays out how the burden of diarrhoeal diseases changed over the past 14 years. Other than couple of countries experiencing rapid decrease in the rate of burden of diarrhoeal diseases from about 20,000 to 9,000 DALY rate and 20,000 to about 13,000 DALY rate, most of the countries' burden of diarrhoeal diseases were less than 10,000 DALY rate and many of which were within the range of 5000 DALY rate and below.

Sub-Saharan Africa remained the region with the highest DALY rate (per 100,000 population) caused by diarrhoea due to lack of WASH coverage. This was followed by South Asia Oceania Western Asia and Southeast Asia and North Africa (please refer to [Figure 11]). Results shown in [Figure 7] are in line with the studies and projects conducted about a decade ago, which predicted that the burden of diarrhoeal diseases will decrease over the years (Mathers and Loncar, 2006)- 64 million DALY in 2002 to about 44 million DALY in 2015 and about 29 million DALY by 2030.

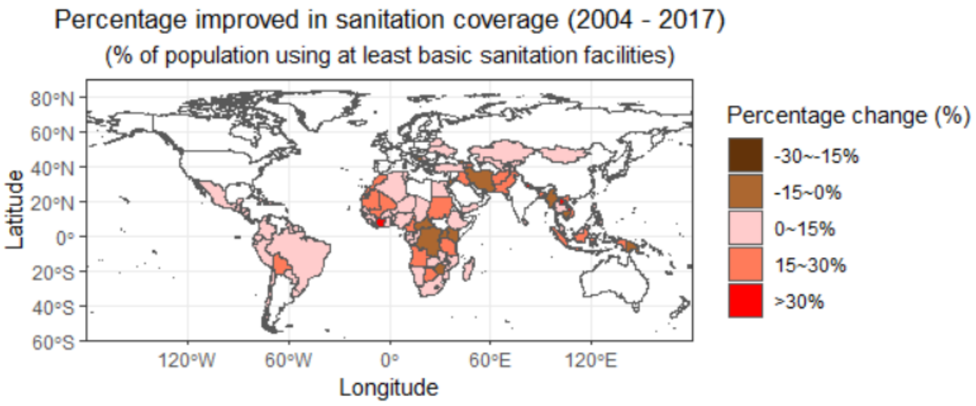
3.3. World Map: WASH coverage and burden of diarrhoeal diseases



[Figure 8] Percentage change in water coverage (2004 – 2017)

[Figure 8] illustrates the percentage change in terms of the population having access to at least basic drinking water among all of the 115 WASH ODA recipient countries from 2004 to 2017. Both the light and dark brown represent countries with lower water coverage in 2017 than that of 2004. The light brown regions represent those countries where the coverage for water has been reduced up to 15% (-15% to 0%) while the dark brown regions represent those countries where the coverage for water has lowered within the range of -15% to -30%. The blue regions represent those countries with improved water coverage, where darker the colour higher the percentage change in water coverage from 2004 to 2017.

Among 110 countries (Argentina, Cape Verde, Dominica, Eritrea and Montenegro were excluded from this comparison due to missing data for the water coverage in either 2004 or 2017), 13 countries had lower water coverage in 2017 as compared to their water coverage in 2004. From 2004 to 2017, the percentage change in the population having access to at least basic drinking water ranged from about -11% to 33%. The water coverage in Solomon Islands decreased by 11% in 2017 as compared to 2004; followed by Serbia (-9%), Colombia (-8%) and Zimbabwe (-7%). On the other hand, Afghanistan had 33% improvement in the water coverage in 2017 as compared to 2004; followed by Mozambique (29%), Myanmar (27%) and Lao PDR (26%). The coverage for water improved in most of the countries within the range of 4% to 7% in 2017 when compared to 2004. Overall, although there were a handful of countries (13 countries) with deteriorated water coverage (%), most of the WASH ODA recipient countries managed to experience improvement in their water coverage.

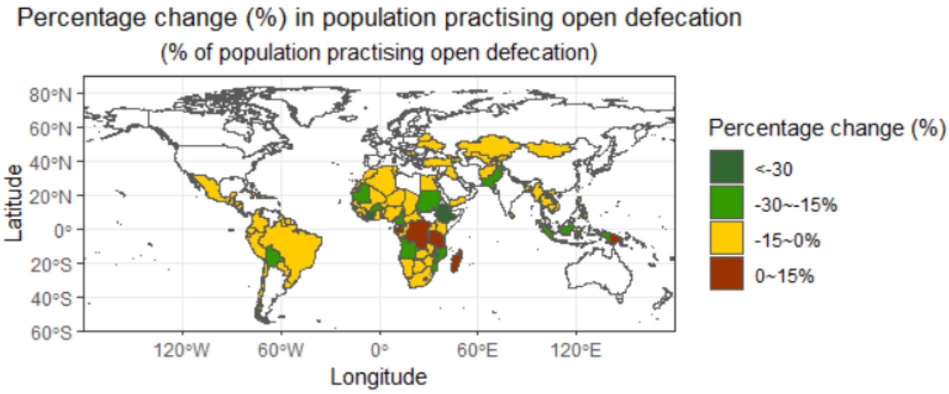


[Figure 9] Percentage change in sanitation coverage (2004 – 2017)

As shown in [Figure 9], it illustrates the percentage change in terms of the population having access to at least basic sanitation facilities from 2004 to 2017. Both the light and dark brown represent countries where the coverage for sanitation has worsened in 2017 as compared to that of 2004. The light brown regions represent those countries where the sanitation coverage has worsened by up to 15% (-15% to 0%) while the dark brown regions represent those countries where the coverage for sanitation has deteriorated by up to 30% (-15% to -30%). The pink and red regions represent those countries with improved sanitation coverage, where darker the colour higher the percentage change in sanitation coverage (improved) from 2004 to 2017.

Among 109 countries (Argentina, Cape Verde, Dominica, Eritrea, Montenegro and Venezuela were excluded from this comparison due to missing data for the sanitation coverage in either 2004 or 2017), 10 countries had lower sanitation coverage in 2017 as compared to their water coverage in 2004. From 2004 to 2017, the percentage change in the population having access to at least basic sanitation ranged from about -13% to 46%. Sanitation coverage in Gambia has worsened by 13% in 2017 as compared to 2004; followed by Zimbabwe (-9%), Papa New Guinea (-8%) and Myanmar (-5%). On the other hand, in Federal States of Micronesia sanitation coverage has improved by up to 46% in 2017 as compared to 2004; followed by Côte d'Ivoire (38%), Nepal (37%) and Lao PDR (34%). Most of the countries sanitation coverage improved within the range of 3% to 7% in 2017 when compared to 2004.

The range of percentage change in sanitation coverage (-13% to 46%) was much higher than water coverage (-11% to 33%). Both the coverages for water (+26%) and sanitation (+34%) in Lao PDR improved significantly while in the case for Zimbabwe coverages for both water and sanitation deteriorated by 7% and 9% respectively. In countries such as Myanmar there were contradicting results in water and sanitation coverage, where the water coverage has improved significantly (+27%) while sanitation coverage has worsened by 5%.



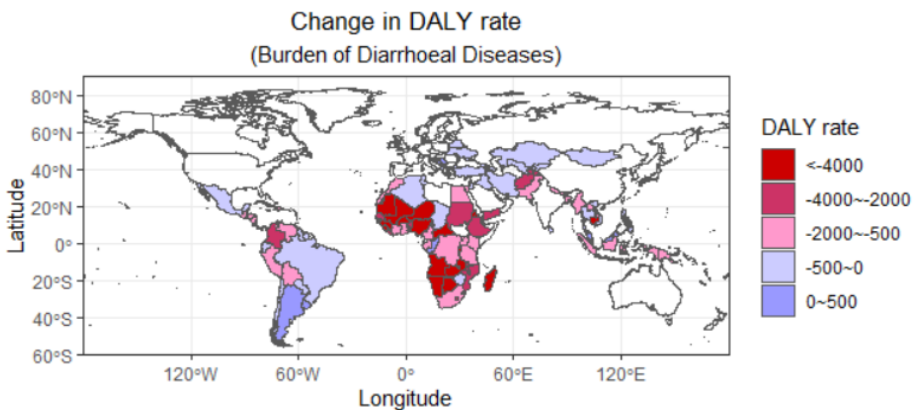
[Figure 10] Percentage change in population practising open defecation

(2004 – 2017)

The percentage change in the population practising open defecation from 2004 to 2017 ranged between -30% to 15%. As shown in [Figure 10] both the light and dark green represent countries that have experienced reduction in the percentage change in the population practising open defecation. The light green regions represent those countries that have managed to reduce the percentage change in the population practising open defecation by up to 30% (-15% to -30%) while the dark green regions represent those countries that have reduced the percentage change in the population practising open defecation above 30% (< -30%). The yellow and dark brown regions represent those countries that have experienced increase in the percentage change in the population practising open defecation. Countries in yellow are those that have experienced -15% to 0% change in the population practising open defecation while the dark brown regions are those countries with 0% to 15% percentage change in the population practising open defecation.

Among 107 countries (Argentina, Cape Verde, Dominica, Eritrea, Iran, Malaysia, Micronesia and Venezuela were excluded from this comparison due to missing data for the sanitation coverage in either 2004 or 2017), 6 countries had higher percentage change in the population practising open defecation in 2017 as compared to that of 2004. From 2004 to 2017, the percentage change in the population practising open defecation ranged from between -44% to 5%. The percentage change in the population practising open defecation in Madagascar increased by 5% in 2017 as compared to 2004; followed by Tanzania (2%), Papa New Guinea (1%) and Gabon (1%). On the other hand, countries that have managed to reduce the percentage of population practising open defecation were: Ethiopia 44% decrease in 2017 as compared to 2004; followed by Côte d'Ivoire (40%), Nepal (35%) and Lao PDR (30%).

Côte d'Ivoire, Nepal and Lao PDR had significant improvement in both sanitation coverage and reduction in the percentage of total population practising open defecation. Sanitation coverage in Côte d'Ivoire improved by 38% while the percentage of total population practising open defecation reduced by 40%. Nepal, too, has experienced significant improvement in sanitation coverage (37%) while 35% reduction in open defecation rate. Last but not the least, Lao PDR achieved 34% improvement in their sanitation coverage and managed to reduce open defecation rate by up to 30%. In Papa New Guinea, however, both sanitation coverage and open defecation rate worsened where sanitation coverage lowered by 8% while open defecation rate increased by 1%. Countries with higher sanitation coverage tend to have lower percentage of total population practising open defecation.



[Figure 11] Change in the burden of diarrhoeal diseases DALY rate (per 100,000 population) (2004 – 2017)

[Figure 11] displays the change in the burden of diarrhoeal diseases (DALY rate per 100,000 population) from 2004 to 2017. The red regions represent countries where the burden of diarrhoeal diseases have reduced by more than 4000 DALY rate (per 100,000 population). The maroon regions represent countries where the burden of diarrhoeal diseases have been reduced between 2000 to 4000 DALY rate (per 100,000 population). Pink regions represent countries where the burden of diarrhoeal diseases have been reduced between 500 and 2000 DALY rate (per 100,000 population). The lighter purple (lavender) regions represent countries where the burden of diarrhoeal diseases did not change or have been reduced within the range between 0 to 500 DALY rate (per 100,000 population). Lastly, the darker purple (lilac) regions represent countries where the burden of diarrhoeal diseases have been worsened in 2017 as compared to that of 2004, where the DALY rate (per 100,000 population) ranges between 0 to 500.

Among 115 countries, 11 countries had greater burden of diarrhoeal diseases DALY rate per 100,000 population in 2017 than compared to 2004. Samoa ranked the top where the burden of diarrhoeal diseases was higher by 107 DALY rate (per 100,000 population) than that of 2004; followed by Malaysia (97 DALY rate), Mauritius (88 DALY rate), Tonga (73 DALY rate) and Dominica (31 DALY rate).

On the other hand, the top five countries where the burden of diarrhoeal diseases have been reduced significantly from 2004 to 2017 were all from the sub-Saharan Africa region. Niger (27,384 DALY rate-per 100,000 population) achieved the highest reduction in the burden of diarrhoeal diseases, followed by Madagascar (14,230 DALY rate), Sierra Leone (12,206 DALY rate), Zambia (10,873 DALY rate) and Guinea (9685 DALY rate). Madagascar had contracting results when the percentage change in open defecation rate and burden of diarrhoeal diseases were compared. The percentage of total population practising open defecation in Madagascar increased by 5% (from 2004 to 2017) while the burden of diarrhoeal diseases (DALY rate per 100,000 population) had fallen by 14,230 DALY rate (from 2004 to 2017).

3.4. Results of Fixed-effects analyses

(All 115 WASH ODA recipient countries)

[Table 8] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic drinking water services (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.001515	0.0018654	0.81	0.417
Population Density	-0.0097905	0.0042494	-2.30	0.021*
Log [GDP per capita (US$2010)]	13.40798	0.64574	20.76	0.000**
Human Development Index	0.0087145	0.00402	2.17	0.030*
Number of observations	1,544			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.5211			
Between	0.0596			
Overall	0.0709			
Sigma_u (σ u)	29.271472			
Sigma_e (σ e)	2.6040622			
rho	0.99214783			

Statistical significance: *<0.05, **<0.01

[Table 9] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic drinking water services (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0000718	0.0023859	-0.03	0.976
Population Density	-0.0209339	0.0060301	-3.47	0.001**
Log [GDP per capita (US$2010)]	16.93798	0.935475	18.11	0.000**
Human Development Index	0.0072758	0.00623	1.17	0.243
Number of observations	1,478			

Number of countries	109
Prob> F	0.0000
R-sq	
Within	0.4983
Between	0.0254
Overall	0.0316
Sigma_u (σ u)	37.159673
Sigma_e (σ e)	3.3287599
rho	0.99203932

Statistical significance: *<0.05, **<0.01

[Table 10] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic drinking water services (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0007539	0.0016165	0.47	0.641
Population Density	-0.0090544	0.0040856	-2.22	0.027*
Log [GDP per capita (US$2010)]	6.282721	0.6337665	9.91	0.000**
Human Development Index	0.0086602	0.004221	2.05	0.040*
Number of observations	1,479			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.2712			
Between	0.1003			
Overall	0.1024			
Sigma_u (σ u)	12.972965			
Sigma_e (σ e)	2.2553565			
rho	0.97066269			

Statistical significance: *<0.05, **<0.01

[Table 11] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic sanitation facilities (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0015346	0.0023319	0.66	0.511
Population Density	0.0261022	0.0053123	4.91	0.000**
Log [GDP per capita (US$2010)]	9.970136	0.80728	12.35	0.000**
Human Development Index	0.0279921	0.005029	5.57	0.000**
Number of observations	1,543			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.4426			
Between	0.1668			
Overall	0.1766			
Sigma_u (σ u)	29.142948			
Sigma_e (σ e)	3.2552389			
rho	0.98767708			

Statistical significance: *<0.05, **<0.01

[Table 12] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic sanitation facilities (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0022981	0.002635	0.87	0.383
Population Density	0.0295994	0.0066597	4.44	0.000**
Log [GDP per capita (US$2010)]	10.5322	1.033143	10.19	0.000**
Human Development Index	0.0314015	0.0068804	4.56	0.000**
Number of observations	1,478			
Number of countries	109			

Prob> F	0.0000
R-sq	
Within	0.4213
Between	0.1616
Overall	0.1647
Sigma_u (σ u)	30.8531
Sigma_e (σ e)	3.6762968
rho	0.98600088

Statistical significance: *<0.05, **<0.01

[Table 13] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic sanitation facilities (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0001847	0.0021871	0.08	0.933
Population Density	-0.0155608	0.0055275	-2.82	0.005**
Log [GDP per capita (US$2010)]	9.62889	0.8574476	11.23	0.000**
Human Development Index	0.0073307	0.0057107	1.28	0.199
Number of observations	1,479			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.2884			
Between	0.0911			
Overall	0.0949			
Sigma_u (σ u)	27.415021			
Sigma_e (σ e)	3.0513605			
rho	0.98776334			

Statistical significance: *<0.05, **<0.01

[Table 14] Fixed-effects model analysis of WASH ODA on the proportion of total population practising open defecation (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0038556	0.0020073	-1.92	0.055
Population Density	-0.0037012	0.0045733	-0.81	0.418
Log [GDP per capita (US$2010)]	-9.489224	0.6960836	-13.63	0.000**
Human Development Index	-0.0183198	0.0043353	-4.23	0.000**
Number of observations	1,534			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.4127			
Between	0.1177			
Overall	0.1270			
Sigma_u (σ u)	22.109406			
Sigma_e (σ e)	2.8018434			
rho	0.98419428			

Statistical significance: *<0.05, **<0.01

[Table 15] Fixed-effects model analysis of WASH ODA on the proportion of rural population practising open defecation (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0057019	0.0024329	-2.34	0.019*
Population Density	-0.015463	0.0061496	-2.51	0.012**
Log [GDP per capita (US$2010)]	-9.731593	0.9548629	-10.19	0.000**
Human Development Index	-0.0296412	0.0063558	-4.66	0.000**
Number of observations	1,473			
Number of countries	109			

Prob> F	0.0000
R-sq	
Within	0.4096
Between	0.1427
Overall	0.1445
Sigma_u (σ u)	25.135378
Sigma_e (σ e)	3.3940785
rho	0.98209289

Statistical significance: *<0.05, **<0.01

[Table 16] Fixed-effects model analysis of WASH ODA on the proportion of urban population practising open defecation (%) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0013563	0.001278	-1.06	0.289
Population Density	0.0060234	0.0032299	1.86	0.062
Log [GDP per capita (US$2010)]	-4.044105	0.5010342	-8.07	0.000**
Human Development Index	-0.0100689	0.003337	-3.02	0.003**
Number of observations	1,479			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.2416			
Between	0.1111			
Overall	0.1084			
Sigma_u (σ u)	9.4905456			
Sigma_e (σ e)	1.783008			
rho	0.96590743			

Statistical significance: *<0.05, **<0.01

[Table 17] Fixed-effects model analysis of water coverage (%) for total population on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-52.00407	7.306248	-7.12	0.000**
WASH ODA (2-year lag)	0.3119655	0.5146177	0.61	0.544
Population Density	-0.8476275	1.17419	-0.72	0.470
Log [GDP per capita (US$2010)]	-1334.912	203.2622	-6.57	0.000**
Human Development Index	-4.157253	1.11057	-3.74	0.000**
Number of observations	1,544			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.3505			
Between	0.2188			
Overall	0.2275			
Sigma_u (σ u)	3227.8224			
Sigma_e (σ e)	718.21286			
rho	0.95282621			

Statistical significance: *<0.05, **<0.01

[Table 18] Fixed-effects model analysis of water coverage (%) for rural population on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-9.358084	6.019754	-1.55	0.120
WASH ODA (2-year lag)	0.2504793	0.5306377	0.47	0.637
Population Density	-1.80953	1.347033	-1.34	0.179
Log [GDP per capita (US$2010)]	-1508.129	231.696	-6.51	0.000**
Human Development Index	-7.342006	1.386275	-5.30	0.000**

Number of observations	1,478
Number of countries	109
Prob> F	0.0000
R-sq	
Within	0.3385
Between	0.1912
Overall	0.1922
Sigma_u (σ u)	3376.7352
Sigma_e (σ e)	740.3337
rho	0.95413606

Statistical significance: *<0.05, **<0.01

[Table 19] Fixed-effects model analysis of water coverage (%) for urban population on the burden of diarrhoeal diseases (DALY rate) with control variables

Statistical significance: *<0.05, **<0.01

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-25.74891	8.859093	-2.91	0.004**
WASH ODA (2-year lag)	0.270175	0.5293388	0.51	0.610
Population Density	-1.849057	1.340124	-1.38	0.168
Log [GDP per capita (US$2010)]	-1503.997	214.8472	-7.00	0.000**
Human Development Index	-7.189586	1.384192	-5.19	0.000**
Number of observations	1,479			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.3413			
Between	0.1872			
Overall	0.1895			

Sigma_u (σ u)	3393.7708
Sigma_e (σ e)	738.46477
rho	0.95479319

[Table 20] Fixed-effects model analysis of sanitation coverage (%) for total population on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for total population	-3.424217	5.964486	-0.57	0.566
WASH ODA (2-year lag)	0.2317355	0.524626	0.44	0.659
Population Density	-0.2882805	1.204901	-0.24	0.811
Log [GDP per capita (US$2010)]	-2075.985	193.104	-10.75	0.000**
Human Development Index	-3.964956	1.18926	-3.33	0.001**
Number of observations	1,543			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.3254			
Between	0.0661			
Overall	0.0752			
Sigma_u (σ u)	4579.5949			
Sigma_e (σ e)	732.19797			
rho	0.97507468			

Statistical significance: *<0.05, **<0.01

[Table 21] Fixed-effects model analysis of sanitation coverage (%) for rural population on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for rural population	25.91713	5.431273	4.77	0.000**
WASH ODA (2-year lag)	0.1816087	0.5284319	0.34	0.731
Population Density	-2.415169	1.344712	-1.80	0.073
Log [GDP per capita (US$2010)]	-2055.057	216.8375	-9.48	0.000**
Human Development Index	-7.411316	1.439238	-5.15	0.000**
Number of observations	1,478			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.3444			
Between	0.0572			
Overall	0.0621			
Sigma_u (σ u)	4399.0783			
Sigma_e (σ e)	737.00697			
rho	0.97269779			

Statistical significance: *<0.05, **<0.01

[Table 22] Fixed-effects model analysis of sanitation coverage (%) for urban population on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for urban population	-31.39305	6.532319	-4.81	0.000**
WASH ODA (2-year lag)	0.2450663	0.5280595	0.46	0.643
Population Density	-2.141125	1.338386	-1.60	0.110
Log [GDP per capita (US$2010)]	-1487.577	218.6847	-6.80	0.000**
Human Development Index	-6.281421	1.427274	-4.40	0.000**

Number of observations	1,479
Number of countries	109
Prob> F	0.0000
R-sq	
Within	0.3445
Between	0.2492
Overall	0.2466
Sigma_u (σ u)	3342.9846
Sigma_e (σ e)	736.68422
rho	0.95368731

Statistical significance: *<0.05, **<0.01

[Table 23] Fixed-effects model analysis of proportion of total population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of total population practising open defecation (%)	58.6013	6.783163	8.64	0.000**
WASH ODA (2-year lag)	0.4635287	0.5131057	0.90	0.366
Population Density	-0.1225077	1.167628	-0.10	0.916
Log [GDP per capita (US$2010)]	-1562.404	191.348	-8.17	0.000**
Human Development Index	-3.004514	1.157028	-2.60	0.010**
Number of observations	1,534			
Number of countries	115			
Prob> F	0.0000			
R-sq				
Within	0.3604			
Between	0.1563			
Overall	0.1689			

Sigma_u (σ u)	3716.1131
Sigma_e (σ e)	715.23552
rho	0.96427905

Statistical significance: *<0.05, **<0.01

[Table 24] Fixed-effects model analysis of proportion of rural population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of rural population practising open defecation (%)	23.46637	5.904195	3.97	0.000**
WASH ODA (2-year lag)	0.3845755	0.5311735	0.72	0.469
Population Density	-1.249741	1.34297	-0.93	0.352
Log [GDP per capita (US$2010)]	-1571.678	218.3572	-7.20	0.000**
Human Development Index	-5.831178	1.443176	-4.04	0.000**
Number of observations	1,473			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.3424			
Between	0.1885			
Overall	0.1880			
Sigma_u (σ u)	3486.4503			
Sigma_e (σ e)	739.48012			
rho	0.9569498			

Statistical significance: *<0.05, **<0.01

[Table 25] Fixed-effects model analysis of proportion of urban population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of urban population practising open defecation (%)	78.28106	11.07134	7.07	0.000**
WASH ODA (2-year lag)	0.3452147	0.523229	0.66	0.510
Population Density	-1473.021	1.323454	-1.60	0.109
Log [GDP per capita (US$2010)]	-5.716194	212.2518	-6.94	0.000**
Human Development Index	-5.716194	1.417362	-4.03	0.000**
Number of observations	1,479			
Number of countries	109			
Prob> F	0.0000			
R-sq				
Within	0.3570			
Between	0.1772			
Overall	0.1800			
Sigma_u (σ u)	3421.3151			
Sigma_e (σ e)	729.64879			
rho	0.95649643			

Statistical significance: *<0.05, **<0.01

Fixed-effects model analysis was conducted for each of the WASH coverage indicators and burden of diarrhoeal diseases. In the case for WASH coverage, Fixed-effects analyses were conducted for three different groups of population which are: 1. Proportion of total population (%) 2. Proportion of rural population (%) 3. Proportion of urban population (%). [Table 26] summarises the results of all of the Fixed-effects model analyses conducted for the WASH coverage and [Table 27] summarises the results of all of the Fixed-effects model analyses conducted for the burden of diarrhoeal diseases. The symbol '✓' indicates that the effect of WASH ODA was significant at 0.05 significance level and ✓✓ indicates that the effect of WASH ODA was significant at 0.01 significance level. Sigma_u (σ u), represents the standard error of state Fixed-effects α_i while Sigma_e (σ e) represents the standard error of error term; rho represents the ratio of individual specific error variance to the entire error variance.

1) Effect of WASH ODA on WASH coverage

(Please refer to [Table 8] - [Table 25] for results)

Results from the fixed-effects model analyses conducted among all 115 countries, indicated that the effect of WASH ODA was only significant in reducing the proportion of rural population practising open defecation (%). With one-unit increase in the amount of WASH ODA, the proportion of rural population practising open defecation (%) is expected to decrease by 0.00570% (standard error = 0.0024329, p-value = 0.019) [Table15].

2) Effect of WASH coverage on burden of diarrhoeal diseases

Results from the fixed-effects model analyses conducted on the effect of WASH coverage on burden of diarrhoeal diseases indicated that improvement in water and sanitation coverage among all 115 countries had significant effect on reducing the burden of diarrhoeal diseases. With 1% increase in the proportion of total population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by about 52 DALY rate (standard error = 7.306248, p-value = 0.000) [Table 17] while with 1% increase in the proportion of urban population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by about 25.75 DALY rate (standard error = 8.859093, p-value = 0.004) [Table 19].

Improvement made in the sanitation coverage in both rural and urban populations in all 115 countries also had significant effect on reducing the burden of diarrhoeal diseases, where with 1% increase in the proportion of rural population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by about 25.92 DALY rate (standard error = 5.431273, p-value = 0.000) [Table 21]. Among the urban populations, with 1% increase in the proportion of urban population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by about 31.39 DALY rate (standard error = 6.532319, p-value = 0.000) [Table 22].

The effect of all populations (total, rural, urban) practising open defecation (%) among the 115 countries had significant effect on worsening the burden of diarrhoeal diseases where 1% increase in the proportion of total population practising open defecation (%) is expected to increase the burden of diarrhoeal diseases by 58.60 DALY rate (standard error = 6.783163, p-value = 0.000) [Table 23]. The burden of diarrhoeal diseases is expected to increase by 23.47 DALY rate (standard error = 5.904195, p-value = 0.000) [Table 24] with 1% increase in the proportion of rural population practising open defecation (%). In the case for urban populations, the burden of diarrhoeal diseases is expected to increase even higher by up to 78.28 DALY rate (standard error = 11.07134, p-value = 0.000) [Table 25] with 1% increase in the proportion of urban population practising open defecation (%).

3.5. Results of Fixed-effects model analyses (income groups)

Low-Income Countries (LICs)

(Please refer to [Appendix C] for results)

1) Effect of WASH ODA on WASH coverage

The effect of WASH ODA on WASH coverage was evident when analyses were conducted according to different income groups. The effect of WASH ODA was significant on improving water coverage for all populations (total, rural, urban) among the LICs. With one-unit increase in the amount of WASH ODA, the proportion of total population having access to at least basic drinking water is expected to increase by 0.05089% (standard error = 0.0143603, p-value = 0.000) [Appendix C1]. In the case for the rural populations, with one-unit increase in the amount of WASH ODA, the proportion of rural population having access to at least basic drinking water is expected to increase by 0.0409% (standard error = 0.0159172, p-value = 0.011) [Appendix C2]. Finally, for the urban populations among LICs, with one-unit increase in the amount of WASH ODA, the proportion of rural population having access to at least basic drinking water is expected to increase by 0.0454% (standard error = 0.013406, p-value = 0.001) [Appendix C3]. The effect of WASH ODA was also significant on improving the sanitation coverage among the urban population in the LICs, where with one-unit increase in the amount of WASH ODA the proportion of urban population having access to at least basic sanitation services is expected to increase by 0.0343% (standard error = 0.0139668, p-value = 0.014) [Appendix C6].

2) Effect of WASH coverage on the burden of diarrhoeal diseases

Results from the fixed-effects model analyses conducted on the effect of WASH coverage on burden of diarrhoeal diseases indicated that improvement in water and sanitation coverage among LICs had significant effect on reducing the burden of diarrhoeal diseases. With 1% increase in the proportion of rural population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by 31.70 DALY rate (standard error = 15.65, p-value = 0.044) [Appendix C11]. In the case for sanitation coverage, with 1% increase in the proportion of urban population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by 43.82 DALY rate (standard error = 17.78637, p-value = 0.014) [Appendix C15]. On the other hand, the burden of diarrhoeal diseases is expected to increase by 132.84 DALY rate (standard error = 40.00818, p-value = 0.001) [Appendix C18] with 1% increase in the proportion of urban population practising open defecation.

Lower-middle-income countries (LMICs)

(Please refer to [Appendix D] for results)

1) Effect of WASH ODA on WASH coverage

The effect of WASH ODA was significant on improving water coverage for rural populations among the LMICs. With one-unit increase in the amount of WASH ODA, the proportion of rural population having access to at least basic drinking water services is expected to increase by 0.0175% (standard error = 0.0083246, p-value = 0.036) [Appendix D2]. Furthermore, the effect of WASH ODA was significant on improving sanitation coverage for both total and rural populations among the LMICs. With one-unit increase in the amount of WASH ODA, the proportion of total population having access to at least basic sanitation services is expected to increase by 0.0224% (standard error = 0.0090259, p-value = 0.014) [Appendix D4]; while for the rural populations with one-unit increase in the amount of WASH ODA, the proportion of rural population having access to at least basic sanitation services is expected to increase by 0.0391% (standard error = 0.0087581, p-value = 0.000) [Appendix D5].

The effect of WASH ODA was significant on reducing the proportion of total and rural populations practising open defecation among the LMICs. With one-unit increase in the amount of WASH ODA proportion of total and rural populations practising open defecation is expected to reduce by 0.0141% (standard error = 0.0070332, p-value = 0.046) [Appendix D7] and 0.0269% (standard error =

0.0083575, p-value = 0.001) [Appendix D8] respectively.

2) Effect of WASH coverage on burden of diarrhoeal diseases

Results from the fixed-effects model analyses conducted on the effect of WASH coverage on burden of diarrhoeal diseases indicated that improvement in water and sanitation coverage among LMICs had significant effect on reducing the burden of diarrhoeal diseases. With 1% increase in the proportion of total population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by 37.35 DALY rate (standard error = 8.978703, p-value = 0.000) [Appendix D10]. Moreover, with 1% increase in the proportion of urban population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by about 48 DALY rate (standard error = 12.39272, p-value = 0.000) [Appendix D13].

Improvement in the sanitation coverage also had significant effect on reducing the burden of diarrhoeal diseases where with 1% increase in the proportion of rural population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by about 25.30 DALY rate (standard error = 6.85765, p-value = 0.000) [Appendix D15]. In the context for urban populations, with 1% increase in the proportion of urban population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by about 37.73 DALY rate (standard error = 7.03141, p-value = 0.000) [Appendix D16]. The effect of urban population practising open defecation (%) was significant on increasing the burden of diarrhoeal diseases among the LMICs where with 1% increase in the proportion of urban population practising open defecation (%) is expected to increase the burden of diarrhoeal diseases by 24.73 DALY rate (standard error = 11.23822, p-value = 0.028) [Appendix D19].

Upper-middle-income countries

(Please refer to [Appendix E1] – [Appendix E10] for results)

1) Effect of WASH ODA on WASH coverage

There were total 47 countries in the UMICs: 6 countries from the East Asia and Pacific region, 10 countries from Europe and Central Asia region, 19 countries from Latin America and Caribbean, 5 countries from the Middle East and North Africa region, 2 countries from South Asia region and lastly, 5 countries from the sub-Saharan African region. The effect of WASH ODA on WASH coverage was not significant at 0.05 significance level in all of the UMICs.

2) Effect of WASH coverage on burden of diarrhoeal diseases

Results from the fixed-effects model analyses conducted on the effect of WASH coverage (total and rural populations) on burden of diarrhoeal diseases (DALY rate per 100,000 population) indicated that the improvement in WASH coverage among UMICs had significant effect on reducing the burden of diarrhoeal diseases at significance level of 0.01. The effect of sanitation coverage (%) for the urban populations was significant in reducing the burden of diarrhoeal diseases at significance level of 0.05. With 1% increase in the proportion of total population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by 24.94 DALY rate (standard error = 3.475734, p-value = 0.000) [Appendix E10]. The effect of WASH coverage on burden of diarrhoeal diseases was also significant among the rural populations having access to at least basic drinking water services among the UMICs where with 1% increase in the proportion of rural population having access to at least basic drinking water services is expected to reduce the burden of diarrhoeal diseases by 14.45 DALY rate (standard error = 2.142751, p-value = 0.000) [Appendix E11].

Improvement in the sanitation coverage for total and rural populations among the UMICs also had significant effect on reducing the burden of diarrhoeal diseases. With 1% increase in the proportion of total population having access to at least basic sanitation services is expected to reduce the burden of diarrhoeal diseases by about 15.46 DALY rate (standard error = 2.606137, p-value = 0.000) [Appendix E13]; while for the rural populations it is expected to reduce the burden of diarrhoeal diseases by about 7.84 DALY rate (standard error = 1.80774, p-value = 0.000) [Appendix E14].

The effect of total and rural populations practising open defecation (%) were significant in increasing the burden of diarrhoeal diseases among the UMICs where with 1% increase in the proportion of total population practising open defecation (%) is expected to increase the burden of diarrhoeal diseases by about 50.91 DALY rate (standard error = 11.95, p-value = 0.000) [Appendix E16]. For the rural populations in UMICs, with 1% increase in the proportion of rural population practising open defecation (%) is expected to increase the burden of diarrhoeal diseases by about 18.57 DALY rate (standard error = 2.335272, p-value = 0.000) [Appendix E17]

[Table 26] Results of all Fixed-effects model analyses conducted for WASH coverage

WASH ODA	Water coverage (% of population)			Sanitation coverage (% of population)			Population practising open defecation (%)		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
All 115 countries	x	x	x	x	x	x	x	✓	x
Low-income countries (LICs)	✓✓	✓✓	✓✓	x	x	✓✓	x	x	x
Lower-middle-income countries (LMICs)	x	✓	x	✓✓	✓✓	x	✓	✓✓	x
Upper-middle-income countries (UMICs)	x	x	x	x	x	x	x	x	x

Statistical Significance: ✓< 0.05 ✓✓ <0.01

[Table 27] Results of all Fixed-effects model analyses conducted for burden of diarrhoeal diseases (DALY rate per 100,000 population)

Burden of diarrhoeal diseases (DALY rate)	Water coverage (% of population)			Sanitation coverage (% of population)			Population practising open defecation (%)		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
All 115 countries	✓✓	x	✓✓	x	✓✓	✓✓	✓✓	✓✓	✓✓
Low-income countries (LICs)	x	✓	x	x	x	✓✓	x	x	✓✓
Lower-middle-income countries (LMICs)	✓✓	x	✓✓	x	✓✓	✓✓	x	x	✓
Upper-middle-income countries (UMICs)	✓✓	✓✓	x	✓✓	✓✓	✓	✓✓	✓✓	x

Statistical Significance: ✓< 0.05 ✓✓ <0.01

Chapter 4: Discussion and Conclusion

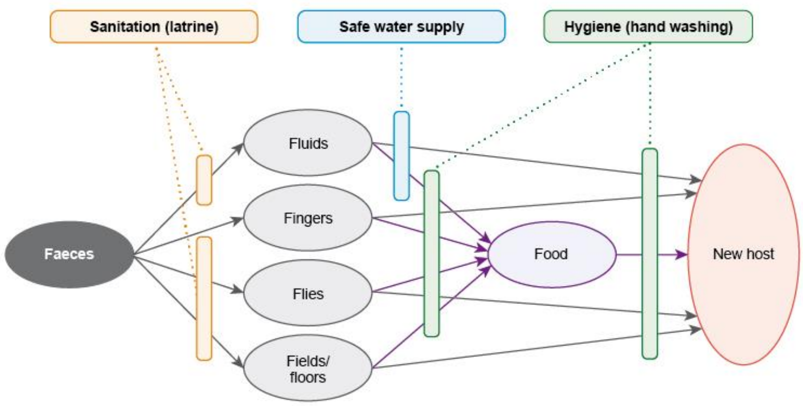
Results of the analyses conducted among all 115 countries indicated that the effect of WASH ODA was only significant in reducing proportion of the rural population practising open defecation (%). From the analyses conducted according to different income groups, the effect of WASH ODA was most significant among the LMICs and least significant among the UMICs. All of the WASH coverage indicators (water, sanitation and open defecation rate) for rural population, sanitation coverage and open defecation rate for total population in LMICs improved with increase in the amount of WASH ODA channelled. The effect of WASH ODA on improving water coverage for all populations (total, rural and urban) and sanitation coverage for the urban population among the LICs was also significant. Results from this study were in line with the results suggested by Gopalan and Rajan (2016) where the effect of WASH ODA was most significant among the LMICs rather than LICs and UMICs. One of the plausible explanations to why the effect of WASH ODA was less significant among LICs could be that for the effect of WASH ODA to occur, the recipient country needs to have a certain level of institutional capacity (Burnside and Dollar, 2004; Gopalan and Rajan, 2016). Countries in the LICs may tend to lack institutional capacity to set targets and achieve them systematically, thus, the effect of WASH ODA may have been less significant. In the case for UMICs, one of the possible explanations to why the effect of WASH ODA on WASH coverage was not significant might be that WASH facilities in UMICs have reached a saturation point and any further increase in the amount of WASH ODA will not have a direct impact on increasing WASH coverage. UMICs, where the level of economic development tend to be higher than those countries in LICs and LMICs, might not have as compelling ODA effect as those countries with lower levels of development.

Results from the fixed-effects analyses conducted for all 115 countries indicated that the improvement in all of WASH coverage indicators did reduce the burden of diarrhoeal diseases significantly except for water coverage for the rural population and sanitation coverage for the total population. From the analyses conducted according to different income groups, the effect of WASH coverage on reducing the burden of diarrhoeal diseases was most significant among the UMICs and least significant among the LICs. Improvement in all of the WASH coverage indicators, except water coverage and open defecation rate of the urban population, significantly reduced the burden of diarrhoeal diseases. For both of LICs and LMICs, improvement in the WASH coverage for urban population had a more significant effect on the reduction of burden of diarrhoeal diseases than the rural population. Improvement in all of the WASH coverage indicators for the urban population in LIMCs significantly reduced the burden of diarrhoeal diseases while improvement in sanitation coverage and open defecation rate of the urban population in LICs had significant effect on the reduction of diarrhoeal diseases. Improvement in water coverage for the rural population in LICs; water (total population %) and sanitation (rural population %) also had significant effect on reducing the burden of diarrhoeal diseases. Unlike the results shown in [Table 26] where the effect of WASH ODA was not significant in improving WASH coverage among the UMICs, the effect of WASH coverage on reducing the burden of diarrhoeal diseases was most significant in UMICs. This could therefore imply that although increase in the amount of WASH ODA may not directly improve WASH coverage in UMICs, improvement in the WASH coverage significantly reduces the burden of diarrhoeal diseases in UMICs.

UMICs being the income group with the largest number of countries (47 countries), in this study sample, the effect of WASH ODA on WASH coverage was not significant at 0.05 significance level (please refer to [Appendix E1] to [Appendix E1]). As shown in [Appendix E: pg. 90], other than Gabon and Namibia, most of the countries in the UMICs group had attained above 50% WASH coverage since 2004. Therefore, perhaps any further increase in the amount of WASH ODA might not have much significant effect on increasing the number of WASH facilities. In the case for percentage of population practising open defecation among the UMICs, Namibia was the only country that had only a slight decrease in the percentage of population practising open defecation (54% in 2004 to 49% in 2017). Percentage of rural population practising open defecation in Namibia was 75% in 2004 and 73% in 2017; percentage of urban population practising open defecation in 2004 was 16% and in 2017 it was 23%. The percentage of urban population practising open defecation had in fact worsened over the years. According to the UNICEF (2015) fact sheet on sanitation, lack of improved sanitation facilities, poor knowledge and low practice of basic hygiene are some of the factors associated high levels of diarrhoeal-related mortality and morbidity in Namibia. This thus, indicates that the scope of ‘WASH coverage’ should go beyond mere provision of WASH facilities and include management of such facilities as well.

Moreover, one of the plausible reasons behind why sanitation coverage is still low in many of the developing countries is due to the lack of political commitment from the local governments. Various reports have indicated that comparatively more funds have been channelled towards increasing water coverage than sanitation despite the MDG for water coverage has already been achieved in 2010 (Cha et. al, 2017). Various researchers in the field of WASH claim that this is due to the fact that water supply facilities tend to be more 'tangible' and objective where the coverage can be measured empirically. Sanitation coverage, on the other hand, tends to be more 'intangible' where management of sanitation facilities are as important as building it and maintenance would require proper management of human resources. National policies for improvement in the sanitation coverage has yet to be one of the main priorities in most the recipient countries. Ethiopia for example can be one of the ideal example to be mentioned when it comes to the importance of local government's involvement in increasing sanitation coverage.

Ethiopia used to be one of the countries with extremely high open defecation rate (%) however, after the local government's strong involvement and commitment in achieving sanitation coverage for all citizens, 7 out of 10 people use toilets instead of defecating in the open (WHO, 2015). Ethiopia has managed to achieve such significant reduction in the proportion of population practising open defecation as the Ethiopian government has placed its priority on sanitation coverage (Ayalew et. al 2018). In 2003, the Ethiopian government initiated a 'Health Extension Program' which was responsible for rolling out key sanitation interventions in rural areas which is where 85% of the Ethiopia's population reside. Services offered under this scheme included hiring female health workers in every kebele (the smallest administrative unit of Ethiopia) to sensitise families about sanitation and to encourage them to build toilets. As such, local governments' acknowledgement towards the importance of WASH coverage, especially sanitation coverage, increase active initiation and involvement of hygiene awareness programmes and policies in Ethiopia (Ayalew, 2018; GLAAS, 2017; WHO, 2017). Moreover, approaches such Community-Led Total Sanitation (CLTS) has been proven to be effective in reducing open defecation (Duflo et. al, 2015), where community leaders get involve in building and using of toilets to reduce the open defecation rate.



[Figure 12] F-diagram (faecal-oral route)

The F-diagram have been commonly used during CLTS as a tool to explain the importance of WASH in preventing WASH-related diseases such as the diarrhoeal diseases. As shown in [Figure 12] there are various routes that one can suffer from diarrhoeal diseases and therefore highlighting the importance of WASH facilities in reducing the burden of diarrhoeal diseases. The F-diagram is a summary of pathways illustrating how WASH-related diseases are spread and at which point WASH facilities and services should be intervened. F-diagram is also commonly used in WASH education programmes where the objective of the programme is to allow participants to understand the importance of personal hygiene and be aware of how they can get infected with various WASH-related diseases (Ayalew, 2018).

Furthermore, limited WASH coverage will likely contribute to wider gap in the gender inequality as both are highly interconnected. Daily activities such as doing of household chores (washing of dishing, clothes) require water and in most of the LICs, LMICs and UMICs such activities are still perceived purely as women's role. Having to travel long distances to collect water can deprive or even restrict women from receiving proper education and which can therefore hindering women from having the capability to earn their own income or be part of the economy. Women, who have yet to receive proper education or earn their own income, are more likely to marry early and depend on their spouse for household income which contributes to the vicious cycle of gender inequality.

From a more macro perspective, for WASH coverage and especially for sanitation coverage to increase further, sanitation policies should be implemented and managed more effectively. Hence, policy makers should also consider various factors hindering the sustainment of WASH coverage such as long distance to the improved water source, high number of users per water point thus leading to long queuing time, availability of rain water as an alternative source during the rainy season etc rather than only focussing on increasing new WASH facilities. A more gender-sensitive policies should be developed and actively implemented as it will not only contribute to the reduction in WASH-related morbidity and mortality but also improvement in female education level, involvement in economic activities. Ultimately, alleviating problems caused by gender inequality. Sustainable management of WASH facilities should be part of the ‘WASH coverage’, in order to be a step closer to achieving SDG 6 that is “Ensure availability and sustainable management of water and sanitation for all”.

4.1. Limitations of the study

One of the main limitations of this study is that although the dependent variables – WASH coverage and burden of diarrhoeal disease have been lagged by 2 years to minimise the effect of reverse causality, this may not be enough to resolve the potential problems caused by it. Some of the other limitations are that the OECD-DAC data on aid disbursements may not be the most complete form of data among all sources on aid flows to the WASH sector. Furthermore, due to limited access to consistent data on local expenditures on WASH sector, this study is not able to explore if ODA initially meant for WASH has been directed to other social sectors (complements or substitutes) which could reduce the net positive impact of ODA (aid) in the outcomes. Moreover, the impact of political, cultural differences, for example, religion practices or cultural perspectives on 'water', 'sanitation' and perhaps cultural reasons behind open defecation have not been directly factored in this study. Despite such limitations, however, this study has the potential to perhaps contribute to better understanding on whether ODA gross disbursements specifically directed to the WASH sector has an impact on improving the WASH coverage; and if improvement in such WASH coverage has an impact on reducing the burden of diarrhoeal diseases.

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[Appendix A]

List of countries classified according to income groups (World Bank classification)

Low-income countries (LICs)	Lower-middle-income countries (LMICs)	Upper-middle-income countries
Afghanistan	Angola	Albania
Benin	Bangladesh	Algeria
Burkina Faso	Bhutan	Argentina
Burundi	Bolivia (Plurinational State of)	Armenia
Central African Republic	Cambodia	Azerbaijan
Chad	Cameroon	Belarus
Democratic Republic of the Congo	Cape Verde	Belize
Eritrea	Comoros	Bosnia and Herzegovina
Ethiopia	Congo	Botswana
Gambia	Cote d'Ivoire	Brazil
Guinea	Egypt	Colombia
Guinea-Bissau	El Salvador	Costa Rica
Haiti	Ghana	Cuba
Liberia	Honduras	Dominica
Madagascar	Indonesia	Dominican Republic
Malawi	Kenya	Ecuador
Mali	Kiribati	Fiji
Mozambique	Kyrgyzstan	Gabon
Nepal	Lao People's Democratic Republic	Georgia
Niger	Lesotho	Guatemala
Rwanda	Mauritania	Guyana
Sierra Leone	Micronesia (Federated States of)	Iran (Islamic Republic of)
Tajikistan	Mongolia	Iraq
Tanzania	Morocco	Jamaica
Togo	Myanmar	Jordan
Uganda	Nicaragua	Kazakhstan
Yemen	Nigeria	Lebanon
	Pakistan	Malaysia
	Papua New Guinea	Maldives

	Philippines	Marshall Islands
	Sao Tome and Principe	Mauritius
	Senegal	Mexico
	Solomon Islands	Montenegro
	Sudan	Namibia
	Timor-Leste	Paraguay
	Tunisia	Peru
	Ukraine	Saint Lucia
	Uzbekistan	Saint Vincent and the Grenadines
	Vietnam	Samoa
	Zambia	Serbia
	Zimbabwe	South Africa
		Sri Lanka
		Suriname
		Thailand
		Tonga
		Turkey
		Venezuela (Bolivarian Republic of)

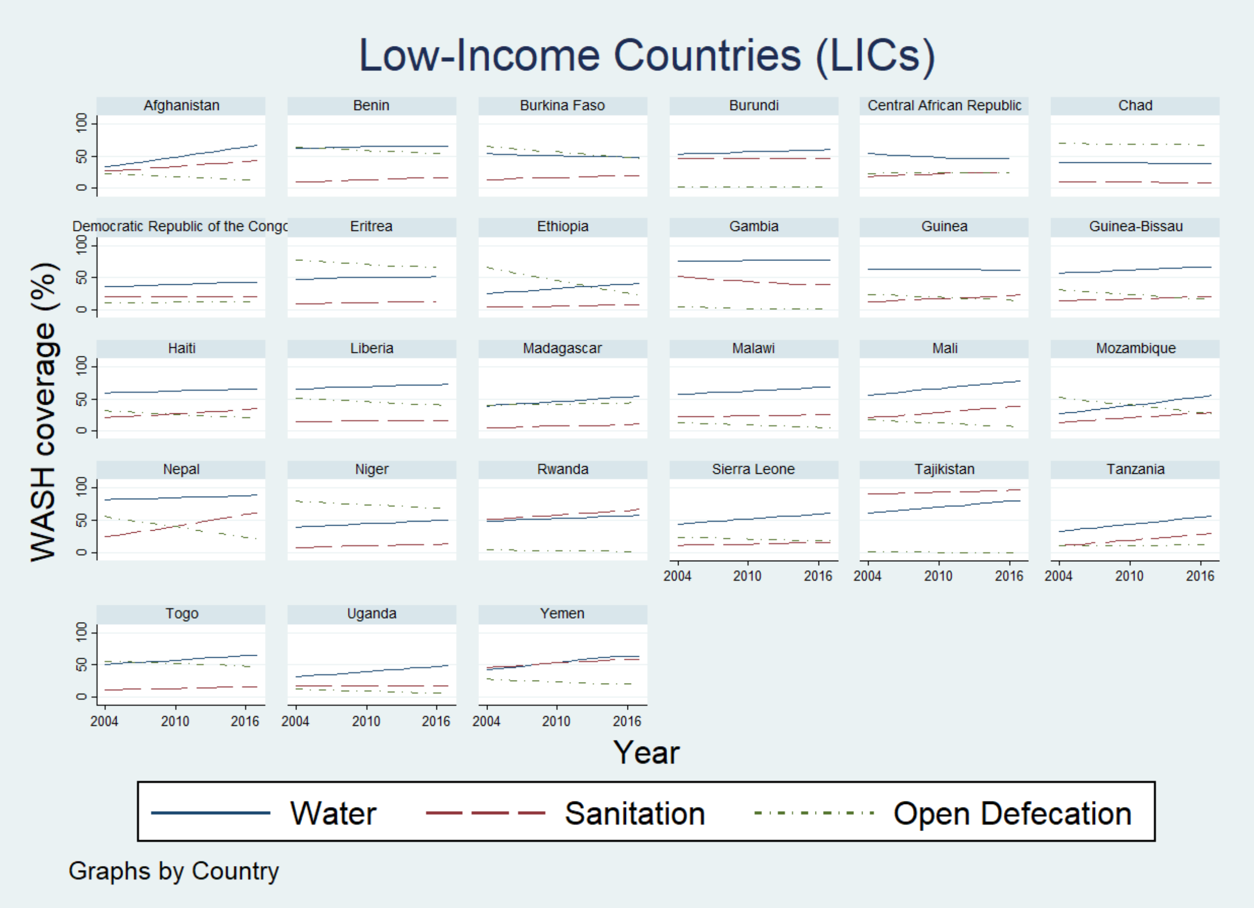
[Appendix B]

List of countries classified according to regions (World Bank classification)

Latin America (LAC)	sub-Saharan Africa (SSA)	Middle East North Africa (MENA)	Europe & Central Asia (ECA)	South Asia (SA)	East Asia Pacific (EAP)
Argentina	Angola	Algeria	Albania	Afghanistan	Cambodia
Belize	Benin	Egypt	Armenia	Bangladesh	Fiji
Bolivia (Plurinational State of)	Botswana	Iran (Islamic Republic of)	Azerbaijan	Bhutan	Indonesia
Brazil	Burkina Faso	Iraq	Belarus	Maldives	Kiribati
Colombia	Burundi	Jordan	Bosnia and Herzegovina	Nepal	Lao People's Democratic Republic
Costa Rica	Cameroon	Lebanon	Georgia	Pakistan	Malaysia
Cuba	Cape Verde	Morocco	Kazakhstan	Sri Lanka	Marshall Islands
Dominica	Central African Republic	Tunisia	Kyrgyzstan		Micronesia (Federated States of)
Dominican Republic	Chad	Yemen	Montenegro		Mongolia
Ecuador	Comoros		Serbia		Myanmar
El Salvador	Congo		Tajikistan		Papua New Guinea
Guatemala	Cote d'Ivoire		Turkey		Philippines
Guyana	Democratic Republic of the Congo		Ukraine		Samoa
Haiti	Eritrea		Uzbekistan		Solomon Islands
Honduras	Ethiopia				Thailand
Jamaica	Gabon				Timor-Leste
Mexico	Gambia				Tonga
Nicaragua	Ghana				Vietnam

Paraguay	Guinea
Peru	Guinea-Bissau
Saint Lucia	Kenya
Saint Vincent and the Grenadines	Lesotho
Suriname	Liberia
Venezuela (Bolivarian Republic of)	Madagascar
	Malawi
	Mali
	Mauritania
	Mauritius
	Mozambique
	Namibia
	Niger
	Nigeria
	Rwanda
	Sao Tome and Principe
	Senegal
	Sierra Leone
	South Africa
	Sudan
	Tanzania
	Togo
	Uganda
	Zambia
	Zimbabwe

[Appendix C]


Low-Income Countries (LICs)
Afghanistan
Benin
Burkina Faso
Burundi
Central African Republic
Chad
Democratic Republic of the Congo
Eritrea
Ethiopia
Gambia
Guinea
Guinea-Bissau
Haiti
Liberia
Madagascar
Malawi
Mali
Mozambique
Nepal
Niger
Rwanda
Sierra Leone
Tajikistan
Tanzania
Togo
Uganda
Yemen
WASH coverage (%)
0
50
100
2004
2010
2016
Year
Water
Sanitation
Open Defecation
Graphs by Country

[Appendix C1] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic drinking water services with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0508874	0.0143603	3.54	0.000**
Population Density	0.0106098	0.0152271	0.70	0.486
Log [GDP per capita (US$2010)]	13.77482	2.052632	6.71	0.000**
Human Development Index	0.0043603	0.0163915	0.27	0.790
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5770			
Between	0.1513			
Overall	0.0905			
Sigma_u (σ u)	22.638665			
Sigma_e (σ e)	3.1985928			
rho	0.98042814			

Statistical significance: *<0.05, **<0.01

[Appendix C2] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic drinking water services with control variables in LIC

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0408655	0.0159172	2.57	0.011**
Population Density	0.0021257	0.016878	0.13	0.900
Log [GDP per capita (US$2010)]	15.26299	2.275172	6.71	0.000**
Human Development Index	-0.0064989	0.0181687	-0.36	0.721
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				

Within	0.5069
Between	0.1005
Overall	0.0727
Sigma_u (σ u)	24.884943
Sigma_e (σ e)	3.5453739
rho	0.98010592

Statistical significance: *<0.05, **<0.01

[Appendix C3] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic drinking water services with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0453537	0.013406	3.38	0.001**
Population Density	0.0106764	0.0142152	0.75	0.453
Log [GDP per capita (US$2010)]	8.162205	1.916231	4.26	0.000**
Human Development Index	-0.0126053	0.0153023	-0.82	0.411
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.3204			
Between	0.0856			
Overall	0.0352			
Sigma_u (σ u)	12.479528			
Sigma_e (σ e)	2.9860414			
rho	0.94584775			

Statistical significance: *<0.05, **<0.01

[Appendix C4] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic sanitation services with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0220329	0.0134846	1.63	0.103
Population Density	-0.0274963	0.0142986	-1.92	0.055
Log [GDP per capita (US$2010)]	-2.491319	1.927465	-1.29	0.197
Human Development Index	0.1118181	0.015392	7.26	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.4170			
Between	0.2150			
Overall	0.2240			
Sigma_u (σ u)	17.575426			
Sigma_e (σ e)	3.0035465			
rho	0.97162374			

Statistical significance: *<0.05, **<0.01

[Appendix C5] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic sanitation services with control variables in LICs

Statistical significance: *<0.05, **<0.01

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0152403	0.0148541	1.03	0.306
Population Density	-0.0232894	0.0157508	-1.48	0.140
Log [GDP per capita (US$2010)]	-2.939319	2.123226	-1.38	0.167
Human Development Index	0.1044877	0.0169553	6.16	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.3134			
Between	0.2071			
Overall	0.2114			
Sigma_u (σ u)	19.173084			
Sigma_e (σ e)	3.308599			
rho	0.97108252			

[Appendix C6] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic sanitation services with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0343431	0.0139668	2.46	0.014**
Population Density	-0.0978353	0.0148099	-6.61	0.000**
Log [GDP per capita (US$2010)]	0.9919366	1.996397	0.50	0.620
Human Development Index	0.0907346	0.0159425	5.69	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				

Within	0.3514
Between	0.0098
Overall	0.0147
Sigma_u (σ u)	20.735768
Sigma_e (σ e)	3.1109624
rho	0.97798685

Statistical significance: *<0.05, **<0.01

[Appendix C7] Fixed-effects model analysis of WASH ODA on the proportion of total population practising open defecation (%) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0134444	0.0143867	-0.93	0.351
Population Density	0.0649106	0.0152551	4.26	0.000**
Log [GDP per capita (US$2010)]	-6.656995	2.056409	-3.24	0.001**
Human Development Index	-0.091615	0.0164217	-5.58	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5341			
Between	0.0089			
Overall	0.0040			
Sigma_u (σ u)	26.693973			
Sigma_e (σ e)	3.2044779			
rho	0.98579392			

Statistical significance: *<0.05, **<0.01

[Appendix C8] Fixed-effects model analysis of WASH ODA on the proportion of rural population practising open defecation (%) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0096718	0.0165254	-0.59	0.559
Population Density	0.0692173	0.017523	3.95	0.000**
Log [GDP per capita (US$2010)]	-7.616269	2.362119	-3.22	0.001**
Human Development Index	-0.0941084	0.018863	-4.99	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.4929			
Between	0.0044			
Overall	0.0019			
Sigma_u (σ u)	31.941632			
Sigma_e (σ e)	3.6808623			
rho	0.98689444			

Statistical significance: *<0.05, **<0.01

[Appendix C9] Fixed-effects model analysis of WASH ODA on the proportion of urban population practising open defecation (%) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0066073	0.0061649	-1.07	0.285
Population Density	0.0244034	0.006537	3.73	0.000**
Log [GDP per capita (US$2010)]	-4.625882	0.8811953	-5.25	0.000**
Human Development Index	-0.012853	0.0070369	-1.83	0.069

Number of observations	369
Number of countries	27
Prob> F	0.0000
R-sq	
Within	0.4294
Between	0.0001
Overall	0.0002
Sigma_u (σ u)	11.532439
Sigma_e (σ e)	1.3731566
rho	0.98602075

Statistical significance: *<0.05, **<0.01

[Appendix C10] Fixed-effects model analysis of water coverage (%) for total population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-31.12861	17.37162	-1.79	0.074
WASH ODA (2-year lag)	18.5422	4.6707	3.97	0.000**
Population Density	8.215475	4.866615	1.69	0.092
Log [GDP per capita (US$2010)]	-2159.831	697.8635	-3.09	0.002**
Human Development Index	-27.3413	5.235566	-5.22	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5431			
Between	0.1427			
Overall	0.1783			
Sigma_u (σ u)	3478.0582			
Sigma_e (σ e)	1021.545			
rho	0.92058455			

Statistical significance: *<0.05, **<0.01

[Appendix C11] Fixed-effects model analysis of water coverage (%) for rural population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for rural population	-31.70239	15.65196	-2.03	0.044*
WASH ODA (2-year lag)	18.25368	4.62473	3.95	0.000**
Population Density	7.952598	4.856879	1.64	0.102
Log [GDP per capita (US$2010)]	-2104.749	696.9228	-3.02	0.003**
Human Development Index	-27.68306	5.229162	-5.29	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5443			
Between	0.1521			
Overall	0.1877			
Sigma_u (σ u)	3438.9804			
Sigma_e (σ e)	1020.2092			
rho	0.91911142			

Statistical significance: *<0.05, **<0.01

[Appendix C12] Fixed-effects model analysis of water coverage (%) for urban population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for rural population	25.03072	18.64681	1.34	0.180
WASH ODA (2-year lag)	15.82291	4.672973	3.39	0.001**
Population Density	7.617971	4.877291	1.56	0.119
Log [GDP per capita (US$2010)]	-2792.928	674.3183	-4.14	0.000**
Human Development Index	-27.16151	5.251156	-5.17	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5412			
Between	0.0956			
Overall	0.1244			
Sigma_u (σ u)	4006.8322			
Sigma_e (σ e)	1023.6671			
rho	0.93872894			

Statistical significance: *<0.05, **<0.01

[Appendix C13] Fixed-effects model analysis of sanitation coverage (%) for total population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for total population	-24.34499	18.54026	-1.31	0.190
WASH ODA (2-year lag)	17.49454	4.614453	3.79	0.000**
Population Density	7.21581	4.900374	1.47	0.142
Log [GDP per capita (US$2010)]	-2649.273	658.6146	-4.02	0.000**
Human Development Index	-24.75482	5.641241	-4.39	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5411			
Between	0.1345			
Overall	0.1643			
Sigma_u (σ u)	3752.0898			
Sigma_e (σ e)	1023.7845			
rho	0.93070785			

Statistical significance: *<0.05, **<0.01

[Appendix C14] Fixed-effects model analysis of sanitation coverage (%) for rural population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for rural population	-1.358348	16.87369	-0.08	0.936
WASH ODA (2-year lag)	16.97885	4.615206	3.68	0.000**
Population Density	7.853573	4.901968	1.60	0.110
Log [GDP per capita (US$2010)]	-2592.615	660.5298	-3.93	0.000**
Human Development Index	-27.3351	5.547477	-4.93	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5388			
Between	0.1071			
Overall	0.1377			
Sigma_u (σ u)	3837.2527			
Sigma_e (σ e)	1026.3903			
rho	0.9332312			

Statistical significance: *<0.05, **<0.01

[Appendix C15] Fixed-effects model analysis of sanitation coverage (%) for urban population on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for urban population	-43.82017	17.78637	-2.46	0.014**
WASH ODA (2-year lag)	18.46307	4.607801	4.01	0.000**
Population Density	3.598048	5.145966	0.70	0.485
Log [GDP per capita (US$2010)]	-2545.155	653.057	-3.90	0.000**
Human Development Index	-23.50103	5.457244	-4.31	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5469			
Between	0.1583			
Overall	0.1887			
Sigma_u (σ u)	3635.5311			
Sigma_e (σ e)	1017.2798			
rho	0.92738828			

Statistical significance: *<0.05, **<0.01

[Appendix C16] Fixed-effects model analysis of proportion of total population (%) practising open defecation on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of total population practising open defecation (%)	25.71167	17.36573	1.48	0.140
WASH ODA (2-year lag)	17.30383	4.599095	3.76	0.000**
Population Density	6.216249	4.999163	1.24	0.215
Log [GDP per capita (US$2010)]	-2417.46	666.6396	-3.63	0.000**
Human Development Index	-25.12146	5.478949	-4.59	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5418			
Between	0.1922			
Overall	0.2237			
Sigma_u (σ u)	3407.555			
Sigma_e (σ e)	1023.078			
rho	0.91731089			

Statistical significance: *<0.05, **<0.01

[Appendix C17] Fixed-effects model analysis of proportion of rural population (%) practising open defecation of the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of rural population practising open defecation (%)	22.73294	15.11668	1.50	0.134
WASH ODA (2-year lag)	17.17802	4.595022	3.74	0.000**
Population Density	6.311695	4.981062	1.27	0.206
Log [GDP per capita (US$2010)]	-2415.482	666.492	-3.62	0.000**
Human Development Index	-25.33767	5.431935	-4.66	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5418			
Between	0.1934			
Overall	0.2240			
Sigma_u (σ u)	3428.5766			
Sigma_e (σ e)	1022.9735			
rho	0.91825445			

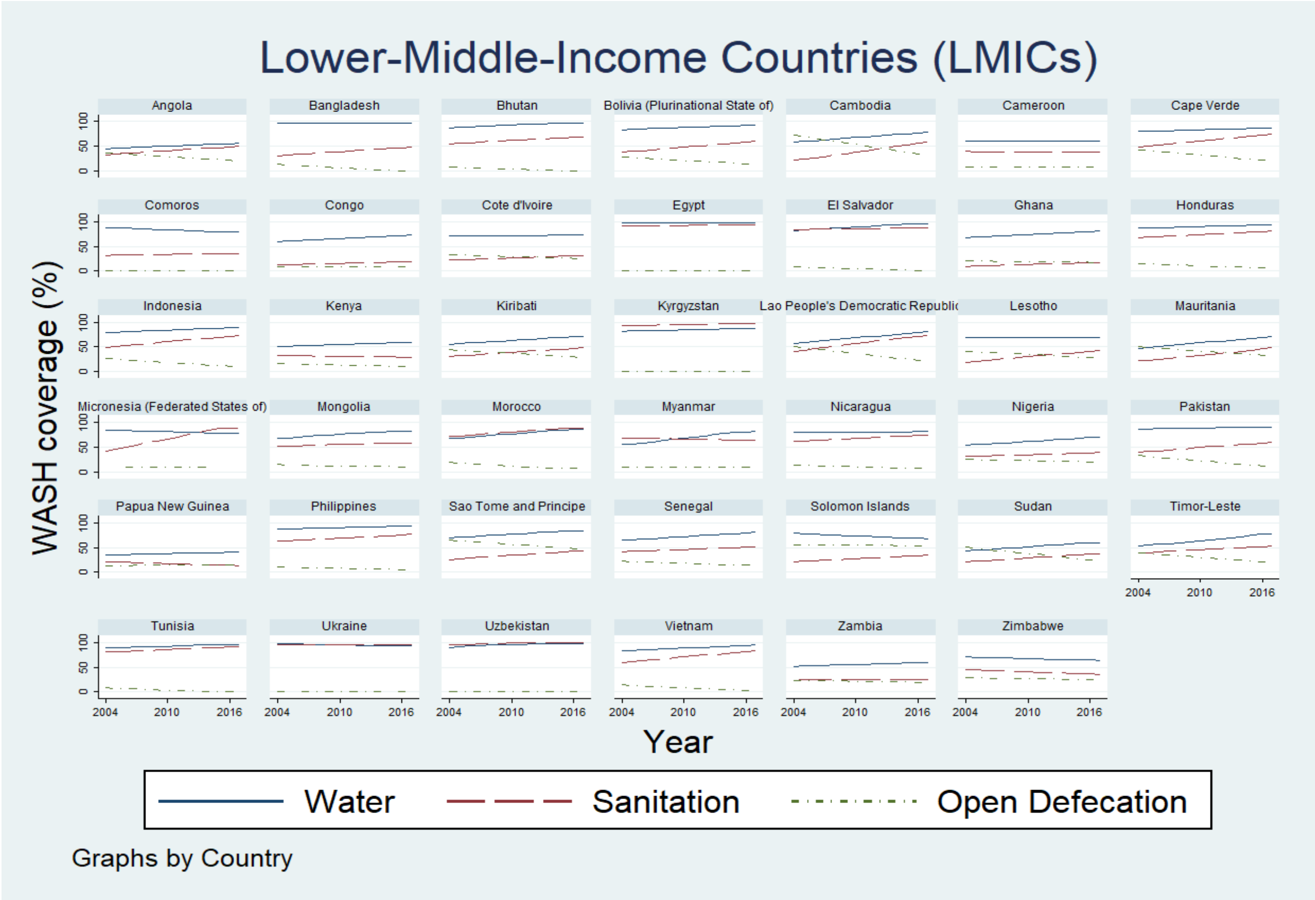
Statistical significance: *<0.05, **<0.01

[Appendix C18] Fixed-effects model analysis of proportion of urban population (%) practising open defecation on the burden of diarrhoeal diseases (DALY) with control variables in LICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of urban population practising open defecation (%)	132.8352	40.00818	3.32	0.001**
WASH ODA (2-year lag)	17.83583	4.54221	3.93	0.000**
Population Density	4.643578	4.906352	0.95	0.345
Log [GDP per capita (US$2010)]	-1974.142	674.0608	-2.93	0.004**
Human Development Index	-25.76971	5.201405	-4.95	0.000**
Number of observations	369			
Number of countries	27			
Prob> F	0.0000			
R-sq				
Within	0.5534			
Between	0.2351			
Overall	0.2714			
Sigma_u (σ_u)	3216.0006			
Sigma_e (σ_e)	1010.0136			
rho	0.91022207			

Statistical significance: *<0.05, **<0.01

[Appendix D]



Lower-Middle-Income Countries (LMICs)
Angola
Bangladesh
Bhutan
Bolivia (Plurinational State of)
Cambodia
Cameroon
Cape Verde
Comoros
Congo
Cote d'Ivoire
Egypt
El Salvador
Ghana
Honduras
Indonesia
Kenya
Kiribati
Kyrgyzstan
Lao People's Democratic Republic
Lesotho
Mauritania
Micronesia (Federated States of)
Mongolia
Morocco
Myanmar
Nicaragua
Nigeria
Pakistan
Papua New Guinea
Philippines
Sao Tome and Principe
Senegal
Solomon Islands
Sudan
Timor-Leste
Tunisia
Ukraine
Uzbekistan
Vietnam
Zambia
Zimbabwe
WASH coverage (%)
0
50
100
2004
2010
2016
Year
Water
Sanitation
Open Defecation
Graphs by Country

[Appendix D1] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic drinking water services with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0068715	0.0064185	1.07	0.285
Population Density	-0.0337245	0.0124006	-2.72	0.007**
Log [GDP per capita (US$2010)]	9.878581	1.731754	5.70	0.000**
Human Development Index	0.0447396	0.0127268	3.52	0.000**
Number of observations	554			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.5280			
Between	0.0162			
Overall	0.0240			
Sigma_u (σ u)	23.890175			
Sigma_e (σ e)	2.9352126			
rho	0.98512922			

Statistical significance: *<0.05, **<0.01

[Appendix D2] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic drinking water services with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0174958	0.0083246	2.10	0.036*
Population Density	-0.0516951	0.0161697	-3.20	0.001**
Log [GDP per capita (US$2010)]	11.31682	2.269711	4.99	0.000**
Human Development Index	0.0509194	0.0167205	3.05	0.002**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4745			
Between	0.0000			
Overall	0.0010			
Sigma_u (σ u)	29.818285			
Sigma_e (σ e)	3.8034034			
rho	0.98399077			

Statistical significance: *<0.05, **<0.01

[Appendix D3] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic drinking water services with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0052235	0.0048407	-1.08	0.281
Population Density	-0.0259037	0.0094026	-2.75	0.006**
Log [GDP per capita (US$2010)]	4.993477	1.319821	3.78	0.000**
Human Development Index	0.0303409	0.0097229	3.12	0.002**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.3729			
Between	0.0059			
Overall	0.0089			
Sigma_u (σ u)	12.249185			
Sigma_e (σ e)	2.2116523			
rho	0.96842909			

Statistical significance: *<0.05, **<0.01

[Appendix D4] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic sanitation facilities with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0223503	0.0090259	2.48	0.014**
Population Density	0.0486354	0.0174382	2.79	0.005**
Log [GDP per capita (US$2010)]	7.791563	2.435253	3.20	0.001**
Human Development Index	0.0545724	0.0178969	3.05	0.002**
Number of observations	554			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.4462			
Between	0.0967			
Overall	0.1046			
Sigma_u (σ u)	26.402248			
Sigma_e (σ e)	4.1275982			
rho	0.976142423			

Statistical significance: *<0.05, **<0.01

[Appendix D5] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic sanitation facilities with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0391433	0.0087581	4.47	0.000**
Population Density	0.0631028	0.0170116	3.71	0.000**
Log [GDP per capita (US$2010)]	12.39163	2.38789	5.19	0.000**
Human Development Index	0.0187385	0.0175911	1.07	0.287
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				

Within	0.5052			
Between	0.0746			
Overall	0.0750			
Sigma_u (σ u)	33.061415			
Sigma_e (σ e)	4.0014401			
rho	0.98556309			

Statistical significance: *<0.05, **<0.01

[Appendix D6] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic sanitation facilities with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0039416	0.008417	0.47	0.640
Population Density	0.007028	0.163492	0.43	0.667
Log [GDP per capita (US$2010)]	10.89968	2.2949	4.75	0.000**
Human Development Index	-0.0035084	0.0169061	-0.21	0.836
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.2637			
Between	0.0345			
Overall	0.0291			
Sigma_u (σ u)	26.545912			
Sigma_e (σ e)	3.8456146			
rho	0.97944506			

Statistical significance: *<0.05, **<0.01

[Appendix D7] Fixed-effects model analysis of WASH ODA on the proportion of total population practising open defecation with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0140583	0.0070332	-2.00	0.046*
Population Density	-0.034469	0.0135887	-2.54	0.011**
Log [GDP per capita (US$2010)]	-2.24127	1.911459	-1.17	0.242
Human Development Index	-0.0826203	0.014076	-5.87	0.000**
Number of observations	550			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.4948			
Between	0.3057			
Overall	0.3302			
Sigma_u (σ u)	13.099285			
Sigma_e (σ e)	3.2158979			
rho	0.94315499			

Statistical significance: *<0.05, **<0.01

[Appendix D8] Fixed-effects model analysis of WASH ODA on the proportion of rural population practising open defecation with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0269031	0.0083575	-3.22	0.001**
Population Density	-0.0419434	0.0162335	-2.58	0.010**
Log [GDP per capita (US$2010)]	-4.425938	2.278659	-1.94	0.053*
Human Development Index	-0.0723997	0.0167865	-4.31	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4663			
Between	0.2758			
Overall	0.2899			
Sigma_u (σ u)	18.060456			
Sigma_e (σ e)	3.8183991			
rho	0.95721281			

Statistical significance: *<0.05, **<0.01

[Appendix D9] Fixed-effects model analysis of WASH ODA on the proportion of urban population practising open defecation with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0025309	0.0053927	0.47	0.639
Population Density	0.0012021	0.0104748	0.11	0.909
Log [GDP per capita (US$2010)]	-0.2723357	1.470329	-0.19	0.853
Human Development Index	-0.0585125	0.0108316	-5.40	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.3259			
Between	0.0564			
Overall	0.0773			
Sigma_u (σ u)	8.6355656			
Sigma_e (σ e)	2.463863			
rho	0.92472286			

Statistical significance: *<0.05, **<0.01

[Appendix D10] Fixed-effects model analysis of water coverage(%) for total population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-37.35323	8.978703	-4.16	0.000**
WASH ODA (2-year lag)	3.294416	1.301646	2.53	0.012**
Population Density	-7.439043	2.530164	-2.94	0.003**
Log [GDP per capita (US$2010)]	887.1887	361.8388	2.45	0.015*
Human Development Index	-20.87343	2.609164	-8.00	0.000**
Number of observations	554			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.4857			
Between	0.4789			
Overall	0.4740			
Sigma_u (σ u)	2014.9532			
Sigma_e (σ e)	594.58238			
rho	0.91989962			

Statistical significance: *<0.05, **<0.01

[Appendix D11] Fixed-effects model analysis of water coverage(%) for rural population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for rural population	-5.555371	7.311889	-0.76	0.448
WASH ODA (2-year lag)	3.195198	1.35208	2.36	0.019*
Population Density	-6.520411	2.641669	-2.47	0.014**
Log [GDP per capita (US$2010)]	655.5361	376.2033	1.74	0.082
Human Development Index	-22.90338	2.729064	-8.39	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4704			
Between	0.5227			
Overall	0.5168			
Sigma_u (σ u)	1609.3702			
Sigma_e (σ e)	614.9735			
rho	0.87258805			

Statistical significance: *<0.05, **<0.01

[Appendix D12] Fixed-effects model analysis of water coverage(%) for urban population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for urban population	-48.00145	12.39272	-3.87	0.000**
WASH ODA (2-year lag)	2.847265	1.328151	2.14	0.033*
Population Density	-7.476641	2.596643	-2.88	0.004**
Log [GDP per capita (US$2010)]	832.3611	366.9451	2.27	0.024*
Human Development Index	-21.72985	2.690898	-8.08	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4855			
Between	0.5099			
Overall	0.5055			
Sigma_u (σ u)	1784.8465			
Sigma_e (σ e)	606.09092			
rho	0.89661024			

Statistical significance: *<0.05, **<0.01

[Appendix D13] Fixed-effects model analysis of sanitation coverage(%) for total population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for total population	-3.443672	6.490981	-0.53	0.596
WASH ODA (2-year lag)	3.114712	1.329718	2.34	0.020*
Population Density	-6.011841	2.573143	-2.34	0.020*
Log [GDP per capita (US$2010)]	545.0234	360.1945	1.51	0.131
Human Development Index	-22.	2.644708	-8.45	0.000**
Number of observations	554			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.4685			
Between	0.5295			
Overall	0.5205			
Sigma_u (σ u)	1546.7573			
Sigma_e (σ e)	604.45867			
rho	0.86751523			

Statistical significance: *<0.05, **<0.01

[Appendix D14] Fixed-effects model analysis of sanitation coverage(%) for rural population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for rural population	25.29991	6.85765	3.72	0.000**
WASH ODA (2-year lag)	2.099852	1.354981	1.55	0.122
Population Density	-7.842342	2.615783	-3.00	0.003**
Log [GDP per capita (US$2010)]	276.6814	371.9503	0.74	0.457
Human Development Index	-23.66409	2.670712	-8.86	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4843			
Between	0.3225			
Overall	0.3377			
Sigma_u (σ u)	1907.3841			
Sigma_e (σ e)	606.80064			
rho	0.90809349			

Statistical significance: *<0.05, **<0.01

[Appendix D15] Fixed-effects model analysis of sanitation coverage(%) for urban population on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for urban population	-37.73317	7.03141	-5.37	0.000**
WASH ODA (2-year lag)	3.246732	1.309041	2.48	0.013**
Population Density	-5.968036	2.54258	-2.35	0.019*
Log [GDP per capita (US$2010)]	1003.947	364.9671	2.75	0.006**
Human Development Index	-23.31864	2.628811	-8.87	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4993			
Between	0.6117			
Overall	0.5925			
Sigma_u (σ u)	1692.3035			
Sigma_e (σ e)	597.94692			
rho	0.88901192			

Statistical significance: *<0.05, **<0.01

[Appendix D16] Fixed-effects model analysis of proportion of total population practising open defecation(%) on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of total population practising open defection(%)	13.28354	8.364638	1.59	0.113
WASH ODA (2-year lag)	3.252545	1.327262	2.45	0.015*
Population Density	-5.673803	2.570517	-2.21	0.028*
Log [GDP per capita (US$2010)]	602.874	359.7893	1.68	0.094
Human Development Index	-21.90537	7880.894	-8.01	0.000**
Number of observations	550			
Number of countries	41			
Prob> F	0.0000			
R-sq				
Within	0.4726			
Between	0.5184			
Overall	0.5105			
Sigma_u (σ u)	1570.9652			
Sigma_e (σ e)	604.49829			
rho	0.87102962			

Statistical significance: *<0.05, **<0.01

[Appendix D17] Fixed-effects model analysis of proportion of rural population practising open defecation(%) on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of rural population practising open defection(%)	-12.40856	7.2658	-1.71	0.088
WASH ODA (2-year lag)	2.764174	1.356957	2.04	0.042*
Population Density	-6.753682	2.625993	-2.57	0.010**
Log [GDP per capita (US$2010)]	537.7475	367.5244	1.46	0.144
Human Development Index	-24.08464	2.747919	-8.76	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4729			
Between	0.5068			
Overall	0.5019			
Sigma_u (σ u)	1594.2954			
Sigma_e (σ e)	613.5065			
rho	0.87101832			

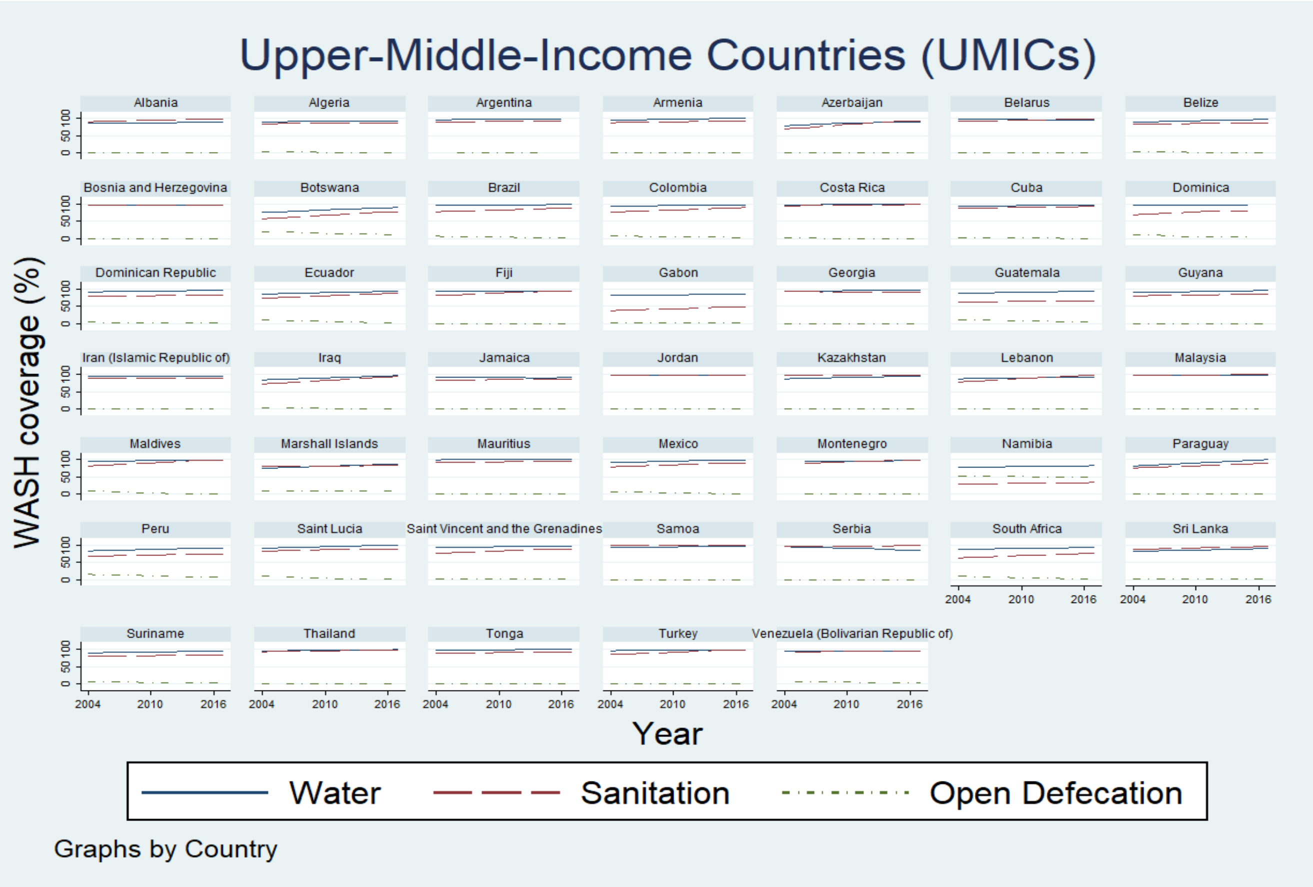
Statistical significance: *<0.05, **<0.01

[Appendix D18] Fixed-effects model analysis of proportion of urban population practising open defecation(%) on the burden of diarrhoeal diseases (DALY rate) with control variables in LMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of urban population practising open defection(%)	24.73211	11.23822	2.20	0.028*
WASH ODA (2-year lag)	3.035407	1.340478	2.26	0.024*
Population Density	-6.262956	2.603181	-2.41	0.017*
Log [GDP per capita (US$2010)]	599.4024	365.4113	1.64	0.102
Human Development Index	-21.73912	2.770977	-7.85	0.000**
Number of observations	532			
Number of countries	39			
Prob> F	0.0000			
R-sq				
Within	0.4749			
Between	0.5265			
Overall	0.5219			
Sigma_u (σ u)	1529.7101			
Sigma_e (σ e)	612.30622			
rho	0.86190486			

Statistical significance: *<0.05, **<0.01

[Appendix E]



Upper-Middle-Income Countries (UMICs)
Albania
Algeria
Argentina
Armenia
Azerbaijan
Belarus
Belize
Bosnia and Herzegovina
Botswana
Brazil
Colombia
Costa Rica
Cuba
Dominica
Dominican Republic
Ecuador
Fiji
Gabon
Georgia
Guatemala
Guyana
Iran (Islamic Republic of)
Iraq
Jamaica
Jordan
Kazakhstan
Lebanon
Malaysia
Maldives
Marshall Islands
Mauritius
Mexico
Montenegro
Namibia
Paraguay
Peru
Saint Lucia
Saint Vincent and the Grenadines
Samoa
Serbia
South Africa
Sri Lanka
Suriname
Thailand
Tonga
Turkey
Venezuela (Bolivarian Republic of)
WASH coverage (%)
0 50 100
2004 2010 2016
Year
Water
Sanitation
Open Defecation
Graphs by Country

[Appendix E1] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic drinking water services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0015328	0.0011373	-1.35	0.178
Population Density	-0.0048251	0.0028875	-1.67	0.095
Log [GDP per capita (US$2010)]	9.595899	0.5655525	16.97	0.000**
Human Development Index	0.0065939	0.002613	2.52	0.012**
Number of observations	621			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.5449			
Between	0.0099			
Overall	0.0136			
Sigma_u (σ u)	22.486594			
Sigma_e (σ e)	1.4707239			
rho	0.99574048			

Statistical significance: *<0.05, **<0.01

[Appendix E2] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic drinking water services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0030664	0.0019594	-1.56	0.118
Population Density	-0.0196295	0.0058003	-3.38	0.001**
Log [GDP per capita (US$2010)]	20.22545	1.105653	18.29	0.000**
Human Development Index	-0.0050251	0.0058986	-0.85	0.395
Number of observations	577			
Number of countries	43			
Prob> F	0.0000			
R-sq				

Within	0.5792
Between	0.0681
Overall	0.0505
Sigma_u (σ u)	49.54354
Sigma_e (σ e)	2.5318117
rho	0.99739531

Statistical significance: *<0.05, **<0.01

[Appendix E3] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic drinking water services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0006603	0.0011177	-0.59	0.555
Population Density	-0.0034666	0.0033086	-1.05	0.295
Log [GDP per capita (US$2010)]	1.901621	0.6304952	3.02	0.003**
Human Development Index	0.0119393	0.0033646	3.55	0.000**
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.1385			
Between	0.1778			
Overall	0.1520			
Sigma_u (σ u)	4.8043313			
Sigma_e (σ e)	1.4442431			
rho	0.91712155			

Statistical significance: *<0.05, **<0.01

[Appendix E4] Fixed-effects model analysis of WASH ODA on the proportion of total population having access to at least basic sanitation services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0016995	0.0015395	-1.10	0.270
Population Density	0.0264711	0.0039093	6.77	0.000**
Log [GDP per capita (US$2010)]	13.25354	0.7656666	17.31	0.000**
Human Development Index	0.0111889	0.00354	3.16	0.002**
Number of observations	620			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.6351			
Between	0.0117			
Overall	0.0102			
Sigma_u (σ u)	31.13866			
Sigma_e (σ e)	1.9909385			
rho	0.9959286			

Statistical significance: *<0.05, **<0.01

[Appendix E5] Fixed-effects model analysis of WASH ODA on the proportion of rural population having access to at least basic sanitation services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0017976	0.0023784	-0.76	0.450
Population Density	0.02608	0.0070405	3.70	0.000**
Log [GDP per capita (US$2010)]	17.61828	1.34207	13.13	0.000**
Human Development Index	0.0111446	0.0071598	1.56	0.120
Number of observations	577			
Number of countries	43			
Prob> F	0.0000			

R-sq	
Within	0.5308
Between	0.0049
Overall	0.0037
Sigma_u (σ u)	43.609343
Sigma_e (σ e)	3.0731771
rho	0.99505843

Statistical significance: *<0.05, **<0.01

[Appendix E6] Fixed-effects model analysis of WASH ODA on the proportion of urban population having access to at least basic sanitation services with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.001473	0.0013402	-1.10	0.272
Population Density	-0.0057817	0.0039669	-1.46	0.146
Log [GDP per capita (US$2010)]	10.81054	0.7559516	14.30	0.000**
Human Development Index	-0.0018046	0.0040341	-0.45	0.655
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.4704			
Between	0.0012			
Overall	0.0007			
Sigma_u (σ u)	26.759363			
Sigma_e (σ e)	1.7316197			
rho	0.99582997			

Statistical significance: *<0.05, **<0.01

[Appendix E7] Fixed-effects model analysis of WASH ODA on the proportion of total population practising open defecation with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	0.0002222	0.000872	0.25	0.799
Population Density	-0.0106857	0.0022155	-4.82	0.000**
Log [GDP per capita (US$2010)]	-3.665135	0.436086	-8.40	0.000**
Human Development Index	-0.0062932	0.0020061	-3.14	0.002**
Number of observations	615			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.3621			
Between	0.0149			
Overall	0.0149			
Sigma_u (σ u)	10.712699			
Sigma_e (σ e)	1.127602			
rho	0.98904207			

Statistical significance: *<0.05, **<0.01

[Appendix E8] Fixed-effects model analysis of WASH ODA on the proportion of rural population practising open defecation with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0009977	0.0017815	-0.56	0.576
Population Density	-0.0237256	0.0052761	-4.50	0.000**
Log [GDP per capita (US$2010)]	-6.681761	1.010343	-6.61	0.000**
Human Development Index	-0.0136106	0.005368	-2.54	0.012**
Number of observations	572			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.3288			

Between	0.0059
Overall	0.0062
Sigma_u (σ u)	19.36331
Sigma_e (σ e)	2.3018877
rho	0.98606476

Statistical significance: *<0.05, **<0.01

[Appendix E9] Fixed-effects model analysis of WASH ODA on the proportion of urban population practising open defecation with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
WASH ODA (2-year lag)	-0.0003885	0.0004699	-0.83	0.409
Population Density	-0.0002462	0.0013908	-0.18	0.860
Log [GDP per capita (US$2010)]	-0.6854881	0.2650368	-2.59	0.010**
Human Development Index	-0.0010412	0.0014144	-0.74	0.462
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.0480			
Between	0.0122			
Overall	0.0115			
Sigma_u (σ u)	3.3778966			
Sigma_e (σ e)	0.60710628			
rho	0.96870826			

Statistical significance: *<0.05, **<0.01

[Appendix E10] Fixed-effects model analysis of water coverage for total population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for total population	-24.93987	3.475734	-7.18	0.000**
WASH ODA (2-year lag)	0.0365	0.0945237	0.39	0.700
Population Density	0.5167311	0.2402009	2.15	0.032*
Log [GDP per capita (US$2010)]	-70.63516	57.57515	-1.23	0.220
Human Development Index	-0.8008894	0.2180419	-3.67	0.000**
Number of observations	621			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.2914			
Between	0.0583			
Overall	0.0754			
Sigma_u (σ u)	574.28179			
Sigma_e (σ e)	122.04363			
rho	0.95678881			

Statistical significance: *<0.05, **<0.01

[Appendix E11] Fixed-effects model analysis of water coverage for rural population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for rural population	-14.44876	2.142751	-6.74	0.000**
WASH ODA (2-year lag)	0.0365844	0.096882	0.38	0.706
Population Density	0.2683996	0.2892025	0.93	0.354
Log [GDP per capita (US$2010)]	75.79866	69.66339	1.09	0.277
Human Development Index	-1.780157	0.2911748	-6.11	0.000**
Number of observations	577			
Number of countries	43			

Prob> F	0.0000
R-sq	
Within	0.3077
Between	0.3308
Overall	0.3226
Sigma_u (σ u)	496.27449
Sigma_e (σ e)	124.89385
rho	0.94043811

Statistical significance: *<0.05, **<0.01

[Appendix E12] Fixed-effects model analysis of water coverage for urban population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Water coverage (%) for urban population	-0.7413016	3.907408	-0.19	0.850
WASH ODA (2-year lag)	0.0803688	0.1006746	0.80	0.425
Population Density	0.5484615	0.2982121	1.84	0.066
Log [GDP per capita (US$2010)]	-214.4864	57.25406	-3.75	0.000**
Human Development Index	-1.699786	0.306521	-5.55	0.000**
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.2481			
Between	0.0048			
Overall	0.0081			
Sigma_u (σ u)	803.54219			
Sigma_e (σ e)	130.03982			
rho	0.97447842			

Statistical significance: *<0.05, **<0.01

[Appendix E13] Fixed-effects model analysis of sanitation coverage for total population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for total population	-15.45749	2.606137	-5.93	0.000**
WASH ODA (2-year lag)	0.0483918	0.0958101	0.51	0.614
Population Density	1.044937	0.2526307	4.14	0.000**
Log [GDP per capita (US$2010)]	-104.8556	58.81041	-1.78	0.075
Human Development Index	-0.7892832	0.22199007	-3.56	0.000**
Number of observations	620			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.2712			
Between	0.1063			
Overall	0.1277			
Sigma_u (σ u)	596.63829			
Sigma_e (σ e)	123.76883			
rho	0.95874255			

Statistical significance: *<0.05, **<0.01

[Appendix E14] Fixed-effects model analysis of sanitation coverage for rural population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for rural population	-7.839224	1.80774	-4.34	0.000**
WASH ODA (2-year lag)	0.0667983	0.0990368	0.67	0.500
Population Density	0.7564695	0.296777	2.55	0.011**
Log [GDP per capita (US$2010)]	-78.32018	64.29596	-1.22	0.224
Human Development Index	-1.620186	0.2986534	-5.42	0.000**
Number of observations	577			

Number of countries	43
Prob> F	0.0000
R-sq	
Within	0.2740
Between	0.1500
Overall	0.1685
Sigma_u (σ u)	563.79792
Sigma_e (σ e)	127.89731
rho	0.95105787

Statistical significance: *<0.05, **<0.01

[Appendix E15] Fixed-effects model analysis of sanitation coverage for urban population (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Sanitation coverage (%) for urban population	-6.665682	3.246165	-2.05	0.041*
WASH ODA (2-year lag)	0.0710399	0.100361	0.71	0.479
Population Density	0.5124921	0.2973294	1.72	0.085
Log [GDP per capita (US$2010)]	-143.8364	66.5515	-2.16	0.031*
Human Development Index	-1.720665	0.3018193	-5.70	0.000**
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.2540			
Between	0.0464			
Overall	0.0559			
Sigma_u (σ u)	659.65826			
Sigma_e (σ e)	129.53001			
rho	0.96287448			

Statistical significance: *<0.05, **<0.01

[Appendix E16] Fixed-effects model analysis of proportion of total population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of total population practising open defecation (%)	50.90949	4.260566	11.95	0.000**
WASH ODA (2-year lag)	0.0645453	0.0882335	0.73	0.465
Population Density	1.1944	0.2287424	5.22	0.000**
Log [GDP per capita (US$2010)]	-132.4412	46.80608	-2.83	0.005**
Human Development Index	-0.6345629	0.2047505	-3.10	0.002**
Number of observations	615			
Number of countries	47			
Prob> F	0.0000			
R-sq				
Within	0.3860			
Between	0.1608			
Overall	0.1886			
Sigma_u (σ u)	653.35321			
Sigma_e (σ e)	114.09396			
rho	0.97040739			

Statistical significance: *<0.05, **<0.01

[Appendix E17] Fixed-effects model analysis of proportion of rural population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of rural population practising open defecation (%)	18.57221	2.335272	7.95	0.000**
WASH ODA (2-year lag)	0.1005567	0.0953546	1.05	0.292
Population Density	1.007776	0.2876979	3.50	0.000**
Log [GDP per capita (US$2010)]	-102.0396	56.26805	-1.81	0.070
Human Development Index	-1.445681	0.2889838	-5.00	0.000**

Number of observations	572
Number of countries	43
Prob> F	0.0000
R-sq	
Within	0.3329
Between	0.1451
Overall	0.1667
Sigma_u (σ u)	609.3913
Sigma_e (σ e)	123.16895
rho	0.9607516 7

Statistical significance: *<0.05, **<0.01

[Appendix E18] Fixed-effects model analysis of proportion of urban population practising open defecation (%) on the burden of diarrhoeal diseases (DALY rate) with control variables in UMICs

Variables	Coefficient	Standard Error	t	P > |t|
Proportion of urban population practising open defecation (%)	11.45379	9.282313	1.23	0.218
WASH ODA (2-year lag)	0.0853086	0.1005654	0.85	0.397
Population Density	0.553851	0.2974962	1.86	0.063
Log [GDP per capita (US$2010)]	-208.0446	57.04638	-3.65	0.000**
Human Development Index	-1.69671	0.3026805	-5.61	0.000**
Number of observations	578			
Number of countries	43			
Prob> F	0.0000			
R-sq				
Within	0.2502			
Between	0.0117			
Overall	0.0169			
Sigma_u (σ u)	780.79717			
Sigma_e (σ e)	129.85784			
rho	0.97308402			

Statistical significance: *<0.05, **<0.01

국문초록

공적개발원조(ODA)가 식수 및 위생 공급률과 설사 질병부담에 미치는 영향: 패널 데이터 분석

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연구배경 및 목적

세계보건기구와 유니세프의 보고서에 의하면 전 세계 인구 중 약 23억 명은 기본적인 식수 및 위생 시설이 없거나 시설이 있더라도 관리가 되지 않아 매년 오염된 식수로 인해 약 110만 명의 인구가 수인성 질환 관련으로 사망하고 있다. 부족한 식수 및 위생 시설은 생명과 직결되어 있으며 특히 오염된 식수와 부족한 위생시설로 얻게 되는 수인성 질환은 이에 대한 증상은 대부분 심각한 설사로 이어져, 전 세계 인구의 설사 질병 부담률은 약 1.5%이다. 충분한 식수위생시설의 공급은 건강한 삶을 위해 모든 국가들이 기본적으로 갖춰야 하는 공중보건학적 과제이며, 대부분의 수인성 관련 질환들의 (콜레라, 기니 벌레 병(Guinea worm disease), 장티푸스 및 이질(Dysentery) 등등) 증상은 설사이며, 식수위생 시설 개선만으로도 (예: 화장실 사용 후 손 씻을 수 있는 시설) 약 42% 설사 질병부담을 감소시킬 수 있다. 식수위생 시설 개선은 무엇보다 중요하다. 식수 및 위생 시설 개선만으로도 설사 관련 사망률을 크게

낮출 수 있을 뿐만 아니라, 이는 개인의 기본 교육수준 및 소득수준에도 영향을 미친다. 이러한 중요성 때문에, 1973년부터 2017까지 국제기구 및 공여국으로부터의 식수위생 분야에 투입되는 원조는 증가를 보였다. 하지만 증가된 원조(ODA gross disbursement) 금액만큼 식수위생 공급률과 설사 질병 부담률이 감소해왔는지를 함께 본 연구는 없었다. 따라서 본 연구는 수원국에 투입된 식수위생 관련 원조 금액이 식수위생 공급률 개선과 식수위생 관련 질병 부담 감소에 영향을 미쳤는지에 관한 것을 보는 것을 목적으로 한다.

연구방법

본 연구에서는 식수위생 투입 원조금액이 식수위생 공급률에 미치는 영향 및 식수위생 공급률이 설사 질병부담에 미치는 영향을 보기로 하였다. 식수위생 공급률의 효과는 장기 개발적이란 특성을 갖기에 패널 회귀 분석(고정 효과 모델)을 활용하여 주제에 대한 방향을 두 단계로 나누어 분석하였다. 첫 번째는 식수위생 원조금액이 식수위생 공급률 개선에 영향을 미쳤는가를 보고, 그다음 식수위생 공급률이 설사 질병부담 감소에도 최종적으로 영향을 미쳤는지를 살펴볼 것이다. 본 연구와 관련된 지표들의 자료는 세계보건기구 WHO Global Health Observatory (GHO) data를 사용하여 식수위생 공급률에 대한 인구지표를 총 세 가지로 분류하여 볼 것이다. 첫 번째 식수를 공급받을 수 있는 인구 비율 (%), 두 번째 개선된 위생 시설을 사용할 수 있는 인구 비율 (%) 세 번째, 노상 배변을 하는 인구 비율 (%). 각 식수위생 공급률 지표들은 전체 인구 비율 (%), 농촌지역에 거주하는 인구 비율 (%), 도시지역에 거주하는 인구 비율 (%) 나눠 개별적으로 분석하였다. 식수위생 원조 금액 관련 자료는 경제협력개발기구 (OECD-CRS)에서 얻었으며, 설사 질병부담 자료는 보건 계측·평가연구소 (Institute for Health

Metrics and Evaluation)에서 얻었다. 설사 질병부담 지표로는 DALY (Disability-Adjusted Life Years) 비율 (인구 100,000 명당)을 사용하였다.

연구결과

결측치가 절반 이상인 국가들을 제외 후 총 115개 국가 대상으로 분석한 결과 식수위생에 투입된 원조가 농촌에 거주하는 인구 비율 중 노상 배변을 하는 인구 (%)를 감소시키는 데에만 유의한 영향을 미치는 것으로 나타났다. 다시 수원국들을 소득별로 나눠서 분석을 시행했을 때는 식수위생 원조의 영향이 식수위생 공급률 개선에 더 유의한 영향을 미치는 것으로 나타났다. 저소득 국가들 중 전체, 농촌, 도시에 거주하는 인구 (%) 모두 식수개선에 유의한 영향을 미치는 것으로 나왔으며 (0.01 유의수준); 위생시설 같은 경우 도시지역에 거주하는 인구 대상만 유의하다고 나왔다. 중저소득 국가들 같은 경우 원조가 농촌지역에 거주하는 인구의 식수개선 및 전체, 농촌인구 위생시설 개선과 노상 배변 감소에 영향을 미쳤다고 나왔다. 중상위 소득 국가들 대상으로 한 분석에서는 식수위생 원조가 식수위생 공급률 개선에 유의한 영향을 미치지 않는 것으로 나타났다. 두 번째 식수위생 공급률이 설사 질병부담에 미치는 영향을 분석한 결과, 전체 115 국가들 대상으로 보았을 때, 식수위생 공급률이 설사 질병부담을 감소시키는 데 유의한 영향이 있다고 나왔다. 소득별로 나눠서 분석한 결과, 식수위생 공급률이 설사 질병부담 감소에 반면에 저소득 국가들 사이에서 식수위생 공급률이 설사 질병부담 감소에 미치는 영향이 가장 적은 것으로 나왔다.

결론

본 연구결과 저소득 국가와 중저소득 국가에는 원조 금액이 증가할수록 식수 및 위생시설에 대한 증가도 함께 이뤄졌다. 두 번째 식수 및 위생 공급률이 설사 질병부담 분석 결과는 국가 소득이 높은 국가들일수록 설사 질병 부담률도 낮아진다고 나왔으며, 설사 질병부담이 중상위 소득 국가들이 사이에서 가장 유의하게 감소했다. 또한, 2010년에 식수개선에 대한 MDG가 이미 달성되었음에도 불구하고 여전히 비교적 많은 원조가 위생시설 개선보다 식수 공급률로 배정되고 있다. 주된 이유 중 하나는 지방 정부의 정치적 참여가 부족하며 식수시설 설계가 위생시설 보다 비교적 눈에 띄는 결과물을 제시하는 경향이 있기 때문이다. 위생 시설 같은 경우는 시설에 대한 관리가 중요한데 이는 꾸준한 인력 관리로 유지해야 된다는 점에서 식수시설 설계 (우물 짓기 등등) 보다 지속적이어야 되고 수치화 시킬 수 있는 원조의 결과물을 단기적으로 낼 수 없다. 위생시설 개선에 대한 각 수원국들의 국내 정책의 우선순위가 아닌 경우가 많으며 여전히 많이 미흡한 점이 있다. 본 연구의 함의는 수십 년간 꾸준히 투입되어 온 식수위생 원조가 과연 그에 따른 목표 달성에 영향을 미쳤는지 분석함으로써 기존에 존재하고 있는 다양한 식수위생 개선 프로그램 및 원조 금액이 각 식수위생 부문에 투입되는 방향성 및 접근 방식에 대해 시사점을 제시한다.

주요어: 식수위생, 설사 질병부담, 공적개발원조, 원조, 패널 분석, 고정효과

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