

# Ecological Study to Set Alternative Strategies for Reducing Child Mortality

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## ABSTRACT

**BACKGROUND:** Infant and child mortality are indicators of population wellbeing. Although Child mortality rates are declining in Egypt, national averages mask regional disparities. Hence, identification and quantification of factors contributing to mortality, at the local level through ecological correlation studies could provide a guide to more focused public health interventions for reducing mortality. The study aims to improve child health and decrease child mortality rate through recognition of ecological/environmental factors predicting child mortality among municipalities in Giza governorate.

**METHODOLOGY:** Ecological cross sectional study adopting the municipalities (n=215) as unit of analysis. The study was conducted to examine associations between child mortality and some human development indicators.

**RESULTS:** Highly significant negative correlation between U5MR and access to water ( $r=-0.966$ ) was found. Access to sanitation and access to electricity were negatively correlated with U5MR with  $r=-0.955$  and  $-0.905$  respectively. The results for IMR were similar to those for U5MR. An increase of one percent access of household to safe water predicts a decrease by 1.05 and 0.78 in U5MR and IMR ( $R^2=0.97$  and  $0.98$ ;  $P\leq 0.001$ ) respectively. This relationship retained its significance in the multivariate analysis: an increase of ten percent access to safe water predicted a decrease by 10.3 and 7.7 in U5MR and infant deaths respectively ( $P\leq 0.001$ ). U5MR and IMR decrease significantly (by 0.82 and 0.61 deaths respectively) with increase access to sanitation by 1%.

**CONCLUSION:** Access to safe water and sanitation are strong predictors of U5MR and IMR. Increased coverage of households by safe water has the greatest impact on the reduction of children mortality rate. Therefore, the study recommends advocacy to ensure coverage of household with safe water and sanitation system.

*Key words: Child mortality; Ecological correlation; Safe water*

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## INTRODUCTION

Infant and child mortality are indicators of population wellbeing and taken as one

of the development indicators of health, socioeconomic status and environment. That is why improving the health outcomes of children have been the central Focus of many public

health programs [1, 2, 3] in the world over the last three decades. There have been several international goals set out to improve child health. The Declaration of Alma Ata (1978) aimed to reduce infant mortality rates (IMR) to less than 50 deaths per 1000 live-births through a global strategy for “Health for All” by the Year 2000[4] Subsequently, the 1990 World Summit for Children Programme of Action and the Programme of Action of the 1994 International Conference on Population and Development (ICPD) encouraged countries to reduce infant mortality. Another international effort targeting infant mortality is the fourth goal of the United Nations Millennium Development Goals (MDG 4). The MDG 4 is set to reduce IMRs between 1990 and 2015 by two thirds [5].

Child mortality rates are declining in Egypt over time to reach 28 deaths per 1000 live birth (2014). However, National averages mask differences among regions and disparities among socioeconomic groups. The identification, targeting and quantification of factors contributing to district mortality can contribute to more focused public health interventions for reducing mortality [6,7]. For that, regional and national studies on childhood mortality determinants at the municipal/ district level are urgently required.

The adoption of the ecological correlation studies that look for the associations between risks and outcomes in populations rather than in individuals could guide for more effective and tailored policy measures for improving child health and reduce mortality rate through identifying the ecological/environmental factors predictors of under-five mortality.

The unit of analysis, in ecological analysis, is the same as the unit of potential intervention, thus provides more comprehensive picture for the design of adequate prevention strategies rather than individual level studies [8].

The study aims to improve child health and decrease child mortality rate through the followings **specific objectives**:

1. Assess correlation between under five mortality and other human development indicators using ecological correlation analysis
2. Recognize ecological/environmental factors contributing to differences in child mortality among municipalities in Giza governorate
3. Determine best strategy to improve child health and reduce mortality rate

## METHODS

### *Study site*

Giza is one of Upper Egypt governorates. It lies on the Nile River, about 165 km along the river Nile. It covers a land area of 85153 km<sup>2</sup> (8.5 % of Egypt land), and has about 5.4 million inhabitants. The Nile passes through the governorate and divides it into eastern and western parts. Farming and economic activities are concentrated in the western part. The eastern part is less inhabited than the western one.

Giza is divided into twenty (ten urban and ten rural) districts, and 215 municipalities (54 urban & 151 rural).

Giza occupies the 10th position among the 26 Egyptian governorates in human development indices. The human development indices showed difference between urban (, 724) and rural (, 616) area of Giza .The registered infant and child mortality rates were 17.6 and 23.7 per 1000 live births in 2003. The crude birth and death rates were estimated to be 27.3 and 5.7 respectively. The adult literacy rate is estimated to be 71.8% and rural illiteracy exceeds 40.8%.

### *Data source*

Data for this study were obtained from National Human Development Report for governorates (Giza governorates) produced by the National Planning Institute in Egypt (N.P.I., 2005) (issued every 15 years for Governorate Districts).

### *Study Design*

Ecological, cross sectional study, adopting the municipalities (n=215) as unit of analysis, to examine associations between child mortality and some human development indicators.

### *Measurement variables*

#### *Outcome variables*

Two key outcome variables were explored: **under-five mortality rate and Infant mortality rate**. Under-five mortality rate is defined as the probability of a child born in a specific year or period dying before reaching the age of five

per 1000 live births, if subject to age-specific mortality rates of that period [9]. Infant mortality rate is the number of deaths of infants under one year of age, in a given period of time, per 1000 live births in the same period [10].

### Independent variables

**Access to water:** Access to safe drinking water is measured by the percentage of the population using improved drinking water sources. Improved drinking water source is a source that, by nature of its construction, adequately protects the water from outside contamination, in particular from fecal matter. Common examples: Piped household water connection and Public stand pipe [11].

**Access to basic sanitation:** Access to basic sanitation is measured against the proxy indicator: the proportion of people using improved sanitation facilities (such as those with sewer connections, septic system connections, pour-flush latrines, pit latrines with a slab or covered pit and ventilated improved pit latrines) [11].

**Access to electricity:** Access to electricity is measured by the percentage of the population linked to electricity.

**Secondary education:** percent of secondary school registration

**Secondary female education:** Percent of female age 6 and over registered secondary education.

**Education rate:** Percent of household population age 6 and over registering in education.

**Literacy rate:** Percent of household population age 15 and over can read and write.

**GDP per capita:** is the GDP (the value of all final goods and services produced in a country in one year.) divided by the midyear population and considered as a measure of the standard of living in a country or the level of economic development.

**Purchasing parity power (PPP):** is the exchange rate of a currency relative to a standard, which is usually the United States dollar and measured in international dollars.

### Data analysis

Data were entered using Microsoft Server. The analysis was carried out in SPSS version

17.0. All p values are two-tailed and were considered significant when  $<0.01$ .

A Correlation analysis between key variables infant and under five child mortality rates and all potential explanatory variables using the spearman test was conducted. Linear correlation coefficient (spearman) indicates power and quality of the correlation between two variables.

The value refers to its power [weak (less than  $+/-0.4$ ), medium ( $+/-0.4 : +/-0.599$ ), strong ( $+/-0.6 : +/- 0.799$ ), very strong ( $+/-0.8 : +/-1.0$ ), while the resulting sign refer to the kind of relation ( $+$ :positive relation), ( $-$ :inverse relation).

To estimate the net impact of independent variables on mortality, simple and multiple linear regressions were used.

Highly correlated covariates as defined by  $r > 0.8$  were not included in the same equation.

The generic model for the linear regression is as follows:

$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_p x_{ip} + \epsilon_i, \quad i = 1, \dots, n,$$

Where  $y$  is the outcome variable,  $B$ 's are the parameter coefficients,

And  $x$ 's are the predictor variable or covariates, and  $\epsilon$  an error term.

In the unadjusted models (1 to 10), simple linear regressions were used. Multiple linear regression (Enter method) was applied in the adjusted model (model 11), including the dependent variable with water and secondary female education.

### Ethical Consideration

No ethics committee approval was needed for this study, as the data used in this research was obtained from a public-use data set.

## RESULTS

Table (1) presents correlation between mortality indicators and some potential explanatory variables: all variables were negatively correlated with mortality rates. Correlated variables were ranked in descending order including: access to water, access to sanitation, and access to electricity, education rate, total secondary education, female secondary education, literacy rate, GDP per

TABLE 1

CORRELATION COEFFICIENT MATRIX		
	IMR	U5MR
WATER	-0.972*	-0.966*
SANITATION	-0.955*	-0.955*
ELECTRICITY	-0.905*	-0.905*
SECONDARY EDUCATION	-0.556*	-0.549*
SECONDARY EDUCATION FEMALE	-0.552*	-0.546*
LITERACY RATE	-0.354*	-0.354*
EDUCATION RATE	-0.576*	-0.569*
GDP/C/Y	-0.266*	-0.271*
GDP/F/Y	-0.247*	-0.250*
PPP/C/Y	-0.249*	-0.254*

\*P<0.001

capita, PPP per capita and GDP per female.

The table (1) and figure (2) showed highly significant negative association between U5MR and access to water ( $r=-0.966$ ). Access to sanitation and access to electricity are negatively correlated with U5MR with  $r=-0.955$  and  $-0.905$  respectively. Moderate significant negative correlations were found between U5MR and education rate ( $r=-0.569$ ), total secondary education ( $r=-0.549$ ), female secondary education ( $r=-0.546$ ). The results for IMR were similar to those for U5MR. Figure 1 showed highly significant negative correlation between percent of household access to safe water and infant mortality rate. The correlations between mortality rates and literacy rate, GDP per capita and GDP per female were weak significant negative correlations. ( $P<0.001$ ).

Table (2) and table (3) demonstrates that access to improved water source has the greatest impact on reducing mortality rates in comparison to all other included variables ( $R^2=0.97$  and  $0.98$  for U5MR and IMR respectively).

Access to safe water was inversely associated with U5MR ( $\beta=-1.05$ ;  $p\leq 0.001$ ,  $R^2=0.97$ ) (See M 1 Table 2). In the adjusted analysis (Model 11, table 2), an increase of ten percent of household access to safe water predicts a decrease by 10.3 in U5MR, this decrease in U5MR continued to be significant at  $p < 0.001$ .

IMR decreased by 7.8 deaths with increased access to improved water source by 10 percent

(See M 1 Table 3). This relationship retained its significance in the multivariable analysis, an increase of ten percent of household access to safe water predicted a decrease in infant deaths by 7.7,  $p < 0.001$  (M11 table 3).

Increasing access to improved sanitation was significantly associated with a decrease in under-five mortality rate ( $R^2=0.926$ ), and a decrease in IMR ( $R^2=0.935$ ). Ten percent improvement in household access to sanitation predicts a decrease by 8.2 and 6.1 in U5MR and infant deaths respectively. (See M 2 Tables 2 & 3). In the unadjusted models, an increase of ten percent in household access to electricity is significantly associated with a decrease in Under-five mortality rate and IMR by 6.9 and 5.1 deaths respectively.

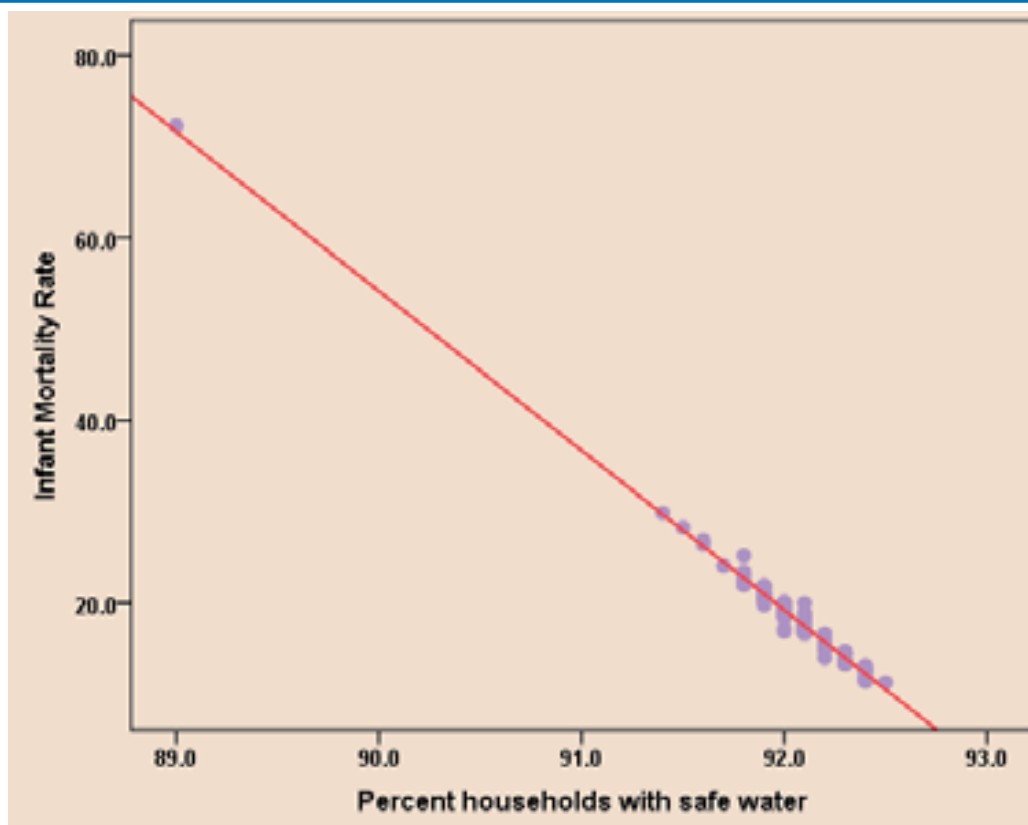
All education variables, were negatively significantly associated with the risk of IMR and U5MR (models 4, 5, 6 & 7 table 2 & 3). The improvement of secondary female education by ten percent predicts a decrease by 0.04 and 0.03 in U5MR and infant deaths respectively in adjusted model 11 (table 2 & 3). Regarding income variables, they were negatively significantly associated with the risk of IMR and U5MR (models 8, 9 & 10).

## DISCUSSION

Access to water and sanitation is known to be related to child health. In the current study,

FIGURE 1

## CORRELATION BETWEEN PERCENT OF HOUSEHOLD ACCESS TO SAFE WATER AND INFANT MORTALITY RATE



statistically significant relationships between water and both infant and child mortality were found. Access to an improved water source was proved to have the greatest effect ( in comparison to all other included variables) in reducing child mortality.

An increase of one percent access of household to safe water predicted 1.05 and 0.78 lower U5MR and IMR respectively. U5MR and IMR decrease significantly by 0.82 and 0.61 deaths in relation to the increase in accessibility to sanitation by 1%.

An earlier study on child mortality across 193 countries, had proved that Under-five mortality rate and IMR had been significantly decreased with increasing accessibility to safe water. The decrease was by 1.17 and 1.14 deaths per 1000 Live birth respectively [12]. In addition, increased access to sanitation was associated with a decrease in both U5MR and IMR by 1.66 deaths . [12]

The relation between water, sanitation, and child health described in the scientific

literature, supports the relations identified in this study.

Children are more susceptible to poor outcomes from diarrhea (such as life-threatening dehydration). This is partially due to the fact that water makes up a larger percentage of their body weight [13]. Diarrhea can also contribute to under-nutrition, through mal-absorption. Diarrhea, along with nematode infections caused by poor sanitation, can lead to 3.5 million under-five child deaths per year [13]. A World Bank publication found that in the absence of diarrhea, the nutritional status of those who are undernourished improves quickly [14]. Water also is essential for mothers who do not breastfeed; the use of dirty containers and unsafe water for formula preparation puts infants' health at risk. In addition, many basic birth practices, including hand washing, can affect infant mortality outcomes [15].

This study demonstrated that increasing access to electricity by 10%, was significantly associated with decreased Under-five mortality

FIGURE 2

CORRELATION BETWEEN PERCENT OF HOUSEHOLD ACCESS TO SAFE WATER AND U5MR

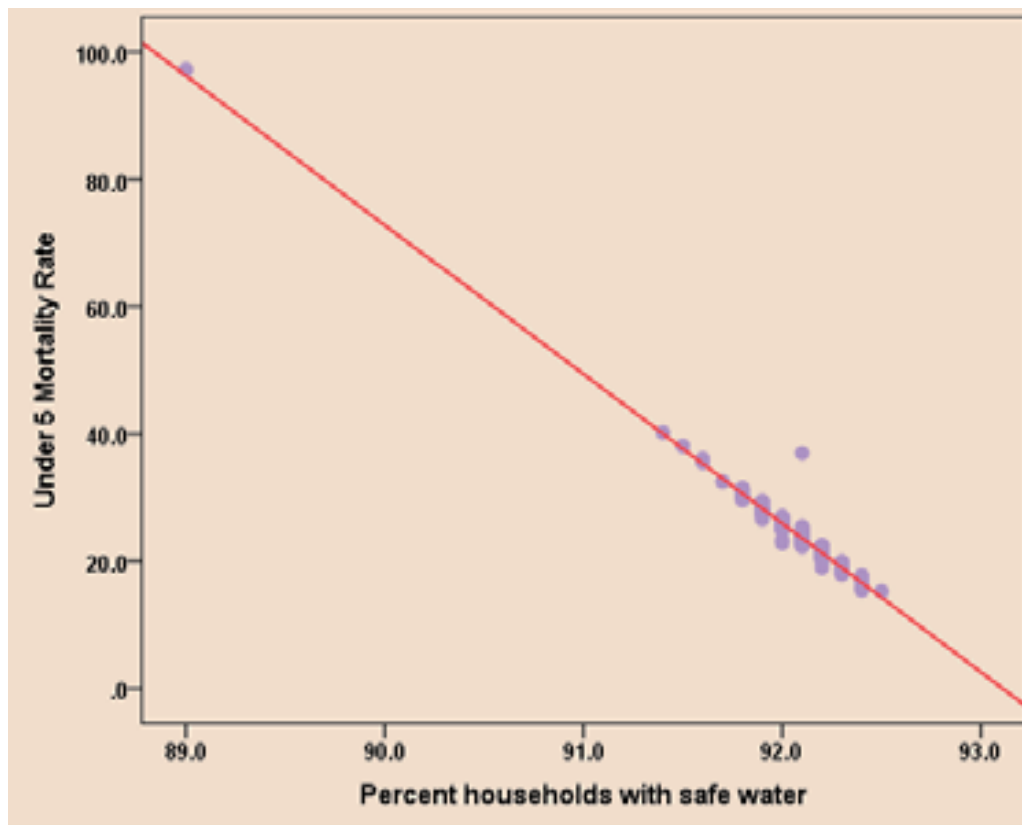


TABLE 2

PREDICTORS OF U5MR PREDICTORS OF U5MR (%)

	INDEPENDENT	R2	F	P VALUE	BETA	95%CI		
M1	WATER	0.967	6260.3	<0.001	-1.057	-1.083	-	-1.03
M2	SANITATION	0.926	2665.6	<0.001	-0.825	-0.856	-	-0.793
M3	ELECTRICITY	0.316	99.4	<0.001	-0.696	-0.833	-	-0.558
M4	2RY TOTAL	0.099	24.5	<0.001	-0.018	-0.025	-	-0.011
M5	2RY FEMALE	0.112	27.9	<0.001	-0.019	-0.027	-	-0.012
M6	LITERACY RATE	0.012	3.6	0.058	-0.007	-0.014	-	0.0002
M7	EDUCATION RATE	0.091	22.4	<0.001	-0.022	-0.031	-	-0.013
M8	GDPCY	0.072	17.6	<0.001	-0.00008	-0.00011	-	-0.000041
M9	GDPFY	0.063	15.2	<0.001	-0.000162	-0.00024	-	-0.00008
M10	PPPCY	0.071	17.2	<0.001	-0.000122	-0.00018	-	-0.000064
M11	WATER	0.971	3538.4	<0.001	-1.037	-1.063	-	-1.011
	2RY FEMALE				-0.004	-0.005	-	-0.002



TABLE 3

PREDICTORS OF IMR								
	INDEPENDENT	R2	F	P VALUE	BETA	95%CI		
M1	WATER	0.984	13399.2	<0.001	-0.787	-0.801	-	-0.774
M2	SANITATION	0.935	3070.5	<0.001	-0.612	-0.634	-	-0.590
M3	ELECTRICITY	0.318	100.4	<0.001	-0.516	-0.617	-	-0.414
M4	2RY TOTAL	0.106	26.1	<0.001	-0.014	-0.019	-	-0.008
M5	2RY FEMALE	0.119	29.8	<0.001	-0.015	-0.02	-	-0.009
M6	LITERACY RATE	0.013	3.7	0.055	-0.005	-0.01	-	0.0001
M7	EDUCATION RATE	0.098	24.2	<0.001	-0.017	-0.023	-	-0.01
M8	GDP CY	0.07	17.1	<0.001	-0.00006	-0.00008	-	-0.00003
M9	GDP FY	0.061	14.9	<0.001	-0.00012	-0.00018	-	-0.00006
M10	PPP CY	0.069	16.7	<0.001	-0.000089	-0.000132	-	-0.000046
M11	WATER	0.989	9766.1	<0.001	-0.771	-0.782	-	-0.759
	2RY FEMALE				-0.003	-0.004	-	-0.002

rate and IMR (6.9 and 5.1 fewer deaths respectively). In 2003, Wang L had found that access to electricity had the largest impact in reducing child mortality. The study was conducted on more than 60 “low income countries”, including Egypt [16].

Many studies explained multiple pathways through which access to electricity can affect health. Electricity as a source of energy for cooking, heating and lighting can reduce the incidence of respiratory infections and child mortality [17]. In addition, access to electricity facilitates refrigeration of food and boiling of water, which have been identified as important measures to reduce the incidence of infectious diseases among young children [18].

The analysis revealed negative significant association between GDP and the risk of IMR and U5MR. The weak association could be explained by the hypothesis that the income mortality relationship is weaker at very low income levels, stronger at middle income levels and disassociates at high-income levels [19, 20].

The strengths of the current study are due to different aspects:

The study provided evidence for the significant association between environment and health in a quantitative style, that could be generalized in different public health problems: Other studies could be done to reduce maternal mortality, reduce the prevalence of non-

communicable diseases, etc. Hence, access to basic, updated, and high quality data is pivotal to initiate evidence-based interventions.

The current study demonstrated a methodology to set plans (at the district level) through conducting ecological analysis between some human development indicators at the district level (independent factors), and infant and U5MR rates (dependent indicator), to identify the most significant factor contributing to child mortalities.

The study faced some limitations. First, emphasis on district level data was a great challenge: The choice of indicators was strongly influenced by the available data (that was extracted in 2005 and needed to be updated). This may have led to the exclusion of relevant variables, and could have affected the results. Second, this study is an observational and cross-sectional study based on databases. The researchers found strong associations between access to water and sanitation, and infant and child mortality. This is supported by previous literature, and reinforces the importance of accessibility to safe water and sanitation in relation to infant and child mortality. However, due to the ecological and observational nature of the study, this relationship could not be proven to be causal (in spite of the strong suggestions of interconnection). Such connections should be

explored by longitudinal analyses to determine the causative relationships.

## CONCLUSION

The general findings of the study demonstrated that there were significant associations between child mortality and some important human development indicators. Access to safe water, sanitation, and electricity were strong predictors of U5MR and IMR. Increased coverage of households with safe water had the greatest impact on the reduction of children mortality rate. Therefore, the study recommends advocacy to ensure coverage of household with safe water and sanitation system. This is in addition to implementation

of policies that ensure protection of surface water. The role of health facilities to ensure safe water and sanitation should be promoted. Health education for the community to protect surface water is equally required. A properly functioning information system for the provision of quality updated data is needed to support decision making

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**CONFLICT OF INTEREST:** *None*

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