The Five-Year Evaluation of Sanitation Improvement In Households Across Rural Zambia: Two Consecutive Cross-Sectional Surveys

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Abstract

Background: In Zambian communities poor water, sanitation, and hygiene conditions give way to severe health concerns (UNICEF, n.d.).

Methods: The research question proposed was: did the Zambia Sanitation & Hygiene Program (ZSHP) increase the proportion of households that had improved sanitation? The primary exposure of interest was involvement in ZSHP and the primary outcome of interest was improved water source. Data was collected from two consecutive cross-sectional surveys given to households in eight different rural regions in Zambia. A test of equal proportions along with a multivariable logistic regression was performed to further analyze results to look for an association between ZSHP involvement and improved water source.

Results: Households in the ZSHP initiation had greater proportions of an improved water source than households that were not in the ZSHP (Difference of proportions = 0.087, (0.027, 0.15), chi-square (1 df) = 8.05, p = 0.0046). The null hypothesis that a proportion of people who had an improved water source was the same in households that took part in ZSHP and those who did not was rejected using the test of equal proportions. The difference of proportions between households in ZSHP with an improved water source compared to households not in ZSHP was statistically significant.

Conclusion: ZSHP involvement was associated with improved water sources. Overall, this study raises awareness on the importance of public health initiatives and their ability to improve health conditions across different communities facing challenges related to social determinants of health.

Background

The United Nations Children's Fund (UNICEF) funded a study from 2012 to 2014 in 8 rural provinces in Zambia to assess the efficacy of the Zambia Sanitation and Hygiene Program (ZSHP). The process of this secondary analysis was to use data generated by UNICEF from two cross-sectional surveys to investigate the association between household involvement in ZHSP and improved sanitation and water sources. We hypothesized that involvement in the ZSHP would result in a greater proportion of households with improved water sources.

Methods

The ZSHP study was a series of two consecutive cross-sectional surveys given to 1,170 households. Study participants took one survey prior to ZHSP initiation and the other three years after initiation. Participants were from eight different rural regions of Zambia (Central, Eastern, Luapula, Muchinga, Northern, North Western, Southern, Western). The study examined a variety of variables relating to household resources (wealth, toilet type) as well as demographic factors (head of household occupation, education level, marital status) from the final survey.

We calculated a prevalence ratio, difference of proportions and 95% confidence interval, and a multivariable logistic regression analysis to obtain an adjusted odds ratio and 95% confidence interval to compare improved sanitation between households that participated in ZHSP and those that did not.

Results

By the program's end, 610 households had an improved water source, while 560 did not. Table 1 shows the proportion of households with improved water sources based on program involvement. Figure 1 shows Latrines with cement slabs had the highest percentage of improved water sources for all toilet types (491 or 80.49%). Figure 2 demonstrates the wealthiest

households had the highest percentage of improved water sources (159 or 26.07%), while the middle 20th percentile had the highest percentage of unimproved sources (142 or 25.36%). Households in the ZSHP initiation had significantly greater proportions of an improved water source than households that were not in the ZSHP (Difference of proportions = 0.087, (0.027, 0.15), chi-square (1 df) = 8.05, p = 0.0046) (Table 2).

A multivariable logistic regression was conducted to analyze the dichotomous outcome of households with improved water sources. Independent variables included ZSHP participation (dichotomous; reference: no participation), household wealth index (5 levels; reference: lowest 20%), and toilet type (4 types; reference: flush toilet). Odds ratios were calculated by exponentiating the model (Table 3). Households that did not participate in ZSHP initiation had 0.79 (0.62, 1.02) times the odds of an improved water source compared to households that were in ZSHP initiation after adjusting for wealth and toilet type, indicating a slightly lower probability.

Discussion

Overall, it was supported that households in ZSHP had a higher prevalence (1.19) of improved water sources when compared to households that were not involved in ZSHP (see Table 1). Furthermore, the odds of improved water sources was lower for households not in ZSHP compared to households involved in ZSHP (see Table 3).

There is a potential for selection bias in the form of missing data. This water and sanitation study was a cross-sectional study that consisted of sending two surveys to participants, one at the start of the study, before ZSHP implementation, and one three years later after ZSHP. The dataset used for the analysis was a subset of the final data set with limited variables and only included data from the second survey. This could potentially cause data to be missed and

unincorporated, excluding variables and values that may be important in the analysis. For this study in particular, this bias would interfere with the association between program initiation (ZSHP involvement) and improved water sources and toilet facilities (which could be towards or away from the null of no association depending upon the type of missing data).

Additionally, results show that there may be potential confounding. One source of confounding could be wealth. This source may cause confounding because there is an uneven distribution in results (improved or not improved water source) among the different wealth categories (1-5, with 1=poorest20%tile and 5=wealthiest20%tile). This variable of wealth may be a confounding factor because it can impact the association between ZSHP and improved water sources, therefore distorting the true association. Wealth could also be associated with both the exposure (being involved in the ZSHP program) and the outcome (improved water sources) and it is not a causal intermediate in this relationship. Due to differences that wealth may create for households across Zambia, wealth could be confounding in the relationship between ZSHP and improved water sources.

This study contained limitations that may impact results and generalizability. One limitation of this cross-sectional study design is temporal bias. Data was collected at a single point in time after the ZSHP was initiated, making it difficult to establish causality within the program. Another limitation is that the program did not achieve 100% coverage across all rural areas, as some households or regions were missed. This limitation could have reduced the program's effectiveness. These results are generalizable to rural communities with similar living conditions to those of Zambian households in the study. They may not be generalization to urban areas, locations with a wide variety of sanitation levels, or wealth discrepancies. The findings

and results obtained from this data set and the study could help design programs for other populations facing similar issues of sanitation and hygiene.

Conclusion

In conclusion, the Zambia Sanitation and Hygiene Program was associated with improved water sources in rural households. Households participating in ZSHP depicted a higher prevalence of improved water sources. The results were statistically significant, as indicated by the test statistic of 8.05 and a p-value of 0.0046. This study highlights how sanitation and hygiene issues can be addressed through focused public health interventions, despite these limitations. Programs like ZSHP can serve as a template to improve health outcomes in underserved areas. Future programs should prioritize stronger research methods, wider coverage, and equitable access to ensure a positive impact and generalizability in addressing sanitation and hygiene challenges.

Table 1 - Proportion of Households with Improved Water Sources Based on Program Involvement.

	Improved Water Source	Unimproved Water Source	
ZSHP, Yes	401	322	723
ZSHP, No	209	238	447
Totals	610	560	1,170

Table 2 - Association Between ZSHP and Access to an Improved Water Source

	Water Source Improvement		
ZSHP Initiation Participation	**No**	**Yes**	**Total**
No	238(53.2%)	209(46.8%)	**447**
Yes	322(44.5%)	401 (55.5%)	**723**
	560	610	**1,170**
Test Statistic		8.05	
p-value		0.0046	
95% CI for Difference in Proportions		(0.027, 0.15)	

Table 3 - Multivariable Logistic Regression

Coefficients	**Odds Ratio**	**95% Confidence Interval**
ZSHP Initiation (No)	0.79	(0.62, 1.02)
Second20%tile wealth	1.21	(0.82, 1.77)
Third20%tile wealth	1.25	(0.87, 1.79)
Fourth20%tile wealth	2.06	(1.41, 3.02)
Wealthiest20%tile	2.31	(1.57, 3.41)
Latrine with cement slab	2.66 x 10^-7	(NA, 14.72)

Latrine without cement slab	2.04 x 10^-7	(NA, 9.69)
No toilet	1.88 x 10^-7	(NA, 9.92)

Figure 1 - Water Source Improvement by Type of Toilet

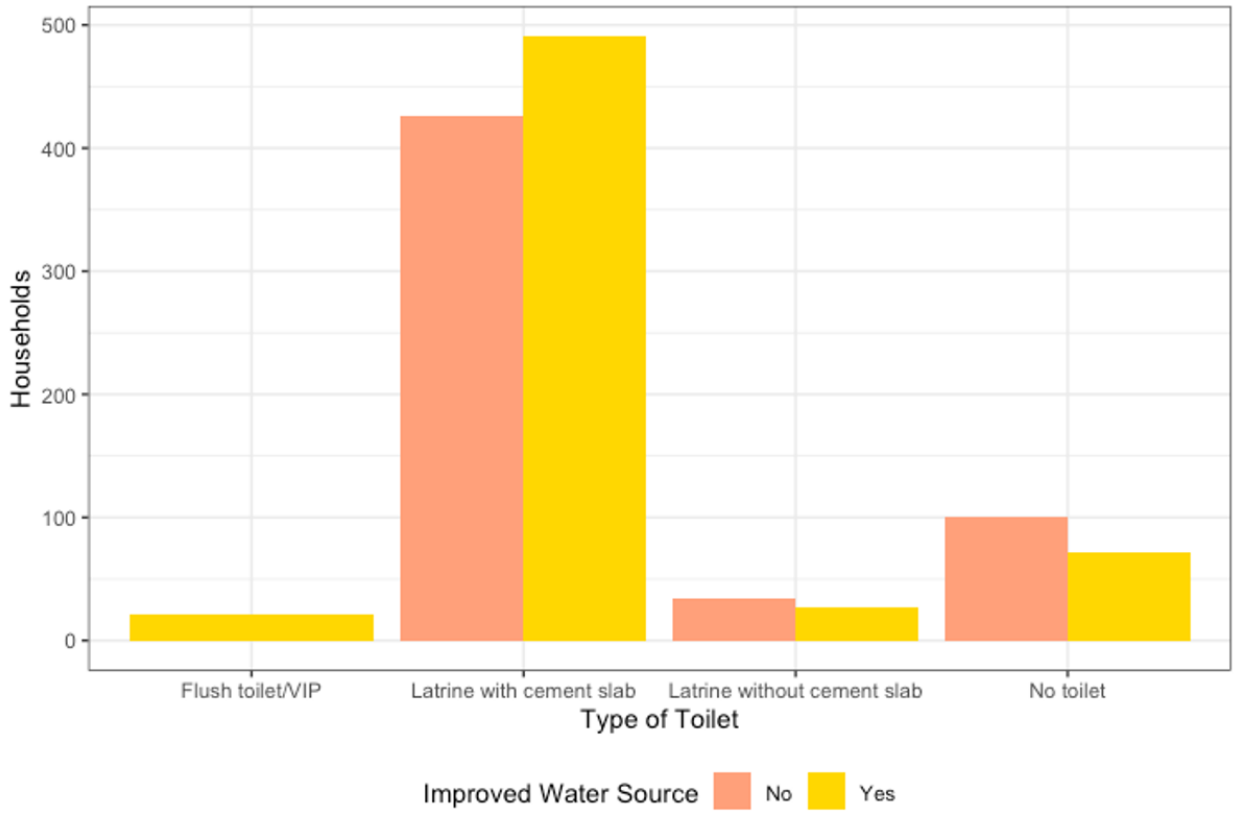
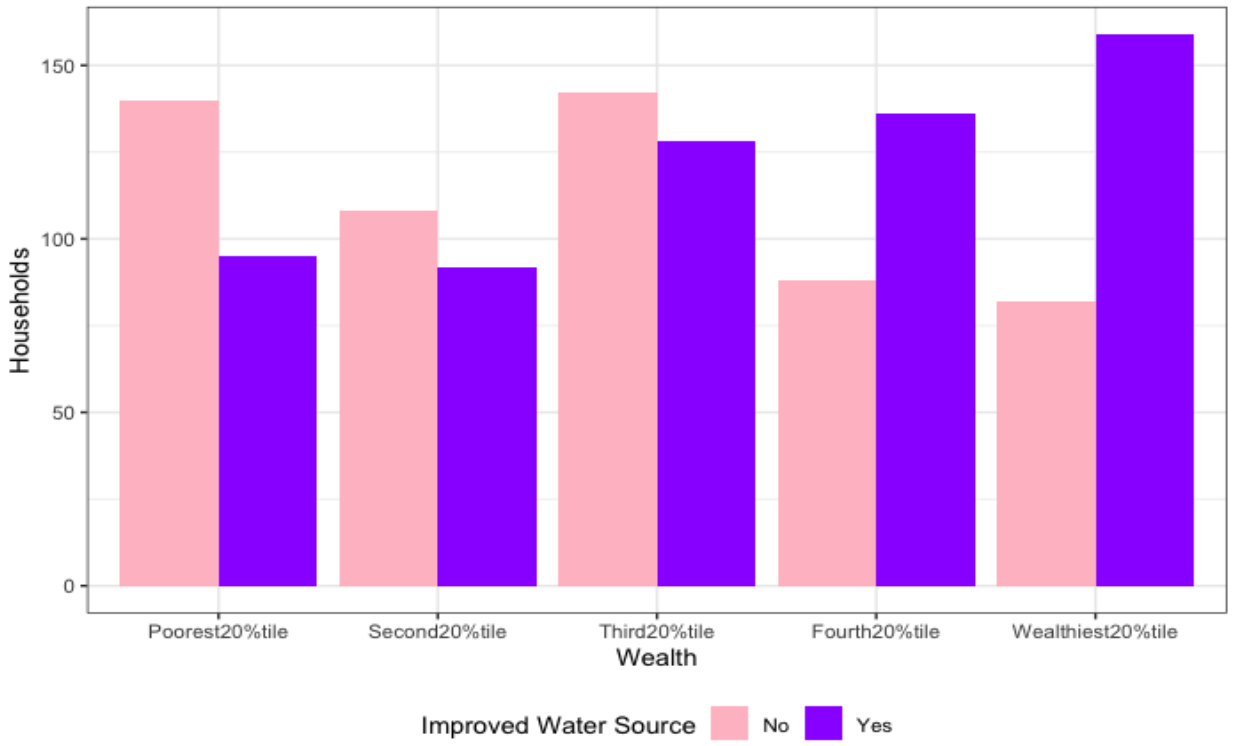


Figure 2 - Water Source Improvement by Wealth Index



References

UNICEF. (n.d.). *Water, sanitation, and hygiene.* UNICEF. https://www.unicef.org/zambia/water-sanitation-and-hygiene#:~:text=Summary%20of%20Water%20and%20Sanitation%20Situation%20in%20Zambia&text=17%25%20of%20schools%20lack%20basic,to%20a%20basic%20water%20service

R CODE

```
library(ggplot2)
library(dplyr)

PC <- read.csv(file = "WASH_data.csv", header = TRUE)
View(PC)
mean(PC$age_hh)
sd(PC$age_hh)

table(PC$improved_water_source)

PC$improved_water_source <- ifelse(PC$improved_water_source == 1, "Yes",
                                   ifelse(PC$improved_water_source == 2, "No",
PC$improved_water_source))
table(PC$improved_water_source)

table(PC$marital_status_hh)
table(PC$ZSHP_initiation)
table(PC$ZSHP_initiation, PC$improved_water_source)
table(PC$improved_water_source)
```

```
table(PC$improved_water_source, PC$type_toilet)
prop.table(table(PC$improved_water_source, PC$type_toilet), 1)

table(PC$improved_water_source, PC$wealth)
prop.table(table(PC$improved_water_source, PC$wealth), 1)

table(PC$improved_water_source, PC$age_hh)
prop.table(table(PC$improved_water_source, PC$age_hh))

table(PC$improved_water_source, PC$ZSHP_initiation)
prop.table(table(PC$improved_water_source, PC$ZSHP_initiation), 1)

table(PC$improved_water_source, PC$water_source)
prop.table(table(PC$improved_water_source, PC$water_source), 1)

table(PC$improved_water_source)

data.class(PC$improved_water_source)

PC$improved_water_source <- as.factor(PC$improved_water_source)
data.class(PC$type_toilet)
PC$type_toilet <- as.factor(PC$type_toilet)

attach(PC)

water_source <- as.factor(water_source)
type_toilet <- as.factor(type_toilet)

Toilet_type.ggp <- ggplot(PC, aes(x = type_toilet, fill = improved_water_source)) +
  geom_bar(position = "dodge") +
  scale_fill_manual(values = c("lightsalmon", "gold")) +
  scale_x_discrete(labels = c("Flush toilet/VIP", "Latrine with cement slab", "Latrine without
cement slab", "No toilet")) +
  theme_bw() +
  labs(title = "Toilet Type Improvement", x = "Type of Toilet", y = "Households", fill =
"Improved Water Source")+
  theme(legend.position = "bottom")

Toilet_type.ggp
```

```
wealth <- as.factor(wealth)

Wealth.ggp <- ggplot(PC, aes (x = wealth, fill = improved_water_source))+
  geom_bar(position = "dodge") +
  scale_fill_manual(values = c("pink", "purple1")) +
  scale_x_discrete(labels = c("Poorest20%tile", "Second20%tile", "Third20%tile",
"Fourth20%tile", "Wealthiest20%tile")) +
  theme_bw() +
  labs(title = "Wealth Improvement", x = "Wealth", y = "Households", fill = "Improved Water
Source")+
  theme(legend.position = "bottom")

Wealth.ggp

prop.table(table(PC$ZSHP_initiation,improved_water_source),1)
table(PC$ZSHP_initiation,PC$improved_water_source)

RRtable<-matrix(c(401,209,322,238),nrow=2,ncol=2)
prop.test(RRtable)
riskratio.wald(RRtable)

PC$improved_water_source <- as.factor(PC$improved_water_source)
data.class(PC$improved_water_source)
PC$ZSHP_initiation <- as.factor(PC$ZSHP_initiation)
PC$wealth <- as.factor(PC$wealth)
PC$type_toilet <- as.factor(PC$type_toilet)

View(PC)


LogitModel <-glm(PC$improved_water_source ~ PC$ZSHP_initiation + PC$wealth +
PC$type_toilet,family = binomial(link=logit))
summary(LogitModel)
exp(LogitModel$coefficients)
exp(confint(LogitModel))

> summary(LogitModel)

Call:
```

```
glm(formula = PC$improved_water_source ~ PC$ZSHP_initiation +
    PC$wealth + PC$type_toilet, family = binomial(link = logit))

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)        -14.9596   312.8182  -0.048 0.961858
PC$ZSHP_initiation2   0.2340     0.1270   1.842 0.065428 .
PC$wealth2          -0.1868     0.1967  -0.950 0.342225
PC$wealth3          -0.2225     0.1833  -1.214 0.224831
PC$wealth4          -0.7211     0.1950  -3.698 0.000217 ***
PC$wealth5          -0.8375     0.1970  -4.252 2.12e-05 ***
PC$type_toilet2      15.1401   312.8182   0.048 0.961398
PC$type_toilet3      15.4040   312.8183   0.049 0.960726
PC$type_toilet4      15.4854   312.8182   0.050 0.960518
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1619.8  on 1169  degrees of freedom
Residual deviance: 1546.7  on 1161  degrees of freedom
AIC: 1564.7

Number of Fisher Scoring iterations: 14

> exp(LogitModel$coefficients)
       (Intercept) PC$ZSHP_initiation2          PC$wealth2          PC$wealth3
      3.185260e-07        1.263650e+00        8.296135e-01        8.005100e-01
        PC$wealth4          PC$wealth5     PC$type_toilet2     PC$type_toilet3
      4.862281e-01        4.327778e-01        3.760648e+06        4.896518e+06
    PC$type_toilet4
      5.311785e+06
> exp(confint(LogitModel))
Waiting for profiling to be done...
                      2.5 %     97.5 %
(Intercept)              NA 16.7950865
PC$ZSHP_initiation2 0.9851047  1.6210901
PC$wealth2          0.5638940  1.2197996
PC$wealth3          0.5583199  1.1460072
PC$wealth4          0.3310109  0.7113058
```

```
PC$wealth5         0.2933589  0.6353437
PC$type_toilet2    0.0679268         NA
PC$type_toilet3    0.1032494         NA
PC$type_toilet4    0.1007571         NA
There were 42 warnings (use warnings() to see them)
```