Impact of Water Supply and Sanitation on Diarrhoea Prevalence Among Children Under Five in Papua New Guinea: Evidence from National Demographic and Health Survey

Kingtau Mambon

School of Business and Public Policy
University of Papua New Guinea

ANU-UPNG Seminar
2026

Motivation

- Globally, diarrhoeal disease kills about **443,832 children under five each year**, thats roughly **51 children every hour** (WHO, 2024).
- In Papua New Guinea, diarrhoea remains a major child health burden.
  - **18%** of children under five experienced diarrhoea in the two weeks before the survey (PNG DHS, 2019).
- This is largely a **preventable** illness, yet inadequate water and sanitation remain persistent development constraints.
  - Only **41%** of the population has access to basic drinking water, and just **19%** has access to basic sanitation (WHO, 2021).

Motivation

- Globally, diarrhoeal disease kills about **443,832 children under five each year**, thats roughly **51 children every hour** (WHO, 2024).
- In Papua New Guinea, diarrhoea remains a major child health burden.
  - **18%** of children under five experienced diarrhoea in the two weeks before the survey (PNG DHS, 2019).
- This is largely a **preventable** illness, yet inadequate water and sanitation remain persistent development constraints.
  - Only **41%** of the population has access to basic drinking water, and just **19%** has access to basic sanitation (WHO, 2021).

- **Research Question**
  - *What is the impact of access to improved water and sanitation on diarrhoea prevalence among children under five in Papua New Guinea?*

Background: WSS interrupts diarrhoea transmission

- Improvements in water supply and sanitation (WSS) are a core public-health mechanism for interrupting faecal–oral transmission from environmental sources to humans (Yantio, 2015).
- WSS reduces diarrhoeal disease through three interrelated channels (Waddington et al., 2009):
  - **Improved water**: safer drinking water and better hygiene practices.
  - **Improved sanitation**:less environmental contamination and reduced pathogen exposure.
  - **Combined interventions**: potentially stronger household and community effects.

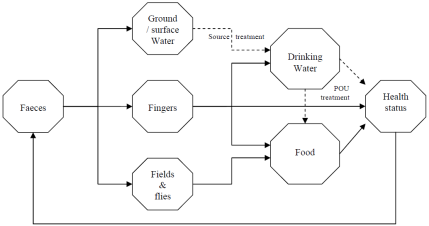


Figure 1: Improved Water as Barrier to Transmission

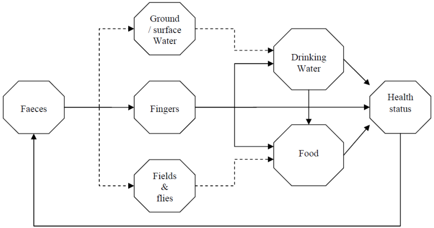


Figure 2: Improved Sanitation as Barrier to Transmission

Background: WSS in Papua New Guinea (1)

- PNG's WSS sector evolve through **two parrallel streams.**

State-led interventions

- 1975: Independence; weaker enforcement and fragmented responsibility (Humanitarian, 2014).
- 1982: National Water Supply and Sewerage Act enacted (NWSSB) (Water PNG, 2026).
- 1986: Amendment establishes the National Water Supply and Sewerage Board (NWSSB) (Water PNG, 2026).
- 1996: Enactment of National Capital District Water Supply and Sanitation Act 1996 (GoPNG, 2020)
- 2016: Enactment of National Water Supply and Sanitation Act 2016 (GoPNG, 2016)
- 2020: Enactment of National Water Supply and Sanitation Act (Amendment) 2020 (GoPNG, 2020)

Non-state interventions

- 1980s: ADRA PNG expands rainwater harvesting and boreholes (Yorio, 2020).
- 2008: Oxfam introduces CLTS.
- 2010–2012: EU RWSSP scales CLTS; 400+ communities mobilised and $\sim$ 20,000 latrines constructed (Dutton et al., 2011).
- 2015–2016: World Vision pilots Healthy Island Concepts; increases latrines and hygiene adoption (Yeung & Selep, 2016).
- 2023-2024; DFAT (AusAID) funded Projects like **Water for Women** to extend WaSH servies. (Water for Women Fund, 2025).

Back Ground: WSS in Papua New Guinea (2)

Policy Frameworks

- PNG lacked a unified national coordination framework until the **National WaSH Policy 2015–2030** (GoPNG, 2015).
- The policy proposes a National WaSH Authority and sets targets (e.g., 70% rural and 95% urban access to safe water by 2030) (GoPNG, 2015).
- In 2019, District WaSH Committees (DWC) were established in districts for effective implementation of National WaSH Policy–First piloted in 12 Districts (Walton et al, 2025)
- Yet structural constraints such as geographic fragmentation, financing gaps, and coordination challenges continues to drive large disparities in access.
- These institutional dynamics generate substantial heterogeneity in WSS access across regions, wealth groups, and rural–urban settings. This further motivates the causal estimate of WSS impacts on child diarrhoea.

Data and variables

Data source

- 2016-2018 Papua New Guinea Demographic and Health Survey (PNG DHS)
- Kids Recode (KR) file
- Unit of observation: child under five
- Full sample: **7,670** children

Outcome Variable

- Whether the child had diarrhoea in the two weeks prior to the interviews (binary)

Treatment variables

- Access to improved drinking water
- Access to improved sanitation
- Acces to both improved water and sanitation (Combined WSS)

Key covariates: Child's Age (in months), Child's Gender, Maternal Education, Household Wealth Index, Household Residence, Household Region

(1) Summary Statistics: Improved Water Sample

Table 1: Panel A: Improved Water Sample (N = 4,763)

Variable	Obs	Mean	Std. Dev.	Min	Max
Child had diarrhea in last 2 weeks	4,763	0.138	0.346	0	1
Access to improved drinking water	4,763	0.500	0.500	0	1
Child age in months	4,763	28.647	17.087	0	59
Child is male	4,763	0.535	0.498	0	1
Mother's education	4,763	1.159	0.639	0	3
Wealth index	4,763	3.397	0.971	1	5
Rural residence	4,763	0.904	0.294	0	1
Region	4,763	2.598	1.199	1	4

(2) Summary Statistics: Improved Sanitation Sample

Table 2: Panel B: Improved Sanitation Sample (N = 3,798)

Variable	Obs	Mean	Std. Dev.	Min	Max
Child had diarrhea in last 2 weeks	3,798	0.147	0.354	0	1
Access to improved sanitation	3,798	0.407	0.491	0	1
Child age in months	3,798	28.734	17.105	0	59
Child is male	3,798	0.543	0.498	0	1
Mother's education	3,798	1.213	0.684	0	3
Wealth index	3,798	3.620	0.940	1	5
Rural residence	3,798	0.843	0.364	0	1
Region	3,798	2.449	1.170	1	4

(3) Summary Statistics: Improved WSS Sample

Table 3: Panel C: Improved WSS Sample (N = 1,379)

Variable	Obs	Mean	Std. Dev.	Min	Max
Child had diarrhea in last 2 weeks	1,379	0.145	0.352	0	1
Access to improved WSS	1,379	0.449	0.498	0	1
Child age in months	1,379	29.197	16.926	0	59
Child is male	1,379	0.555	0.497	0	1
Mother's education	1,379	1.187	0.622	0	3
Wealth index	1,379	3.751	0.621	2	5
Rural residence	1,379	0.875	0.331	0	1
Region	1,379	2.551	1.192	1	4

[1] Level 1 of the wealth index was lost due to the matching exercise.

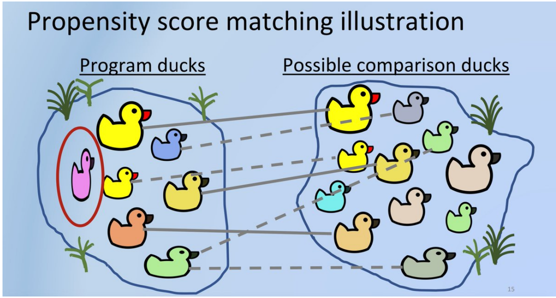
Empirical Strategy: Identifying a Credible Effect

- Because the DHS is observational, I use **Propensity Score Matching (PSM)** technique developed by Rosenbaum and Rubin (1983) to approximate a quasi-experimental comparision.
- I estimate the Average Treatment Effect on the Treated (ATT) for three binary treatments:
  - T^W: access to improved water.
  - T^S: access to improved sanitation.
  - T^{WSS} : access to both improved water and sanitation
- The outcome is define as,

$$Y = \begin{cases} 1 & \text{if child had diarrhoea in the past 2 weeks,} \\ 0 & \text{otherwise.} \end{cases}$$

Empirical Strategy: Identifying a Credible Effect

- Think of the children with improved water or sanitation as the **program ducks** on the left pond.
- The challenge is that these ducks are not randomly selected, so I cannot simply compare them with all other ducks.
- Instead, Propensity Score Matching (PSM) finds **similar-looking comparison ducks** in the right pond based on observed household and child characteristics.
- In other words, each treated child is matched with untreated children who had a similar probability of receiving improved water, sanitation, or both.



Duck illustration of propensity score matching: treated ducks are matched to observationally similar comparison ducks.

Empirical Strategy: Potential Outcome Framework

Potential outcomes framework (Rubin-Causal Model)

- Let $Y(1)$ denote the diarrhoea outcome if a household has improved WSS.
- Let $Y(0)$ denote the diarrhoea outcome if a household does not have improved WSS.

Key assumptions

1. **Conditional Independence (CIA)**

$$\big(Y(1),\, Y(0)\big) \perp T \mid X$$

Once I condition on observables X, treatment assignment is assumed as-good-as-random.

2. **Overlap / Common Support**

$$0 < \Pr(T = 1 \mid X) < 1$$

Treated units must have comparable untreated units.

Target parameter

$$\mathrm{ATT} = \mathbb{E}[Y(1) - Y(0) \mid T = 1]$$

Empirical Strategy: Implementation

Propensity Score Matching following Guo and Fraser (2014)

Step 1. Estimate treatment probabilities.

$$\hat{p}(X) = \Pr(T = 1 \mid X) = \frac{\exp(\alpha + X'\beta)}{1 + \exp(\alpha + X'\beta)}.$$

Covariates in X

- Child's Age (in months)
- Child's Gender
- Mother's Education
- Household Wealth
- Urban/rural residence
- Region's fixed effects.

Empirical Strategy: Implementation

Step 2. Match treated to similar controls.

- Nearest-neighbour (1:1, without replacement) — *main estimator*.
- Kernel matching (Epanechnikov kernel) — robustness check.
- Radius/Caliper matching— robustness check

Common support

- Drop observations with extreme scores
- Ensures matched comparison is made in regions of covariate overlap.

Estimation

- Compute $\widehat{ATT}$ as the average difference in Y between treated and matched controls.

Empirical Strategy: Balance Checks

Step 3. Assess covariate balance before and after matching.

- **Standardized Mean Differences (SMD)**

$$\text{SMD}(X) = \frac{\bar{X}_T - \bar{X}_C}{s_X},$$

  where s_X is pooled SD.

- Target: $|\text{SMD}(X)| < 0.1$ for all covariates after matching.
- Compare variance ratios between treated and control.
- Inspect distribution of propensity scores graphically.

Quality Rule: Proceed only if all covariates balanced and overlap is sufficient; otherwise refine specification or tighten caliper.

Step 4.Robustness and Heterogeneity

Alternative matchers.

- Compare ATT estimates across alternative matching algorithms (Kernel and Radius methods).

Heterogeneous effects.

- Subgroup analysis by urban vs rural households.
- Check whether infrastructure and behavioural contexts mediate WSS impacts differently.

Results and Discussion

Table 4: Summary Statistics by Treatment Group

Panel	Group	Obs	Mean	Std. Dev.	Min	Max
A: Water	Treatment (Improved Water)	2381	0.144	0.351	0	1
	Control (Unimproved Water)	2382	0.134	0.341	0	1
	Total	4763				
B: Sanitation	Treatment (Improved Sanitation)	1547	0.135	0.342	0	1
	Control (Unimproved Sanitation)	2251	0.155	0.362	0	1
	Total	3798				
C: WSS	Treatment (Improved WSS)	619	0.137	0.344	0	1
	Control (Unimproved WSS)	760	0.151	0.359	0	1
	Total	1379				

Results and Discussion

Table 5: ATT Estimates (Nearest Neighbor Matching)

Intervention	Treated Mean	Control Mean	ATT	S.E.
Access to Improved Water	0.144	0.181	-0.038**	0.017
Access to Improved Sanitation	0.135	0.221	-0.086***	0.020
Access to Improved WSS	0.137	0.230	-0.082**	0.034

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

- Improved water reduces diarrhea prevalence by **3.8 percentage points.**
- Improved sanitation reduces diarrhea prevalance by **8.6 percentage points**.
- Combined WSS reduces diarrhea by **8.2 percentage points**
- **Improved sanitation delivers the largest effects.**

Results and Discussion

Access to Improved Water

- Treated mean = 14.4% of children had diarrhoea.
- Control mean = 18.1% of children had diarrhoea.
- ATT = –3.8 percentage points.
- If children with improved water had not gotten it, their diarrhoea rate would have been 3.8% higher on average.

Access to Improved Sanitation

- ATT = –8.6 percentage points.
- Children with improved sanitation had about 9% fewer diarrhoea cases than they would have had without sanitation.

Combined WSS (Water + Sanitation)

- ATT = –8.2 percentage points.
- Children with both improvements had about 8% fewer diarrhoea cases compared to if they didn't have access.

Robustness Checks

- Covariate balance improved substantially post-matching.

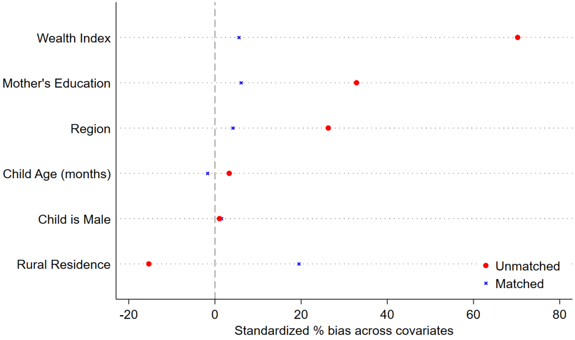


Figure 3: Improved Water

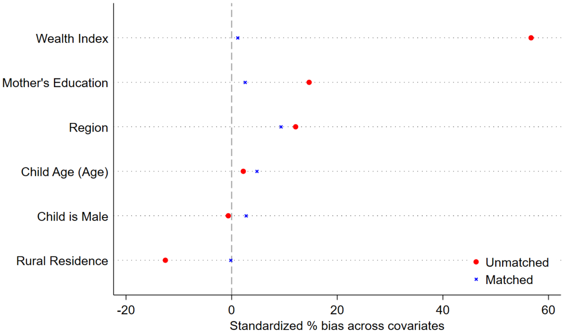


Figure 4: Improved Sanitation

Robustness Checks

- Covariate balance improved substantially post-matching.

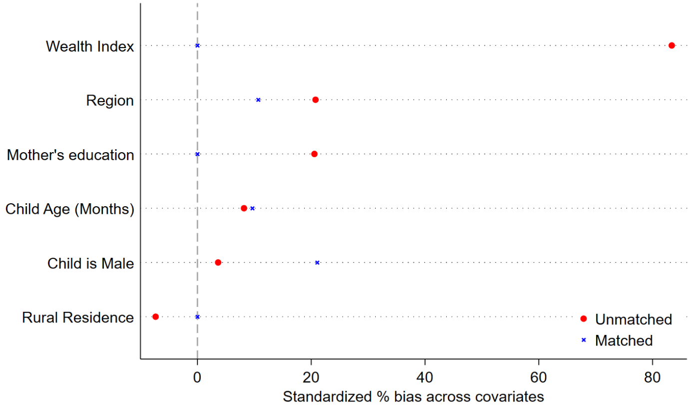


Figure 5: Improved WSS

Robustness Checks

- Common support satisfied (overlap of treatment and control).

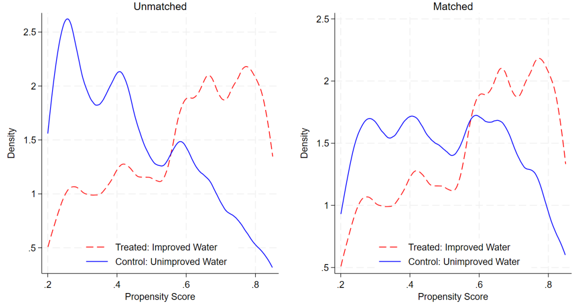


Figure 6: Improved Water

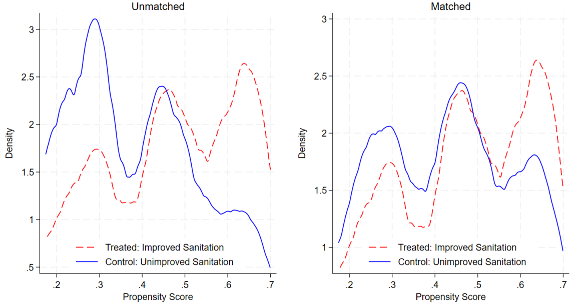


Figure 7: Improved Sanitation

Robustness Checks

- Common support satisfied (overlap of treatment and control).

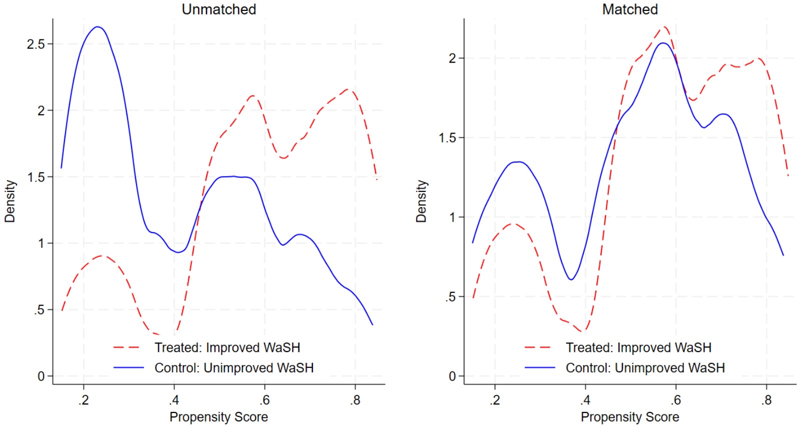


Figure 8: Improved WSS

Robustness Checks

- Alternative algorithms (kernel, radius) consistent with main results.

Table 6: ATT Estimates Across Matching Methods

Intervention	Matching Method	Treated Mean	Control Mean	ATT	S.E.
Improved Water	Kernel Matching	0.1436	0.1580	-0.0144	0.0119
	Radius Matching (0.1)	0.1436	0.1509	-0.0072	0.0115
Improved Sanitation	Kernel Matching	0.1351	0.1821	-0.0473***	0.0126
	Radius Matching (0.1)	0.1351	0.1814	-0.0463***	0.0124
Improved WSS	Kernel Matching	0.1373	0.1845	-0.0472**	0.0233
	Radius Matching (0.1)	0.1373	0.1834	-0.0460**	0.0224

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Heterogeneity Analysis

Table 7: Heterogeneous Effects by Area Type

Intervention	Area Type	Treated Mean	Control Mean	ATT	S.E.
Improved Water	Rural	0.1295	0.1552	-0.0257	0.0174
	Urban	0.2491	0.3274	-0.0783	0.0576
Improved Sanitation	Rural	0.1197	0.2005	-0.0808***	0.0205
	Urban	0.2035	0.3123	-0.1088*	0.0605
Improved WSS	Rural	0.1257	0.2139	-0.0882**	0.0354
	Urban	0.2093	0.2674	-0.0581	0.1154

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

- The most robust gains appear in **rural sanitation and rural combined WSS.**
- This is policy-relevant because standard infrastructure in rural PNG are mostly lacking.

Conclusion and Policy Implications

- This paper provides first national quasi-causal evidence on WSS and child health in PNG.
- Using country's representative dataset, the paper found that though improve water matters, but the strongest and most consistent effects comes from **improved sanitation**
- Broader Lesson
  - To reduce child diarrhoea in PNG, sanitation cannot be treated as the secondary intervention.
- Policy Implications
  - **First**, prioritize sanitation expansion, especially in rural areas where open defecation and exposure risks remain high.
  - **Second**,water investments should be paired with safe storage, household handling, and hygiene behaviour change.
  - **Third**, integrated WSS programs should focus on implementation quality and sequencing, not infrastructure role out alone.
  - **Finally**,the results support targeting limited public funds toward interventions with the largest expected child health return.

Limitations and Further Research

- PSM can address selection bias arising from observed characteristics, but it cannot fully eliminate bias from unobserved confounding factors.
- Diarrhoea is self-reported in the DHS, so the measure may be subject to recall error.
- Although the DHS records household access to water and sanitation infrastructure, it does not always capture the reliability, quality, or sustained use of those services.
- Further Research would be to;
  - combine DHS household data with geospatial layers such as distance to the nearest health facility or water source, service-quality measures such as whether the water source functions year-round
  - Investigating impact of behavioral change programs on improved WSS uptakes.

Thankyou Everyone

Questions, Comments, Suggestions, and Constructive Critiques are welcome.

References

Dutton, P., Blackett, I., & Weitz, A. (2011). *Could Papua New Guinea meet its MDG for rural sanitation? Findings on a new approach to a neglected question*. Water and Sanitation Program (WSP), World Bank.

Government of Papua New Guinea (GoPNG). (1986). *National Water Supply and Sewerage Act 1986*. No. 68 of 1986. Certified by the Office of Legislative Counsel, Papua New Guinea. https://www.paclii.org/pg/legis/consol_act/nwsasa1986452/

Government of Papua New Guinea (GoPNG). (1996). *The 1996–2000 National Health Plan in Papua New Guinea: Budget contingencies, implementation plans, and final recommendations*. National Department of Health, Papua New Guinea.

Government of Papua New Guinea (GoPNG). (2015). *Papua New Guinea National Water, Sanitation and Hygiene (WASH) Policy 2015–2030*. Department of National Planning and Monitoring.

Government of Papua New Guinea (GoPNG). (2016). *National Water Supply and Sanitation Act 2016*. Act No. 52 of 2016. Papua New Guinea.

References (Con't)

Government of Papua New Guinea (GoPNG). (2020). *National Water Supply and Sanitation (Amendment) Act 2020*. Act No. 18 of 2020. Papua New Guinea.

Greenhill, A. R., Guwada, C., Siba, V., Michael, A., Yoannes, M., Wawarie, Y., Ford, R., Siba, P. M., & Horwood, P. F. (2014). *Antibiotic resistant Shigella is a major cause of diarrhoea in the Highlands of Papua New Guinea*. Journal of Infection in Developing Countries, 8(11), 1391–1397. https://doi.org/10.3855/jidc.4396

Guo, S., & Fraser, M. W. (2014). *Propensity Score Analysis: Statistical Methods and Applications*. SAGE Publications.

National Statistical Office (NSO) [Papua New Guinea] and ICF. (2019). *Papua New Guinea Demographic and Health Survey 2016–18: Final Report*. Port Moresby, Papua New Guinea, and Rockville, Maryland, USA: NSO and ICF. Available at: https://www.dhsprogram.com/pubs/pdf/FR364/FR364.pdf.

RWSSP & International, O. (2011). *Community-led total sanitation in PNG*. Programme Brief. EU-RWSSP Coverage.

References (Con't)

The New Humanitarian. (2014). *Papua New Guinea battles open defecation*. Available at: https://reliefweb.int/report/papua-new-guinea/papua-new-guinea-battles-open-defecation.

Waddington, H., *et al.* (2009). *Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries*. International Initiative for Impact Evaluation (3ie).

Walton, G. W., Fanaian, S., Davis, T., Wanga, S., Yeung, S., Wickham, T., Rua, K., Kanini, D., Rovou, S., & Maris, E. (2025). *Improving water governance in PNG*. Final Report FR2025-002, Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia.

World Health Organisation (WHO). (2021). *Progress on household drinking water, sanitation and hygiene 2000–2020*. Accessed May 2025.

World Health Organization (WHO). (2024). *Diarrhoeal disease*. Diarrhoeal disease – Fact sheet. https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

Water for Women Fund. (2025). *Water for Women Fund*. The Australian Government's flagship WASH program. https://www.waterforwomenfund.org/en/index.aspx

Yorio, D. (2020). *ADRA Papua New Guinea*. Encyclopedia of Seventh-day Adventists. Accessed July 4, 2025.