Chapter 4.2

PhD Thesis Childhood diarrhoea and its prevention in Nicaragua

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.

Determinants of Domestic Water Use in Rural Nicaragua

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Summary

In order to investigate the factors affecting domestic water use in rural areas of developing countries, an analysis was performed of water consumption estimates from 1029 different households in Nicaragua collected between May 1986 and December 1988. Eight of the 22 variables hypothesised to be related to per capita domestic water consumption, were included in the final multiple regression model. These were; household size, site of clothes washing, the type of water source, mother's and father's levels of schooling, distance to the water source, wealth, and ownership of cattle. According to this model, a decrease in the distance to the water source from 1000 to 10 metres is associated with an increase in per capita water consumption of 20%. Similarly, families where the mother has 6 years of schooling use 17% more water than families where the mother has had no formal education. The same difference in the father's schooling is associated with 12% greater per capita water consumption. A better understanding of the factors affecting domestic water use is needed to improve the design of interventions aimed at reducing the transmission of water-washed disease in developing countries.

Introduction

It is has now become apparent that the quantity of water used for the purposes of domestic and personal hygiene is an important factor in the control of diarrhoea (and possibly other faecal-oral diseases) (Esrey & Habicht 1986; Esrey *et al.*1985; Victora *et al.*1988; Sandiford 1989). Increasing domestic water use in many settings is believed to be at least as effective in preventing diarrhoea morbidity and mortality in children as improving the microbiological quality of drinking water (Cairncross 1987). In fact, some of the spectacular failures of water supply interventions to improve child health and survival can be attributed to the absence of any significant increase in domestic water consumption by the intended beneficiaries (Kawata 1978; Schliessman 1959).

There is therefore clearly a need to develop water supply and health promotion interventions which raise per capita domestic water consumption and/or increase the proportion of domestic water used for purposes of domestic and personal hygiene. A review of the published literature revealed a poverty of information on the factors related to domestic water use in rural areas of developing countries.

Given the well-recognised public health importance of childhood diarrhoea in developing countries, such a gap in our knowledge is of some significance. This paper presents an investigation of the variables related to water consumption obtained from a large case-control study of diarrhoea performed in rural Nicaragua from May 1986 until December 1988. It is not intended to be a definitive study of all the possible factors which combine to determine behavioural patterns of water use. Rather, it is an exploratory analysis of certain correlates of rural domestic water use, with a view to contributing to the design of health promotion programmes which maximize the quantity of water used for domestic and personal hygiene, with or without structural improvements in rural water supplies.

Material and methods

The study was carried out in Villa Carlos Fonseca, a rural municipality on the Pacific coastal plains of Nicaragua with a population of approximately 30 000. Children under the age of 5 years who presented with diarrhoea to health facilities in the study zone were matched by age and clinic to children presenting with non-diarrhoeal illnesses (mainly acute lower respiratory tract infections). A total of 1228 episodes of diarrhoea and 1228 control illnesses were recruited to the study. Trained interviewers collected data on a variety of factors from female heads of household at their homes. These included reported daily water consumption, the types of water source, distance from the house to the water source(s), the ownership of cattle and presence of domestic animals, the parents' occupations and levels of education, indicators of socio-economic status, and household size including the proportion of inhabitants under the age of 5.

Water consumption estimates were not collected from houses with piped water as the precision of the data was likely to be low. Therefore water consumption figures were available for only 1962 of the 2456 interviews. The selection procedure used for the case-control study was such that children could be recruited on more than one occasion so some homes were visited more than once. The 1962 figures for water consumption were thus obtained from a total of 1455 separate interviews, of which 1029 were initial visits and 426 were repeat visits (after an interval of at least 3 months). The repeatability of the mothers' water consumption estimates was assessed by comparing the rates given at the initial visit with those obtained in the repeat interview. Only the first home visits were used in the analysis of the factors relating to domestic water consumption.

Per capita daily domestic water consumption (PCWC) was obtained by dividing total daily water consumption by the number of household inhabitants. The total water consumption was calculated by the computer programme for data entry which multiplied the volume of each water container by the number of times it was filled in a day. The fact that there is little variety in the bucket size used for water collection in Villa Carlos Fonseca made it a simple matter for field workers to estimate the volumes. The result was then tested for association with 22 factors which could potentially influence it, using a linear regression model.

Following the recommendations of MacClure and Willett (1987), the measurement of repeatability for the continuous and ordinal scale variables was evaluated by the intraclass (i.e. within household) correlation coefficient. For indicator variables, repeatability was measured using the kappa score which takes into account the degree of concordance to be expected by chance alone (Fleiss 1981). Negative kappa scores indicate less concordance than that which would be expected by chance. Positive kappa scores suggest better concordance than that expected by chance with kappa scores of 1 representing perfect agreement between the repeated measurements. For dichotomous variables, it is generally accepted that values below 0.40 imply poor repeatability, 0.40 to 0.75 good repeatability, and values above 0.75 indicate excellent repeatability (Fleiss 1981). It is important to bear in mind that kappa scores for variables with more than two categories tend to be lower than those for dichotomies. In the statistical analysis, the natural logarithm of daily per capita domestic water consumption log(PCWC) was used as the dependent variable in fitting a linear model by analysis of covariance. The transformation was performed in order to make the variance of log(PCWC) approximately the same for each value of the independent variables and to normalise the distribution of the residuals. The final model was arrived at by stepwise inclusion of the variable which at each stage gave rise to the greatest statistically significant ($P<0.05$) improvement in the goodness of fit. At the same time, any variable whose exclusion did not significantly reduce the goodness of fit was removed from the model at each stage. Interactions between the hypothesized factors were also assessed for statistical significance.

Table 1. Repeatability of measurement of the parameters studied.

Variable	Intraclass Correlation Coefficient
Continuous variables	
Total daily water consumption	0.57
Household size	0.64
Per capita water consumption	0.45
Log (Per capita water consumption)	0.44
Mother's level of schooling	0.89
Father's level of schooling	0.79
Distance to the water source	0.65
Log (Distance to water source)	0.73
No. houses sharing water source	0.71
No. of under 5 year-olds	0.51
Frequency of drawing water*	
children	0.45
women	0.41
men	0.44
Indicator variables	Kappa score
Type of water source	0.84
Site of clothes washing	0.58
Site of bathing	0.59
Presence of a latrine	0.75
Literacy of mother	0.77
Literacy of father	0.67
Mother's occupation†	0.56
Father's occupation†	0.68
Type of flooring in house	0.74
Electric power	0.76
Domestic animals owned	
pig	0.47
horse	0.57
poultry	0.32
cattle	0.66
Ownership of land (yes/no)	0.60
Drinking water protection	0.31

* Ordinal variables with three levels corresponding to 'usually', 'sometimes' and 'never'.
† These variables each have four levels of classification. All others are dichotomous.

Results

Table 1 lists the 22 factors hypothesized to be related to PCWC and presents the repeatability estimates for each.

The variables included in the final regression model are shown in Table 2. Although it was found that PCWC is greater when men contribute to water collection, this variable was not included in the final regression model because it was felt that the involvement of men in water collection may be a consequence of high rates of PCWC rather than a cause. None of the interactions tested were found to be statistically significant. In particular, the likelihood of the child suffering from diarrhoea was found to be unrelated to per capita domestic water consumption wether as a main effect or as an interaction term.

Table 2. Variables included in the final regression model of water consumption

Variable	Coefficient	Std error	*t*-Value
Household size	-0.0761	0.0059	12.82***
Site of clothes washing	-0.2461	0.0517	4.77***
Type of water source	-0.1731	0.0472	3.66***
Mother's level of schooling (years)	0.0267	0.0083	3.22**
Father's level of schooling (years)	0.0190	0.0073	2.67**
Log (distance to the water source)	-0.0401	0.0156	2.56*
Type of flooring in the house	-0.1147	0.0503	2.28*
Ownership of cattle	0.0785	0.0386	2.04*
Constant term	4.0186	0.0842	47.75***

* $P<0.05$; ** $P<0.01$; *** $P<0.0005$

As the dependent variable in the regression model was the natural logarithm of PCWC, the coefficients obtained represent relative rather than absolute differences. The effect of each variable is therefore best expressed in terms of the associated percentage increase or decrease in PCWC. These differences are summarized in Table 3 which shows mean values and the percentage change in PCWC for each level of the variables included in the final model. The effect of water availability (as measured by the distance from the home to the main water supply) on PCWC is portrayed in figure 1. It was found that a logarithmic transformation of the distance from the home to the water source improved the fit of this variable in the regression model. The crude PCWC rates (and their 95% confidence limits) were calculated by taking the geometric mean PCWC within log-distance intervals of equal size.

Discussion

The repeatability of the mother's daily per capita domestic water consumption estimates was not very high, perhaps owing to the fact that PCWC is calculated as the ratio of two other variables (total daily household water consumption and the number of household inhabitants), each of which is subject to measurement error. As no objective measure of PCWC was obtained, it is uncertain to what extent these estimates reflect actual rates of water consumption. Cairncross and Cliff (1987) found that observed domestic water consumption

was quite similar to reported water consumption in a study performed in Mozambique, though the estimates were obtained from different samples of the population. No published research has been identified which directly compares observed with reported rates of water consumption. It would be valuable to know how accurately women estimate their household water consumption. This would permit comparisons of the relative efficiency of observation versus interview as data collection methods for studies of water use.

Table 3. Levels and changes in PCWC associated with the indicator variables included in the regression model.

Variable	Mean PCWC (l/person/day)	Crude % change	Adjusted % change
Site of clothes washing			
in the home	32.8		
at the river	20.7	-36.9	-21.8
Ownership of cattle			
not owned	24.0		
owned	23.1	-3.8	8.2
Flooring of house			
tile or concrete	29.7		
clay	22.4	-24.6	-10.8
Type of water source			
protected well	27.7		
river/spring/unprotected well	18.2	-34.3	-15.9
Mother's level of schooling*			
nil	19.9		
3 years	23.1	16.1	8.3
6 years	27.5	38.2	17.4
9 years	37.2	86.9	27.2
Father's level of schooling*			
nil	20.5		
3 years	23.4	14.1	5.9
6 years	28.0	36.6	12.7
9 years	23.9	16.6	18.7
Household size*			
4 persons	32.9		
8 persons	23.3	-29.2	26.2
12 persons	18.8	-42.9	45.6
16 persons	23.7	-28.0	59.9

* Crude and adjusted percentage change is in relation to the minimum level shown in the table.

Of the total variance explained by the regression model (28.7%), a large proportion (12.3%) was attributable to just one variable, namely household size. The inverse correlation between

PCWC and household size can be explained by the economies of scale in certain activities requiring water, such as cooking and cleaning the house. Only a minority of water uses (e.g. drinking and bathing) can be expected to increase in direct proportion to the number of people living in the house. Household size has consistently been found to be inversely related to PCWC in previous studies (Darr *et al.* 1975; Feachem *et al.* 1978; White *et al.* 1972; Wong 1987).

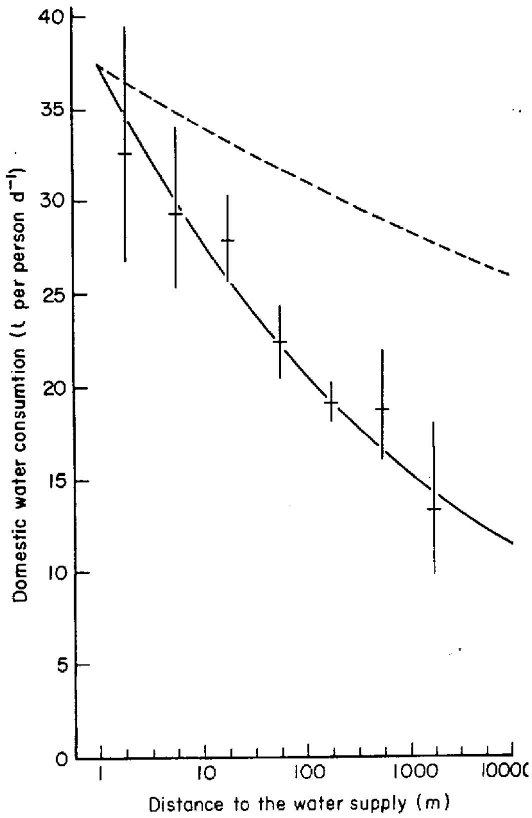

Figure 1. The relationship between water consumption and the distance from the house to the water supply. ———, Crude regression line; - - - - - - , adjusted regression line. Bars represent mean and upper and lower 95% CI.

The importance of the site of clothes washing is mostly a consequence of the way PCWC was measured. Water consumption estimates by female heads of household pertain only to water carried home. They do not include water which is used for washing clothes at the source. Furthermore, those families which wash clothes at the river generally bathe there too. Though the site of bathing was also included in early regression models, it became statistically insignificant when the site of clothes washing was introduced. Obviously, the high level of collinearity existing between the site of clothes washing and the site of bathing makes it difficult to separate the independent effects of one from another. The 21.8% lower PCWC in households washing clothes at the riverside compared with those who perform their laundry at home is thus an indication of water used for bathing as well as for clothes washing.

A statistically significant relationship was identified between water availability and PCWC. This is consistent with results from research in Thailand (Frankel & Shouvanavirakul 1973), but not all investigations have demonstrated such a correlation. In studies performed in Lesotho (Feachem *et al*. 1978) and in East Africa (White *et al*. 1972), per capita water use did not decrease significantly for unpiped rural areas until the source was at least 1 km from the home. The constraints of linear regression modelling prevent one from defining the shape of the adjusted distance/PCWC curve, but it is interesting that the crude relationship shows some similarity to the model postulated by Cairncross (1987) on the basis of studies in Africa. According to this model, PCWC increases sharply when water is supplied to the home or yard but flattens out for return journey times from 10 to 30 minutes and then decreases gradually for distances greater than 1 km. The crude rates plotted in Figure 1 offer some support for this model. For water sources up to 18 m from the house, PCWC varies little. From 18 to 180 m PCWC drops from 27.9 to 19.1 l per person d^{-1}. There is then virtually no change in PCWC for distances up to 560 m. PCWC falls again from 18.7 to 13.2 l per person d^{-1} between 560 and 1800 m.

It should be recognised, however, that these are crude rates which do not allow for factors such as the change in site of clothes washing which could partly explain the observed falls in PCWC. It is for this reason that the slope of the unadjusted regression line is much steeper than the adjusted regression line. It seems that as distance from the house to the water source increases, people change their patterns of water use; more families bathe and wash clothes at the river rather than carry the water to their homes. Nevertheless, there remains a small but statistically significant, independent effect of water availability on PCWC. This was also found by Frankel and Shouvanavirakul (1973) who noted that when public standpipes were far from villagers' houses (they do not state how far), washing and bathing occurred at the site of water collection, but even allowing for this change in the pattern of water use, PCWC was still higher in the villages with closer water sources.

A close relationship was found between water consumption and the type of household flooring (clay versus concrete or tile), a variable found to be a good indicator of wealth in this setting (Sandiford *et al.* 1989). The correlation between wealth and PCWC persisted even after controlling for water availability, education levels, the ownership of cattle, household size and the site of clothes washing (although the relationship was weaker). Other studies have also observed associations between water consumption and socio-economic indicators (Darr *et al.* 1975; White *et al*. 1972; Wong 1987). There are several reasons why poor people might consume less water. On the one hand they may have fewer tools or equipment associated with water use, smaller gardens, or fewer containers and less time to draw water. On the other hand, there may be cultural factors such as differences in hygiene practice between the wealthy and the poor. The relative importance of cultural factors in domestic water use is supported by the associations which have also been noted with parental schooling (Darr *et al*. 1975; Wong 1987) and race (Darr *et al.* 1975) and by White and colleagues' finding that PCWC 'seems to be more sensitive to gross differences in material wealth from one area or culture to another than within such groups'.

Parental schooling emerged as a particularly strong determinant of PCWC in this analysis. The mother's and the father's levels of education each independently predicted PCWC. Other studies have either found no relationship with schooling (White *et al*. 1972) or have not distinguished between male and female levels of education (Darr *et al.* 1975; Wong 1987). In Nicaragua, the father's level of schooling is probably a reasonable proxy for family income while the mother's level of schooling may indicate more cultural family characteristics such as hygiene practice. More work is needed to identify the precise mechanism by which education affects PCWC.

PCWC was significantly higher in households drawing water from protected wells than from unprotected shallow wells, springs or rivers. One reason may have been the limited capacity and flow of water from unprotected wells and springs. It is customary to 'clean' these wells by emptying them with a small basin before and allowing them to refill before drawing water (Sandiford *et al*. 1989). This takes about 30 minutes in the dry season and thus adds considerable time to daily water collection. Another possible reason for the lower PCWC associated with these sources is that the riverbeds where they are found are often at the bottom of steep paths. The importance of terrain has been mentioned by White *et al.* (1972).

No significant variation in water consumption between the dry and wet seasons was detected in this study. This is consistent with results from East Africa (White *et al.* 1972), but in Thailand, rainwater collection during the wet season reduced the demand from piped water sources. In contrast, rainwater use is not common in this area of Nicaragua.

Families with cattle had higher rates of PCWC than those without, but only after controlling for the other variables in the model. The 8.2% difference in PCWC is likely to be an underestimate as in some cases cattle were watered from a different source so their consumption was not included as a part of domestic water use.

The multiple regression model developed in this analysis, while a useful first approximation is undoubtedly deficient in several respects. Only a small proportion of the total variance in water consumption estimates was explained by the various factors tested. Although much of the residual variance could be accounted for by measurement error associated with the rather low repeatability of the mother's water consumption estimates, there are also factors which have been found to be significant in other studies which were not tested in this analysis. They include the size of the water container, the number of baths per day, and family income.

One should note that PCWC was found to be unrelated to the case/control status of the child suggesting that water consumption may not be an important risk factor for childhood diarrhoea in rural Nicaragua. However, in another analysis it was found that the distance from the house to the water source (i.e. the availability of water) was significantly associated with diarrhoea (Sandiford, 1989). A likely explanation for this is the low repeatability of water consumption estimates (as measured by the intraclass correlation coefficient), compared with the repeatability of water availability measurements. This could mean that the distance from the house to the water source is actually a better proxy for the quantity of water used in hygiene-related activities than the per capita domestic water consumption estimate itself, especially since the water used by a family for the practice of hygiene may be only a small proportion of total daily water consumption.

It is clear from this analysis that several factors are important determinants of domestic water consumption. Those most likely to be related to the amount of water used for hygiene practice (and therefore to diarrhoea morbidity) are the mother's and father's level of schooling, the distance from the home to the water source, and the type of water source. Given the strength of the association between water supply and schooling, it may prove more cost-effective, in some settings, to increase domestic water consumption for hygiene (and thereby reduce child diarrhoea morbidity) by educational interventions than by structural improvements in water supplies.

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