Health, Safe Water and Sanitation:
A Cross-Sectional Health Production Function for Central Java, Indonesia

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The study describes the development of health production functions and their application in the evaluation of the health impact of investment in safe water and sanitation. For this purpose, data on the morbidity of waterborne disease and diarrhea were collected from medical record in the province of Central Java, Indonesia. A reciprocal production function was found to fit the data best. The health production functions exhibit constant return to scale, i.e., a simultaneous m-fold increase in both safe water and sanitation coverage produces a 1-1/m decrease in morbidity. Safe water was found to be more important for health than the sanitary disposal of excreta.

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Introduction

Although safe water supply and sanitation (WSS) have long been accepted as basic necessities for healthy living, measuring the health benefits that result from their availability remains controversial. Some studies indicated that improved WWS facilities are not efficacious in improving health status and not particularly cost-effective *(1)*. in contrast, a review of 67 studies from 28 countries found that WSS investment can reduce diarrhea morbidity and mortality rates by a median of 22% and 21%, respectively *(2)*. Most of the studies reviewed, however, appear to have serious methodological deficiencies e.g., in adequate heath indicators and failure to control for confounding variables *(3)*. These control versies, along with the introduction of selective primary health care (SPCH) *(1)*, have placed greater emphasis on the use of oral re-hydration therapy (ORT). WSS policies and ORT should nevertheless both be adopted, since the benefits of WSS extend far beyond its role in improving health status *(4)*.

The health benefits resulting from investment in WSS have been measured by a number of case-control studied since the end of the 1980s. Such studies have been carried out in Malawi*(5)*, the Philippines *(6)* and Lesotho *(7)*, where it was reported that WSS investment can produce a 20%, 20%, and 24% reduction, respectively, in the incidence of diarrhoea.

Despite these findings, doubts remain about the benefits of WSS since the 95% confidence intervals (CI) of both the crude and adjusted odds ratios in the studies in Melawi and the Philippines included the value for the null hypothesis. The 95% CI of the adjusted odds ratio in Lesotho study also included the null hypothesis value. In other word, at the 95% CI the WSS investments may not be efficacious in reducing diarrhoea incidence.

We describe here an alternative approach to measuring the effect of WSS on health, using a production function. Such functions have been used in agriculture and industry for some time *(8, 9)*. Specification of the production function permits analysis of how health inputs interact to produce a particular level of health status. The importance of specifying health production function is underlined if a cost benefit analysis of WSS investment is carried out; failure to specify production functions is a serious methodological flaw in most health care cost-benefit analyses.

The present study takes the community as the unit of analysis instead of the individual or house-hold and implicity assumes that the health status of individuals and household is strongly affected by community environment. Community health indicator such as morbidity, mortality, infant mortality rates or life expectancy can be used as a measured of health status. In this study we have adopted morbidity as the dependent variables, based on the premise that the health benefits of safe water and sanitation are better reflected by morbidity rather than by mortality rates *(4, 11)*. Morbidity from diarrhea and morbidity from all waterborne disease were taken as dependent variables.

In addition to safe water and sanitation, a number of other factors may affect diarrhoea morbidity (or mortality). Water quality is a significant determinant of diarrhea incident in Quindio, Colombia *(12)*; and socioeconomics conditions, e.g. per capita income, occupation, or literacy rate, are often important factors that affect morbidity *(5-7, 11)*.

Level of formal education can also influence the incidence of diarrhea *(13)*, although a specially designed education programme for personal hygiene and diarrhoea prevention seems to be more effective in this respect *(12, 13)*. Nutritional status may affect diarrhoea mortality in developing countries, where the condition is a predominant cause of infant death *(14)*. The following factors that affect the incidence of diarrhoea diseases have also been identified: breast-feeding behaviour *(15)*, food hygiene *(16)*, cholera and rotavirus immunization *(17)*, measles immunization *(16)*, and human and animal/livestock populations *(12)*. Diarrhoea incidence increases during warm rainy season (5, 6, 12). Furthermore, availability of health services in a community, as indicated by the ratio – number of health centres or medical staff: population size – can also influence measured health status *(11)*.

The above-mentioned variables can influence morbidity from waterborne disease and diarrhea; however, in adequate data (either not available or inaccurate) precluded their inclusion in the study. Data on per capita income and water quality, for example, were not available for most sub district in the study area. In addition, data on breast-feeding behaviour and food hygiene were not readily available. Therefore we focused on safe water supply and sanitation as the only independent variables.

Methods

Model Specification

The models is specified by the following general productions:

$$MWB = f(WTR, SAN) \tag{1}$$

$$MDR = f(WTR, SAN) \tag{2}$$

Where *MWB* = morbidity of waterborne disease, including recorded incidences of diarrhea, cholera, bacillary dysentery, typhoid fever, paratyphoid fever, and viral hepatitis A from January to December 1990 per 1000 population;

MDR = diarrhoea morbidity, i.e. the recorded incidence of diarrhoea from January to December 1990 per 1000 population;

WTR = safe water supply coverage, i.e., the percentage of the population with access to a safe water supply; and

SAN = sanitation (sanitary excreta disposal) coverage, i.e. the percentage of the population with access to excreta disposal facilities.

In contrast to production function used in industry, where output normally increases when the quantities of the inputs increase, the morbidity of disease(s) will presumably decrease as the quantities of the input included in the model increase. This has the following consequences: first, the expected sign of each independent variables is the opposite of that for the usual production function (Table 1); second, the marginal productivity and the elasticity of production are negative (see Annex for definitions of the production economics terms used in the article and also ref. 8, 9, 18). To avoid complications, we will use the absolute values in the article.

Definitions

The definition shown below were used in the study.

"Waterborne disease" were taken to refer to all disease resulting from pathogens in water that can be transmitted by direct and by indirect faecal-oral routes, for example via food prepares with or washed in contaminated water. The usual definition of diarrhea is three or more watery stools passed in the last 24 hours.

The definitions of "safe water supply" and "sanitation" used by WHO, and adopted by the Indonesia Ministry of Health, were employed in the study. Safe water supply includes treated surface or unthread but uncontaminated water such as that from protected boreholes, springs and sanitary wells, either in the home or within 15 minute walking distance of it (*19, 20*).

Because data on sanitation facilities such as solid waste disposal were inadequate, we used only sanitary excreta disposal as the sanitation variable. Sanitary excreta disposal includes collection and disposal, with or without treatment, or human excreta and wastewater by waterborne system or the use of pit latrines and similar installations (*19*).

Data Collection

Data for the period January-December 1990 were collected in June-July 1991 from 14 districts (*kabupaten*) and municipalities (*kecamatan*) in Central Java Province, Indonesia. Sub-districts were used as the unit of analysis, and there were therefore 194 observation. Data on the variables shown below were collected.

- Population
- Recorded incidences of waterborne disease, including diarrhea, Cholera, bacillary dysentery, typhoid fever, paratyphoid fever, and viral hepatitis A. there may have been some unrecorded cases within the community in remote villages because the villagers failed to visit medical facilities or because medical centres did not diagnose the condition accurately
- The number of people having access to safe water facilities, both piped and non-piped systems. Piped system supply water to various service outlets such as public taps and homes; water distributes by government enterprises and community groups covered. Non-piped water included all other system of providing safe water, i.e., shallow wells, deep wells, spring captations, rainwater collectors and household treatment system.
- The number of people with access to adequate sanitation (sanitary excreta disposal) facilities, including those with access to improve pit latrines, pour-flush latrines, septic tank with or without latrines, and public latrines.

To ensure that data of adequate quality were collected, discussions were held with the officers responsible for medical records at the district level. If inconsistencies were found (either inadequacy of definition or misrecording), the data were revised. Site visits were also made to health centres and district hospitals.

Econometric Procedures

Six basic production function (linear, quadratic, reciprocal, log-linear, reciprocal log-linear, and double-log (Cobb-Douglas)) were fitted to the data (*8*). The properties of each function's estimators (parameter) are shown in table 1. the SHAZAM econometrics package was used (*21*).

The ordinary least square (OLS) method was employed initially. Since a plot of the data indicated both vertical and horizontal asymptotes, however, regressions without a constant term (β_0=0) were also examined. In this case, the sum of squares was calculated from zero instead of from the mean value, resulting in a raw moment of R^2 adjusted (*21-23*).

Use of cross-sectional data could result in heteroscedasticity, and the consequences the OLS estimates of the parameter β_i would no longer be the best obtainable. The test of hypotheses would no longer be valid in this cases because the OLS method produces a biased variance estimator (*22, 23*).

Table 1. Expected signs of estimates of the parameters, β_i, in the models

Specification [a]	**β_0**	**β_1**	**β_2**	**β_3**	**β_4**
Linear	(+)	(-)	(-)	N.A.[b]	N.A.
Quadratic					
First alternative	(+) or 0	(-)	(+)	(-)	(+)
Second alternative	(+) or 0	(+)	(-)	(+)	(-)
Reciprocal	(+) or 0	(+)	(+)	N.A.	N.A.
Log-linear	(+) (-) or 0	(-)	(-)	N.A.	N.A.
Log-linear Reciprocal	(+) (-) or 0	(+)	(+)	N.A.	N.A.
Double Log	(+)	(-)	(-)	N.A.	N.A.

[a] The general mathematical form of each specification is as follows:

Liner : $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2$
Quadratic : $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_0 + \beta_3 X_1^{2} + \beta_4 X_2^{2}$
Reciprocal : $Y = \beta_0 + (\beta_1 / X_1) + (\beta_2 / X_2)$
Log Linear : $Y = \exp [\beta_0 + \beta_1 X_1 + \beta_2 X_2]$
Log Linear Reciprocal : $Y = \exp [\beta_0 + (\beta_1 / X_1) + (\beta_2 / X_2)]$
Double-log : $Y = \beta_0 X_1^{\beta 1} X_2^{\beta 2}$

[b] N.A. = not available.

To test for heteroscedasticity, we first applied the multiplicative heteroscedasticity test. If this test failed, the Breusch-Pagan test was used (*22*). If heteroscedasticity was detected, we employed the generalized least squares (GLS) method to estimate the value of β_i (*21-23*).

To compare specifications, we used R^2 adjusted, generalized cross validation (GCV), the Hanan and Quinn criterion (HQ), the Rice criterion (RICE), the SHIBATA criterion, the Schwarz criterion (SC), and the Akaike information criterion (AIC) (23). Preferred specifications were those having a higher value of R^2 adjusted or, if the total sum of square was equal, a lower value of the measures of the other criteria; however, such criteria should not be to compare specifications having a constant term with those that do not (23). In those cases where there was no constant term, the raw moment of R^2 always increases if a new variables is added to the model. Thus, we did not use this criterion to compare the goodness of fit of the quadratic function with that of the others.

Results

The data collected in this study relate to approximately 11,24 million people (about 40% of the population of Central Java). The incidence of morbidity from waterborne disease in the study area in 1990 was estimated to be about 31 per 1000, while that for diarrhea disease and 111 of diarrhea were recorded each month.

Diarrhoea accounted for 75% of the total recorded waterborne disease and bacillary dysentery for about 18%. In comparison, the incidence of other disease was very low. Although the mean incidences of Typhoid fever and paratyphoid fever in most sub-districts were very low or even zero, the maximum incidences of these disease were relatively high (Table 2). Thus these disease pose a serious health problem in certain sub-districts.

Table 2. Summary statistics of the variable examined in the study[a]

	Mean		Max.	Min.
Morbidity (per 1000 population)				
Diarrhoea	23.1	(15.8)[b]	105.4	0.0
Cholera	0.0	(0.1)	0.5	0.0
Bacillary dysentery	5.8	(7.6)	39.1	0.0
Typhoid fever	1.2	(3.6)	38.3	0.0
Paratyphoid fever	0.6	(2.3)	24.7	0.0
Viral hepatitis A	0.2	(0.3)	2.2	0.0
Total Waterborne disease	31.0	(21.5)	146.2	0.0
% of population with access to:				
Safe water supply	56.3	(20.3)	100.0	14.1
Sanitation	38.9	(22.0)	98.4	3.0

[a] No. of observations = 194 subdistricts; population covered in the study = 11.236.798

[b] Figures in parentheses are the standard deviations.

The mean level of save water coverage in the study sample was 56%, slightly lower than the level of 61% for the whole province of Central Java. About 39% of the population had access to sanitation facilities (excreta disposal), compare with 37% for the province as a whole. Sanitation coverage had a more uneven distribution than that of safe water, as indicated by the differences in their standard deviations.

Using the OLS method, we found that the specification that included a constant term exhibited inferior statistical performance. This arose because the value for R^2 adjusted and the F-ratio were low, and neither safe water coverage nor sanitation coverage was statistically significant for those specifications. Application of the OLS method to specifications without a constant term indicated that reciprocal function exhibited the best statistical performance, having the lowest value of GCV, HQ, RICE, SHIBATA, SC, and AIC. For the *MWB* and *MDR* regression, the R^2 value were 0,54 and 0,55, respectively, which are reasonably acceptable for a cross-sectional analysis. In addition, only the reciprocal function showed the significance of both the safe water and sanitation variables. The general form of the reciprocal function without a constant term is as follow:

$$Y = (\beta_1 / X_1) + (\beta_2 / X_2) \tag{3}$$

Multiplicative heteroscedasticity occurred in the *MWB* regression at the 2.5% significance level. For the *MDR* regression, multiplicative heteroscedasticity existed at the 11% significance level. Thus, the GLS method was used to estimated $\beta_{1.}$

Table 3 shows the regression result for the reciprocal function obtained using the OLS and GLS method. It is clear that the GLS method produced better specifications than the OLS method; the R^2 for the GLS specifications were higher, while those for GCV, HQ, RICE, SHIBATA, SC, and AIC were lower than those for the OLS specification. Also, the OLS result underestimated $\beta_{1.}$

The preferred estimated reciprocal production function (eq. (3)) for *MWB* and *MDR* are shown below:

$$MWB = 1346.6/WTR + 136.1/SAN \tag{4}$$

$$MDR = 938.5/WTR + 101.5/SAN \tag{5}$$

For the *MWB* and the *MDR* regression, the standardized coefficient for *WTR* were about twice those for *SAN* (Table 3). This implies that increased safe water coverage can produce a greater reduction in *MWB* and *MDR* than that resulting from increased sanitation coverage, i.e. safe water has a greater effect than sanitation on the incidence of waterborne disease and diarrhoea.

The properties of eq. (4) and (5) can be explored using an isoquant map (a set of isoquant curve). The following morbidity levels were chosen for this purpose: the mean value +0.5 standard deviations (SD), the mean value, the mean value -0.5 SD, and the best case. The best case represents the lowest morbidity level achievable at the maximum coverage of save water and sanitation. The isoquant maps for *MWB* and *MDR* are shown in Fig.1 and 2, respectively. The abscissa represent safe water coverage and the ordinate, sanitation coverage. The further a curve is from the origin the lower is the morbidity level.

Table 3. Result of the regression analysis of morbidity from waterborne disease (*MWB*) and Morbidity from diarrhea (*MDR*): reciprocal specifications.

	MWB Regression[a]		**MDR Regression**[a]	
	OLS	**GLS**	**OLS**	**GLS**
Estimated coefficients	1133.7	1346.6	846.1	938.5
Safe water supply	(9.1175)[b]	(8.6036)[c]	(9.2580)	(8.6273)[c]
	79.8	136.1	60.8	11.5
Sanitation	(1.894)	(2.1970)d	(1.9623)	(2.3082)[d]
Standardized coefficients				
Safe water supply	0.491	0.583	0.498	0.552
Sanitation	0.167	0.284	0.173	0.288
Specification comparisons				
R2	0.54	0.57	0.55	0.57
F-ratio	111.92	127.93	116.07	126.15
GCV	671	291.02	362.45	197.91
HQ	680.14	294.99	367.39	200.61
RICE	671.07	291.05	362.49	197.94
SHIBATA	670.78	290.93	362.34	197.85
SC	693.91	300.96	374.83	204.67
AIC	670.92	290.99	362.42	197.89

[a] OLS = Ordinary Least Square method; GLS = Generalized Least Square method

[b] Figures in parentheses are t-statistics.

[c] Significant at α = 2.5%

[d] Significant at α = 0.5%

A number of important conclusion can be drawn from the isoquant maps, as discussed below.

- To achieve a given level of morbidity, a minimum coverage of safe water or sanitation is required. For example, to maintain the morbidity of waterborne disease at level of 31 per 1000 (the mean value of our data), it is necessary to have a safe water coverage of 45% at a sanitation coverage of 100% or a sanitation coverage of 8% at a safe water coverage of 100%. These minimum values can be seen in Fig.1 by drawing a perpendicular from the 45% point on the abscissa, indicating the minimum value of sanitation coverage. Table 4 shows the minimum values of safe water and sanitation coverage for the four morbidity levels selected.
- There is a limit to the reduction in the morbidity of waterborne disease and diarrhea that can be produced by safe water supply and sanitation interventions only. These

limits are illustrated by the isoquant that are furthest from the origin (15 per 1000 for *MWB* and 10.5 per 1000 for *MDR*).

- If any one input is held constant at the current coverage level, i.e., at the mean value of *WTR* or *SAN*, it is impossible to reach the most distant isoquant curve (the lowest morbidity level) by increasing the coverage of the other variables to 100%. Fig.1 (points A, B, and P) and Fig.2 (points C, D, and P) show that the existing mean coverage (*WSS*: 56%; and *SAN*: 39%) is well below the level needed to minimize morbidity if the only controlled variables are provision of safe water and sanitation.

Fig 1. Isoquant curves of morbidity from waterborne disease (point A, B, and P are explained in the text)

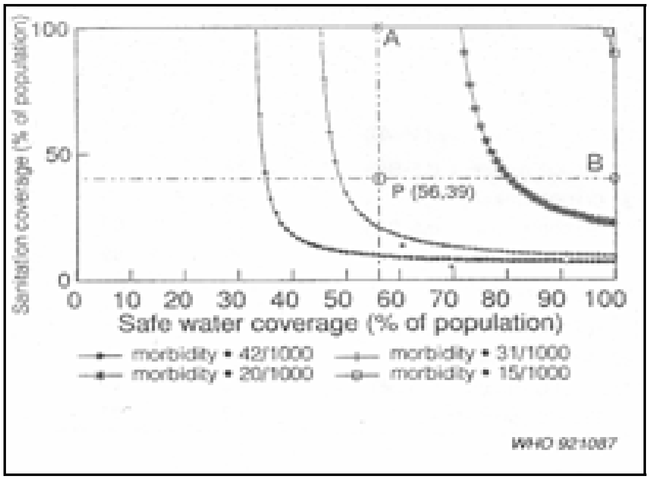
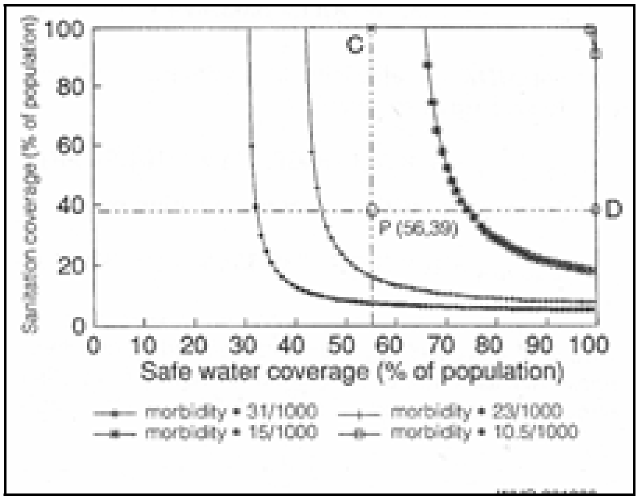


Fig 2. Isoquant curves of morbidity from diarrhoea (point A, B, and P are explained in the text)



To illustrate how morbidity declines if the levels of the inputs changes, we show below the expressions for the elasticity of production. For *MWB* the elasticity of production with respect to safe water supply ($\xi_{WTR\text{-}MWB}$) is given by:

$$\xi_{WTR\text{-}MWB} = 1346.6\ SAN/(1346.6SAN + 136.1\ WTR$$

while the elasticity of production with respect to sanitation ($\xi_{SAN\text{-}MWB}$) is given by:

$$\xi_{SAN\text{-}MWB} = 136.1\ WTR/(1346.6SAN + 136.1\ WTR$$

For *MDR* the elasticity of production with respect to safe water is given by:

$$\xi_{WTR\text{-}MDR} = 938.5\ SAN/(938.5SAN + 101.5\ WTR$$

and the elasticity with respect to sanitation by:

$$\xi_{SAN\text{-}MDR} = 101.5\ WTR/(938.5\ SAN + 101.5\ WTR$$

Table 4. Minimum requirement for the coverage of save water (*WTR*) and sanitation (*SAN*) at four morbidity levels

	% coverage for:	
Morbidity level	***WTR***	***SAN***
Waterborne disease (*MWB*)		
41.7/1000 (mean + 0.5 SD)	33	5
31.0/1000 (mean)	45	8
20.2/1000 (mean - 0.5 SD)	71	20
15.0/1000 (best case)	99	89
Diarrhoea (*MDR*)		
31.0/1000 (mean + 0.5 SD)	31	5
23.1/1000 (mean)	42	7
15.2/1000 (mean - 0.5 SD)	66	17
10.5/1000 (best case)	99	91

From these expression it can be seen that the values of ξ_{WTR} and ξ_{SAN} for both morbidity of waterborne disease and diarrhoea are always <1. in other words, if the coverage of ether *WTR* or *SAN* is multiplied by a positive constant, *m*, while the coverage of the other is held constant, the morbidity of waterborne disease and diarrhea decline by less than 1-1/*m*. For example, doubling the sanitation coverage while holding *WTR* constant less than halves the morbidity.

The sum

$$\xi_{WTR\text{-}MWB} + \xi_{SAN\text{-}MWB}$$

is equal to the elasticity of production of *WMB* (ξ_{MWB}) and the sum

$$\xi_{WTR\text{-}MDR} + \xi_{SAN\text{-}MDR}$$

to be elasticity of production of *MDR* (ξ_{MDR}).

We can easily see that both ξ_{MWB} and ξ_{MDR} are always equal to one. Thus, the production functions to *MWB* and *MDR* exhibit constant return to scale. Therefore if we multiply safe water and sanitation coverage by a positive constant, *m,* the morbidity of the waterborne disease or diarrhoea decreases by 1-1/*m*. For example, if the coverage of both safe water and sanitation are simultaneously doubled, the morbidity of waterborne disease and diarrhoea will be halved. Table 5 shows the potential morbidity reduction resulting from various levels of input.

Table 5. Expected reduction in morbidity if sanitation (SAN) and water (WTR) inputs are increased simultaneously or if one input is held constant while the other is changed.

Both inputs changed			Both inputs changed			WTR held constant		
% Input increase	**% MWB reduction**	**% MDR reduction**	**% WTR increase**	**% MWB reduction**	**% MDR reduction**	**% SAN increase**	**% MWB reduction**	**% MDR reduction**
1	1	1	1	1	1	1	0	0
50	33	33	50	29	29	50	4	5
75	43	43	75	37	37	75	5	6
100	50	50	100	44	43	100	6	7
200	67	67	200	58	58	200	9	9
300	75	75	300	65	65	300	10	10
400	80	80	400	70	69	400	10	11

Along an isoquant one input can be substituted for another to maintain the same morbidity level. The elasticities of substitution between safe water and sanitation (η) are constant (0.5) for both the MWB and the MDR production function. Hence at any level of morbidity, safe water and sanitation exhibit a low and constant substitutability.

Discussion

This study has provided additional evidence that safe water and sanitation are efficacious improving health status (*5-7, 11*). The health production functions that fit the data best have a reciprocal form, and both safe water and sanitation are significant regressors for morbidity from waterborne disease as a whole, and for diarrhoea in particular.

Some workers have suggested that provision of sanitation may be more efficacious than safe water in reducing morbidity from waterborne disease (2, 24); our findings, however, indicate hat a safe water supply is more important than sanitation (sanitary excreta disposal) in this respect. If there are budget constraints, investment is provision of safe water should therefore be given higher priority than investment in sanitation.

The above suggestion does not mean that investment in sanitation is unimportant. First, safe water and sanitation have a low substitutability, making it relatively difficult to replace one input with another while maintaining the same morbidity level. Second, a reduction in morbidity is unlikely to be maximized (in relation to increase investment) if an increase in safe water coverage is not accompanied by an increase in sanitation coverage. Finally, if the sanitation coverage falls below the minimum level required to achieve a particular targeted a morbidity level, this target will not be achieved even if safe water coverage is increased to 100%. Consequently, if health policy aims at maximizing health status in relation to investment, i.e. minimizing morbidity levels, the coverage of safe water and sanitation facilities must both be increased simultaneously.

We estimated the reduction in morbidity resulting from a given increase in safe water and/or sanitation coverage. This differs from the case-control approach (*5-7*), which estimates the reduction in morbidity caused by a shift from “not being exposed to safe water/sanitation facilities” to being exposed to such facilities”. Thus, the case control method implies an increase from zero to 100% coverage, which was not necessarily the situation in our study.

We calculated a larger reduction in morbidity than that reported by other workers (*5-7*). The 20% morbidity reduction reported in these studies requires an increase from zero to 100% coverage. In our study, the same reduction was produced by a 25% increase in safe water an sanitation coverage.

Fig. 1 and 2 show that id safe water and sanitation coverage are maximized (equal to or almost equal to 100% coverage), total eradication of waterborne disease and diarrhoea is unlikely. Other parameters such as habitat and socioeconomics factors also influence their incidence.

The approach used in our study is not intended to be a substitute for the case control method permit in depth observation of an individual’s health status with greater capability for controlling the confounding variables; however, the possibilities for model exploration are limited because of its binary- dependent variable. Our approach used community observations and has a greater potential for model exploration (a quantitative dependent variable is used); however its ability to control the confounding factors was lower because of data limitations.

The study demonstrates how proper medical record and/or surveillance data can be used to assess the relationship between health inputs and community health status. The quality of medical record and/or surveillance data, particularly morbidity record, plays an essential role in this case. As discussed above, the morbidity data collected may be an underestimate, even though strenuous effort were made to obtain complete data. Thus, it is necessary to developed an improved medical or surveillance record system that incorporates data from all medical facilities, including health centres, clinics, hospitals, and private practitioners. This will not only be beneficial for research purposes, but also for health planning and policy making.

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Annex

Explanation of the production economics terms used in the text

- The *Production Function* expresses the maximum output that can be produced as a mathematical function of a set of variable inputs, at a given technological level.
- *Marginal productivity* is the variation in total output if the quantity of an input is increased infinitesimally, holding the quantity of other inputs constant.
- *An isoquant curve* represent all combination of inputs that yield the same level of output.
- *The elasticity of production* measures the proportionate change in all inputs. The elasticity of production with respect to an input measures the proportionate change in output relative to the proportionate change in that input, holding other inputs constant.
- *Constant returns to scale* occur when the output increases m-fold if all input are multiplied by a positive constant, m, i.e., the value of the elasticity of production is equal to unity.
- *Elasticity of substitution* is a measure of how "easy" it is to substitute one input for another along an isoquant. Low substitutability between inputs occurs if the value of the elasticity of substitution is below unity.