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CHILD SURVIVAL AND
ENVIRONMENTAL HEALTH INTERVENTIONS:
A Cost-Effectiveness Analysis

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I INTRODUCTION

1.1 Background

This paper argues that to achieve the maximum health impact from limited funds, agencies like USAID should give environmental health[1] interventions more prominence in child survival programming. Environmental health interventions are environmentally based preventive measures, such as changing hygiene behaviors to increase the health impact of water supply and sanitation hardware, or destroying vector breeding sites, or substituting non-polluting for polluting fuels.

Environmental health interventions prevent illness by reducing exposure to adverse environmental conditions and by promoting behavioral change. Traditionally most public health issues were environmental health problems. It is only in the context of international health programs that delivery of subsidized clinically or medically based curative interventions (which are "private goods") have been become such an important element of public health activities. Historically public health was concerned with supplying preventive "public goods".

USAID's child survival strategy gives prominence to a "package" of interventions including immunization for childhood diseases, breastfeeding, vitamin supplementation, and oral rehydration therapy (ORT) for the treatment of severe diarrhea. These low-cost interventions, which are delivered to child and mother, are funded through the health sector. Recent innovations—for example, the Integrated Management of Childhood Illness (IMCI)—have tried to increase the effectiveness of health staff by combining interventions, integrating case management across disease complexes, and incorporating low-cost preventive interventions such as food hygiene education. However, despite enormous progress over the last two decades there has been a plateauing of reductions in child mortality and morbidity. New environmental conditions in urbanizing societies and demographic transformation have created new problems which threaten the sustainability of progress made over the last two decades.

Health planners and program designers in most agencies usually use at least some form of cost-effectiveness analysis for deciding which interventions to include in their programs, and which to exclude. In essence, cost-effectiveness analysis compares program costs to program performance as measured by health impact. It appears to be straightforward, is widely cited in discussion of policy issues, and is more easily understood than cost-benefit analysis, in which benefits are measured in money and not health terms. For example, the present package of child survival interventions for the control of diarrheal diseases has been justified in terms of high cost-effectiveness, i.e., a low dollar cost per unit of effect. Recent studies of international health policy put the cost-effectiveness of IMCI for diarrheal diseases in the range of $30-$100 per DALY (disability-adjusted life year) saved (Murray, Lopez, and Jamison 1994). For diarrheal diseases in children less than five, a cost of $100 per DALY saved corresponds to approximately $3,000 per death averted.

One of the reasons that current child survival packages do not include environmental health interventions is that they are not perceived to be cost-effective or considered the responsibility of mainstream health service providers. The origins

[1] Environmental Health is defined as "the body of knowledge concerned with the prevention of disease through control of biological, chemical or physical agents in the air, water and food, and the control of environmental factors that may have an impact on the well-being [health] of people." (Listorti 1996).

of this view can be traced to an influential short article by Walsh and Warren, published in 1979. Using the logic of cost-effectiveness and the goal of child survival, the authors argued the case against a broad public health strategy in favor of a strategy of *selective* primary health care: with a limited budget, select only the most cost-effective interventions to achieve maximum health impact. In their analysis, the gross disparity between the cost-effectiveness of water supply and sanitation, costed at $10,000 per death averted in 1996 prices, and selective primary health care, costed at $600-750 per death averted in 1996 prices, seemed to many a justification for ignoring water supply and sanitation. Other reasons for favoring the child survival interventions currently in the package had to do with ease of implementation, simplicity, and feasibility of management. However, cost was a prime factor.

1.2 Goal of the Paper

This paper presents a cost-effectiveness methodology that differs fundamentally from the Walsh and Warren analysis, which assumed that the health sector bore the costs of water and sanitation infrastructure. When cost-effectiveness analysis is applied correctly to environmental health interventions, the costs should be *limited to those which have to be financed from the health sector budget and which lead to health impact*. In the case of controlling childhood diarrhea, for example, the relevant cost for the health sector is that which is required to ensure adequate hygiene, whereas the cost of water supply and sanitation infrastructure is financed by some combination of user fees and public investment subsidies (even public health subsidies may not be channeled directly through the health budget). Water supply and sanitation coverage cannot be significantly impacted by the health sector, due to the high costs involved.

To produce positive health impact on diarrhea morbidity and mortality, three components are necessary, as shown in the box below.

The first two components are not health-sector interventions, although the health sector should influence the design of infrastructure and even how it is operated for health results. Only the third element is the responsibility of the health sector.

When cost-effectiveness analysis is limited to health-sector costs, environmental health interventions are clearly as cost-effective as many of the well-known child survival interventions. The disparity of Walsh and Warren disappears.

1.3 Organization of the Paper

The new model of cost-effectiveness is presented in six chapters. Following this brief introduction, Chapter 2 describes a framework developed by the Environmental Health Project (EHP) for integrating environmental

		Components			➜	Results
1. Water Supply Infrastructure	+	2. Sanitation Infrastructure	+	3. Ensuring Adequate Hygiene	= Health	Expected Impacts

health interventions with child survival. Chapter 3 discusses the impact and effectiveness of hygiene interventions that can be used to control childhood diarrhea. These will be used as an example to show how the cost-effectiveness model can be applied. Chapter 4 explains the principles underlying the proposed cost-effectiveness model and how the costs of the interventions were estimated. Chapter 5 presents the results obtained by applying the model. Chapter 6, the final chapter, presents conclusions and recommendations.

2 AN ALTERNATIVE FRAMEWORK: PREVENTION PRESERVES WELLNESS

EHP has developed a “well child” framework to show how environmental health can complement child survival programs (see Figure 1). The framework diagram lists representative environmental health interventions designed to block breeding, transmission, and human exposure to disease agents that cause the three major childhood diseases. The framework complements IMCI and further moves child survival programs in a direction which is explicitly “demand driven” and decentralized (Murphy, Stanton, and Galbraith 1996). Environmental health interventions respond to the needs of mothers, families, and communities who want to acquire new knowledge and improve environmental conditions. They can have a significant impact on health using their own resources, including social capital.

Effective environmental health strategies coordinate social marketing and health education as well as monitoring and support of ongoing development activities. A key recommendation emanating from the framework is that health planners cooperate with other sector partners, such as municipal governments and water supply and sanitation utilities, that are responsible for complementary activities—for example, water supply and sanitation hardware and services. This alternate framework for child survival promises to be more sustainable than a program consisting solely of facility-based curative and preventive services that are heavily dependent on central government budgetary support.

Since many environmental health interventions rely upon mobilizing community efforts and “piggy-backing” on development activities financed by other sectors, health sector budgetary costs can be kept low. Many of these other activities will take place regardless of what the health sector does. Widening the scope of prevention by including interventions that address the major environmental causes of childhood morbidity and actively fostering coordination with complementary development activities in other sectors will make child survival programs more effective. Many activities with an impact on the environment, both privately and publicly financed, affect children’s health—water supply, drainage, and irrigation are good examples. However, most of these activities are carried out independently by agents from the other sectors without any health sector involvement.

In activities coordinated among sectors, each partner can commit to financing some investment and operations expenditures for their own sector’s ends, while complementing the effectiveness of each other’s interventions. For instance, if the health sector funded basic market research on soap and handwashing, the results could be used to persuade corporate producers of household soap to add prevention of childhood diarrhea to the marketed attributes of the product. Or, the health sector could capitalize on the willingness of commercial, plantation, and industrial interests to contribute to preventive public health measures for malaria control, such as spraying and environmental management, which reduce sickness and increase the productivity of the labor force.

Some further examples of health-sector-funded environmental health interventions are suggested in Figure 1. All sample interventions in one way or another create barriers against the agents of the three priority disease

Figure 1: Prevention Preserves Wellness

Pathways to Improved Child Survival and Maternal Healt

SAMPLE COMMUNITY AND HOUSEHOLD INTERVENTIONS

	Inhibiting Breeding Multiplication, & Production of Disease Agents →	Interrupting Transmission or Emission of Disease Agents →	Reducing Exposure to Disease Agents
Preventing Diarrheal Disease	✶ Proper maintenance of water supplies ✶ Protection of food supply ✶ Proper food storage ✶ Excreta disposal	✶ Protection of drinking water ✶ Disposal of food that might be contaminated ✶ Handwashing ✶ Reduction of solid waste ✶ Corralling livestock to limit zoonotic transmission ✶ Reduction of fly breeding sites	✶ Purification of drinking water ✶ Proper cooking ✶ Proper infant feeding practices ✶ Personal protection: wearing shoes
Preventing Malaria	✶ Application of larvicides ✶ Reduction of breeding sites ✶ Appropriate agricultural practices ✶ Proper maintenance of water supplies	✶ Vector diversion ✶ Residual spraying ✶ Surveillance/early treatment to reduce disease reservoir	✶ Domestic protection: screening ✶ Personal protection: bednets, protective clothes, insect repellents
Preventing Acute Respiratory Infection (ARI)	✶ Use cleaner fuels ✶ Reduce burning of solid waste ✶ Reduce agricultural burning	✶ Use of efficient, vented household stoves ✶ Improve household ventilation ✶ Street sweeping	✶ Reduce activity on high pollution da ✶ Move cooking fires outdoors ✶ Keep children away from smoky coo

Other Child Survival Interventions Also Contribute to Wellness	✶ Immunizations ✶ Oral rehydration ✶ Breastfeeding ✶ Prevention of low birth weight (birth-spacing, antenatal care) ✶ Micronutrients ✶ Prompt diagnosis and treatment

complexes—diarrhea, malaria, and acute respiratory infections (ARI). Thus, environmental health interventions may target the breeding of disease vectors, such as malarial mosquitos, through spraying or through control of irrigation flows and drainage. Preventing a disease, such as cholera, from reaching the household can be achieved by appropriate sanitation practices and public sewerage facilities. At the household level, the manner in which children's and adults' excreta are handled and disposed, which in turn has an impact on the hygiene of food preparation, is another level at which diarrheal disease transmission can be interrupted.

In addition to the interventions shown in Figure 1, other types of preventive interventions that target environment and behavior are possible.

- *Project design:* modifying the design of development projects to achieve positive health impacts.
- *Surveillance:* monitoring and reporting on water quality and water-borne diseases.
- *Marketing:* social marketing of water supply and sanitation.
- *Regulation:* drinking water and food safety.
- *Education:* hygiene behavior programs.
- *Advocacy:* the promotion of public health in general.

In principle, interventions in all of these areas can lead to substantial health impacts at relatively low costs to the health budget; they are cost effective even if they have a modest impact on disease incidence.

3 THE EFFECTIVENESS AND IMPACT OF HYGIENE INTERVENTIONS

3.1 The Interventions and Their Effectiveness

Five types of interventions to prevent diarrheal disease were selected to illustrate the cost-effectiveness model. All fall into the general category of hygiene.

- **Excreta hygiene**: disposal of feces and user-friendly designs to encourage use of excreta disposal systems by all family members.
- **Water hygiene**: protection of water sources, safe water storage and handling, and household-level disinfection systems.
- **Personal hygiene**: washing of hands with an abrasive after defecation and handling children's feces, as well as before meal preparation and consuming foods.
- **Food hygiene**: protection of food supply from contamination and food preparation practices to reduce existing contamination.
- **Domestic hygiene**: reduction of pathogen-transmitting vectors through the containment of domestic livestock, as well as wastewater, organic waste, and solid waste management.

A review of 65 water supply and sanitation studies (Solari 1996) was used to estimate the health effectiveness of these interventions as measured in reductions in diarrhea mortality and morbidity. Arriving at a reasonable estimate was difficult for the following reasons.

- Many studies view changes in behavior at the household level as the outcome of the intervention. Or the intervention may be considered an intermediate step to be accomplished before people change their behavior. Results are not expressed by reductions in morbidity and mortality.
- Many factors other than the intervention can explain changes in diarrhea incidence and severity. These confounding variables cannot easily be added and subtracted except under controlled conditions.
- The studies often use non-parametric statistical techniques, which show causation or a significant relationship but not the size of the effect.
- Because the epidemiology of diarrheal disease varies widely geographically, a large number of results are required to draw general conclusions.
- Few studies look at effectiveness under implementation conditions. For example, pilot studies of hygiene education using skilled personnel may not be replicable using ordinary personnel. The results represent an upper bound of effectiveness for the intervention.
- If the order in which an intervention is introduced determines its effectiveness, no single measure of effectiveness can be determined. For example, the conclusion that sanitation is more effective than water supply is usually an artifice of the order of implementation. If the interventions were carried out in the opposite order, water supply might appear more effective than sanitation. This effect is sometimes called synergy or complementarity between interventions. To our knowledge no single study has tried to find out whether combined packages offer substantially greater efficacy than single interventions.

Because the proposed cost-effectiveness model describes health impact in terms of a percentage reduction in the number of cases that occur when the intervention is applied, values were assigned by looking at the range of figures in the literature. A precise point estimate is neither possible nor necessary to be able to categorize interventions as "not cost-effective," "of doubtful cost-effectiveness," or "clearly cost-effective."

The cost-effectiveness model, like the Walsh and Warren study, is based on African conditions. The model presupposes a town of one million inhabitants, most of whom are slum-dwellers or peri-urban residents who receive few formal services from the central or local government. They are characterized by squatting, lack of legal tenure, extreme poverty, an absence of basic infrastructure, and high informal-sector employment. Such areas provide a favorable environment for both existing tropical and emergent diseases.

Two water supply and sanitation related interventions are considered: providing the hardware (i.e., the physical water supply and sanitation infrastructure) and providing the software (i.e., interventions which increase the health-effectiveness of the hardware, in this case the hygiene interventions). The preventive effectiveness of a health software intervention depends on whether or not there is adequate water supply and sanitation coverage. Recall that this model is concerned only with impact on health and takes into account only those costs to be paid from the health budget.

3.2 Scenarios: Software and Hardware Combinations

Only two of four possible scenarios for combining software and hardware interventions are plausible additions to child survival programs. These can be presented as formulas using "SW" for software, "HW" for hardware, a "+" sign for the presence of the intervention, and a "-" sign for its absence. Thus,

- Adding software to hardware: (HW+, SW-) ➜ (HW+, SW+).
- Adding software to inadequate hardware: (HW-, SW-) ➜ (HW-, SW+).

The estimated preventive effectiveness, expressed as the percentage reduction in cases, for these four scenarios is summarized in Table 1. A more complete justification for these values is contained in EHP Applied Study No. 3, "Prevention: Environmental Health Interventions to Sustain Child Survival."

Table 1
Percentage Reduction in Episodes/Year/Child for Four Scenarios

Combinations	**SW+** (Software for health impact present)	**SW-** (Improper use of hardware for health impact)
HW + (Hardware present and used)	**40%** (Base assumption) 30% (Pessimistic) 50% (Optimistic)	**15%** (Base assumption) 10% (Pessimistic) 20% (Optimistic)
HW- (Inadequate or no hardware)	**15%** (Base assumption) 10% (Pessimistic) 20% (Optimistic)	**0**%

Table 2 : Effects of Interventions

Pre- and Post-Intervention	Description	Example of Health Effect Cited i		
		Initial HW Coverage	SW Intervention	Impac
I (HW+, SW-) ➜(HW+, SW+)	Adding software to existing hardware. This is likely to be the most cost-effective intervention. The additional effectiveness in moving from III to II (i.e., from hardware alone, to both hardware and software) is 25%, and the study argues that software costs are low. The preventive effectiveness is assessed to be **25% +/- 5%**.	Tube well/tap access 17%	Hand-washing Child defecation practices	↓ Diar 26%
II (HW-, SW-) ➜(HW+, SW +)	Adding both hardware and software where none currently exists. This corresponds to the traditional treatment of WS&S where the health sector is assumed to be responsible for both hardware and software. Preventive effectiveness is **40% +/- 10%.** Even at this level of effectiveness <u>this is not a cost-effective intervention for the health sector</u>.	None None	Combined SW & HW Combined WS&S hardware +hygiene	↓ Diar rate 25 ↓ Diar 30-50
III (HW-, SW-) ➜ (HW+, SW-)	Adding hardware only. This is <u>not a scenario that is relevant for the health sector</u>. It would be inconsistent to spend large sums on hardware without achieving the full preventive impact. In this scenario, the cost-effectiveness of moving to I is very high. Hardware alone is given a preventive effectiveness of **15% +/- 5%.**	None	None - WS&S hardware only Hardware	↓ Diar media studie (deper “sound ↓ Diar 22-25
IV (HW-, SW-) ➜(HW-, SW+)	Adding software only. Although this scenario assumes there is no coverage of adequate software or hardware, nearly every community, however poor, can establish a rudimentary water supply and method of disposal of wastewater and sewage at low costs. Changes, such as simple pit latrines and safe water containers, should be a precondition for the health sector to invest in hygiene education and other complementary environmental health interventions. A preventive effectiveness of **15% +/- 5%** is assumed for software alone when there is no adequate hardware. This is supposed to represent average conditions and presupposes some preventive effect from existing hardware and practices.	Water - not described Latrines - not described	Hand-washing Disposal of child feces Disposal of animal feces	↓ Diar 11%

The greatest preventive effectiveness is achieved through combining hardware and software: a range of 30% to 50% and a base assumption of 40%. Hardware alone or software alone produces a lesser effect: a range of 10% to 20% and a base assumption of 15%. Table 2 summarizes information from the technical literature that served as the basis for the estimates of effectiveness.

These estimates are used in the next sub-section to calculate impacts in terms of DALYs (disability-adjusted life years) saved and other measures.

3.3 Assumptions Used to Calculate Impact

The model calculates impact in terms of cases averted, deaths averted, and DALYs saved. Explaining the complicated formula used to compute DALYs is beyond the scope of this paper. Briefly, DALYs are the combination of years of life lost to premature mortality and years of life lived with disability (see Murray and Lopez 1995). The assumptions underlying the DALY formula are explained below.

To calculate cost-effectiveness using the model, it is necessary to have data on incidence, the case fatality rate, severity, and age. The assumptions used to arrive at values for these parameters are given below.

Incidence. The maximum incidence of child diarrhea used in the model is 10 cases per child per year, based on the upper range of incidence reported from 276 World Health Organization/Combatting Diarrheal Disease standardized surveys conducted in sixty coun-tries (Martines, Phillips, and Feachem 1993). A summary of these studies reports a mean of 3.5 episodes per child per year within the range of 0.8 to 10.8. An upper limit of 10 represents the incidence under minimal water supply and sanitation and hygiene conditions. This figure is close to the upper limits found in Latin America and the Caribbean (10.4), sub-Saharan Africa (9.9), and the Middle East and North Africa (10.8). High ranges are also reported in a summary of 22 longitudinal studies which use data acquired over a period of one year from biweekly household interviews in 12 country reports. Data from studies in Brazil show up to 15.1 episodes per child per year in children age one and in Peru, 10.6 for children less than age two (Bern *et al.* 1992). Since health officers are more likely to know the average number of episodes a year than the preventive effective-ness of interventions, incidence was selected as one of the key variable inputs to the model. The basic assumption for the model is five episodes per year, lasting 10 days each.

Case Fatality Rate. The case fatality rate (CFR) is the proportion of cases that end in death after disease onset. The case fatality rate for diarrhea in children under five, used as a standard by the U.S. Institute of Medicine (1986), is 2 per 1,000. With the advent of global diarrhea control programs and ORT promotion, the current average case fatality rate is given as 3 per 1,000 (range 1.5 to 5) to reflect developing country situations. These data are calculated from median morbidity and mortality values reported from longitudinal studies (Bern *et al.* 1992). Estimates must be used to represent a situation where no treatment has been offered. It is estimated that approximately 1% of all diarrhea cases will be severe. Without treatment, 70% of these will end in death. This would yield a case fatality rate of 7 per 1,000. The model uses a rate of 0.5% or 5 per 1,000 as representative of conditions in an African township.

Severity. Ranking according to severity is derived from a disability weighting index designed for the World Bank Global Burden of Disease Study (Murray 1994) and is required only for the calculation of DALYs. It converts time lived with a disability (in this case, diarrhea) into equivalent years of life lost. The maximum value is 0.92 for an acute illness. “Disability” is defined as an individual’s inability to perform the following activities: recreation, education, procreation, or occupa-tion. These activities apply more appropriately to adults.

The proposed model assumes that a child ill with diarrhea will have limited ability and probably cannot engage in most childhood activities. Therefore, the model uses the Class 4 disability weight of 0.6. This amounts to saying that 10 episodes of diarrhea, averaging 10 days each, will be equivalent to 60 days or 0.16 years of life lived normally.

Age. Age is the median age at the onset of diarrheal disease. Although the midpoint of the under-age-five group would be 2.5, the distribution of morbidity will not be equal through-out this age span. The model assumes that not all children up to age two are benefiting from the protective effects of breastmilk. Given this scenario, the bulk of morbidity would be dur-ing weaning (6 to 18 months). Therefore, the model uses age one as the median age of onset.

Age is also the basis for another adjustment in the DALY calculation. It is used to weight the value of years lived at different ages according to their socio-economic value. Thus, a young adult family provider of 20 has the highest weight (1.4) and newborn infants (0) and the very old (0.3) have the lowest weights. Applying this weighting factor, the 60 days of diarrhea mentioned above are further reduced by a factor of 0.158 for age one, to an equivalent of only ten days of normal life.

To sum up, the DALY methodology gives ten, ten-day episodes of diarrhea a health impact or value of ten days or 0.027 DALYs.

Discount Rate. The DALY formula introduces one more subjective parameter: a discount rate to adjust the value of future years of life saved for those infants who would have died without the intervention. The model adopts the 3% discount rate used in the World Bank's *1993 World Development Report* (WDR) to calculate disease burden. Like the WDR approach, the impact of an intervention is considered for only one year. In that year the intervention reduces incidence and saves lives. The impact of reducing morbidity is given as disability-adjusted time saved by averting the episodes that would have occurred in the year in question. On the other hand, the impact of averting a death is given as all the future years of the child's life that are saved. These future years are discounted both by the age-weighting factor and the discount rate. For diarrhea interventions targeted at the under fives a good approximation of the health value of saving a child's life is 30 DALYs.

The subjective parameters used in the DALY formula determine the relative health value of morbidity and mortality. If one uses DALYs saved as the measure of program performance, then the WDR's subjective parameters imply that one child death averted has the same health impact as preventing 11,500 episodes of diarrhea. An even more surprising implicit valuation is that one child death averted has the same health impact as preventing 115,000 days of diarrheal disease.[2]

Even though the DALY measure is controversial, the model presents its "average conditions" or "base" cost-effectiveness estimates in terms of dollars per DALY to keep the results on a comparable basis with the WDR. Where the DALY measure should be useful is in comparing preventive and curative interventions. If reducing mortality is used as the sole measure of effectiveness, curative interventions will be favored; if reducing the number of cases is the sole measure, preventive interventions will be favored. DALYs represent a compromise, but they are useful only if the planner understands the methodology. Changing the values of the "subjective parameters" (severity factor, age weight and discount rate) used in computing DALYs can drastically change the relative value of the health impact of preventive and curative interventions.

[2] A child death averted is worth 30 DALYs. One episode of diarrhea lasts 10 days and has a severity of 0.6 = 6 days, multiplied by an age-weighting factor of 0.158 (for the median age of onset of 1 year) = 1 ÷ 365 = 0.0026 of a DALY. Hence 30 DALYs = 11,538 episodes or 1 DALY = 385 episodes. Put another way, if DALYs are used as a measure of program performance, then averting a child death is worth the same measured in health units as preventing 115,000 child-diarrhea days.

4 COSTS AND THE COST-EFFECTIVENESS PRINCIPLE

4.1 Definitions of Cost-Effectiveness and Cost-Effective

“Cost-effectiveness” and “cost-effective” are similar terms with quite different meanings.

- “Cost-effectiveness” is the cost of producing a certain unit of effect through some intervention. Cost-effectiveness is a quality of every intervention, however costly. It can vary for a given intervention depending on the “unit of effect” chosen.
- “Cost-effective” is an adjective meaning “economical” in terms of measurable outcomes produced by money spent. Whether or not an intervention is cost-effective can be determined only by comparing its cost-effectiveness with a cut-off or test value. For example, an intervention to reduce diarrhea with a cost-effectiveness of less than $100/DALY could be considered cost-effective, or a “good buy” for the money. If the cost-effectiveness of an intervention is below the cutoff value, the intervention should be implemented. The value can be determined only when it is known how much money is available for, in this case, diarrhea prevention, and that will be country and/or agency specific.

The model based its cost-effective value on several recent studies. The 1993 WDR used the following definition of “cost-effective”: “Sever-al activities stand out because they are highly cost-effective: the cost of gaining one DALY can be remarkably low—sometimes *less than $25 and often between $50 and $150*” (p. 8). A recent WHO publication presents several different “cost-effective” interventions for the control of childhood diseases, applying the same DALY methodology. For diarrheal diseases, the main intervention is IMCI, with a cost-effectiveness of $30-$100 per DALY. For comparison, the value for the Expanded Program of Immunization (EPI) is $12-30 and for iodine supplementation, $20-34, both per DALY saved. These values are expressed in 1990 U.S. dollars; they would be approx-imately 20% higher in 1996 dollars.

4.2 Principles of the Cost-Effectiveness Model

The model uses a simple interactive spreadsheet that incorporates three principles, as explained below.

The first principle is that the preventive effectiveness, or percentage reduction in incidence, of a health-sector intervention depends upon the environment in which it takes place. Many aspects of this environment are beyond the direct control of public health authorities. For example, the presence or absence of urban water supply and sanitation hardware would affect the preventive effect-iveness of health-sector interventions. Water and sanitation hardware, or infrastructure, is rarely financed directly from the ministry’s health budget, but it may be considered an additional and essentially free resource for the health sector. To fully exploit the health potential of the hardware, the health sector must supply the education, social marketing, and advocacy. The experience of the 1980s Water Decade has shown the limitations of an approach which concentrates on delivery of hardware rather than creating demand for infrastructure and ensuring, through adequate software, its best use for health purposes.

The second principle is that program performance should be measured by a unit which combines both morbidity and mortality. The value of preventive interventions is downgraded when deaths averted are the sole measure of health impact.

The third principle is that the financial or budgetary impact of an intervention or program on the health sector agency alone should be used as the measure of cost. While programs undoubtedly have direct and indirect economic consequences (for instance, savings of time, increased productivity), the value of these should not be added or subtracted from program costs in an ad hoc manner. Economic adjustments to prices are not required for the financial and budgetary analyses prepared by program planners.

Cost-effectiveness must always be measured in relation to another intervention, or to satisfying a cutoff value. In neither case is it legitimate to jump to the conclusion that the monetary value of the health impacts is greater than the costs. Estimating the monetary value of the health impacts requires cost-benefit analysis.

Environmental health interventions are often favored for reasons other than cost-effectiveness. For instance a broad “social cost-benefit” analysis would assign a monetary value to the positive effects of a more equal distribution of income. Improved environmental conditions benefit rich and poor alike since it is more difficult for elite groups to “capture” the benefits of a government program. Creating a clean and healthy environment is a “public good” and the services are often not provided without public spirited interventions. Conversely, for some medical services, public provision at subsidized cost can have less impact than expected since public provision replaces private provision.

The model presented here does not address all the economic and social arguments for health sector intervention but is based on the global disease paradigm as presented by Murray and Lopez 1994 and the WDR. In this approach, cost-effectiveness (or more correctly “cost-utility in terms of DALYs”) provides policy guidance for ranking interventions and determining research priorities. The only modification made to the WDR approach has been to insist on using a financial, rather than an economic, measure of program costs. Current practice in cost-effectiveness analysis often mix both types of costs in an arbitrary fashion.

4.3 Estimating Costs

A program designer and planner who wants to compute the cost-effectiveness of a proposed intervention needs to answer three broad questions.

- **Inputs.** What activities and inputs does the intervention comprise and how are they put together? The answer must include labor and overhead to implement the intervention in a program context.
- **Measure of Health Outcome.** What difference does the intervention make to health outcomes? The impact may be described in terms of percentage reduction in cases, reduction of death rates, or infant-DALYs saved.
- **Cost.** What does the intervention cost? The relevant cost is the financial cost or the amount of the budget used for the intervention.

This section explains the principles that should be applied to the costing of interventions. Actual costs will vary widely among countries; there are no universally correct costs for specific interventions.

Environmental health interventions in general, and hygiene in particular, improve environmental conditions thereby preventing people from becoming sick from environ-mentally transmitted diseases. Costs range widely from the simplest on-site facilities to full-blown continuous high pressure house water connections and modern sewerage. For peri-urban conditions a range from $10-$50 per capita per annum covers the technologies likely to be feasible on a large scale.[3] Rural costs for piped systems tend to be higher.

Although some feasible health-sector interventions, such as chlorination of water and/or

[3] See for instance Esrey, Feachem, and Hughes 1985; Cairncross, Hardoy, and Satterthwaite 1990; and World Bank, WDR 1993, Box 4.5.

water quality management, require commod-ities or "hardware," most health-sector-spon-sored environmental interventions require expenditures on services, which are largely labor inputs. Hygiene costs are proportional to the number of households with whom contact must be made, rather than the total population. Because hardware costs for water supply[4] and sanitation are usually expressed as per capita per annum, water supply and sanitation costs per household are computed by multiplying the per capita cost by five, the average number of household members. Water supply and sani-tation cannot be supplied to children under five alone (who comprise only 17% of the pop-ulation); therefore, total water supply and sani-tation costs per household are approximately five times higher than per capita costs. Although some households will have no children under the age of five, the benefit of having complete coverage is high, so all households are included in the target population.

Finding a range of costs for hygiene interventions of the type described was hampered by a number of factors.

- Most studies are conducted by epidemiologists and other health-sector professionals whose primary interest is not the cost. Despite extensive literature searches for cost data, few were found. None of the 65 studies reviewed gave any usable intervention costs.
- Total costs usually include two parts, fixed and variable. The attribution of fixed costs is a matter of accounting policy, which differs among organizations and countries.
- Many pilot studies are conducted in abnormal conditions resulting in over-estimation of impact and underestima-tion of costs. There is no a priori reason to believe that these errors will balance each other out and produce an estimate of cost-effectiveness that would be valid under implementation conditions.
- Costs are expressed in currency terms without distinguishing the year or the exchange rate and neglecting to specify whether they are lump-sum investments (equipment) or annual expenditures (salaries).
- The analysis of a behavioral intervention could be treated as an investment over a short term (say five years) which leads to sustained changes in the behavior of future generations. This would yield benefits over a much longer period. In DALY analysis of child survival interventions, the majority of health benefits come from mortality effects. Life years saved are those of the presently under-fives who would live over the next 80 years (so-called DALYs from averted deaths). The studies reviewed, however, provided no basis for projecting either cost- or preventive-effectiveness over time.

To determine the costs to be used in the model, a costing matrix was developed using formats suitable for deriving health extension costs for hygiene per annum, as shown in Table 3. Cost variables include health extension worker-client ratios, number of contacts per year, and the time required for program implementation. The costs for hygiene in the short-to-medium term are best thought of as the costs of carrying out ongoing campaigns of hygiene promotion and maintaining contact with target clients. The cost derived for hygiene is just over $3 per household per year. In a city of one million inhabitants, this would mean an annual budget for environmental prevention of childhood diarrhea of approximately $600,000.

Because data on the long-term effect of preventive behavioral interventions is lacking, this paper has erred on the side of overstating costs. Prevention suggests that investment now will save costs in the future. It could be argued that changes in cultural practices and attitudes required for changed hygiene behavior are so fundamental that they would be transmitted to future generations, without the need for active hygiene interventions. If the $600,000 per year mentioned above had to

[4] A discount rate of 3% is used to annualize water supply and sanitation investment and operational costs. For a simple technology the longevity of infrastructure may be five to ten years. For comparability with a DALY measure of effect one assumes the infrastructure is replaced every five to ten years.

be spent for five years only, then the present value of those expenditures (at a 3% discount rate) would be $2.75 million. If this sum were annualized, or converted to an equivalent annual cost, to match an 80-year time period for the benefits (the time horizon for DALY health impact), the cost would be only $91,000 per year, not $600,000. But in the absence of data to support the claim of sustainability of hygiene behavioral changes, the model assumes that public health expenditures must continue for 80 years at the same level of $600,000, to sustain the health benefits. These expenditures probably would be required to support community health surveillance, and monitoring and enforcement of environmental health regulations. However, no reasonable basis for costing them exists.

ORT is used as an example of a curative intervention. This allows the model to show that reducing the incidence of diarrhea through prevention will result in savings to the health budget because demand for ORT treatment will decrease. The model estimates that treating a case of diarrhea with ORT costs $2 and that 30% of all cases will be treated. With an average of five cases of diarrhea per child per year, the budget required for ORT would be $510,000 (17% of the population under five or 170,000 x 5 episodes x $2 x 30%).

Table 3
Estimated Health Extension Costs in 1996 $ per Eligible Household per Year
(assuming continued contact from year to year of all eligible households)

Eligible Households: City of 1 Million with 20% of Households with Child under 5			200,000
Contact Hours per Mother (Individual) per Visit			0.33
Visits per Annum			4
LABOR COST			
Health Extension Worker Cost in $ per Hour		$	1.00
Total Work Hours per Health Worker per Month			160
Available Contact Hours per Worker per Month			120
Travel and Reporting Hours per Month for Workers			40
Workers Needed			184
Travel Cost and Benefits per Health Worker per Month		$	50
Total Labor Costs	Per Year	**$**	**463,680**
	Per Month	$	38,640
	Per Worker per Month	$	210
	Per Household per Year	$	2.32
SALARY COST			
Health Workers per Supervisor			20
Number of Supervisors			10
Salary Rate Including Benefits per Month		$	250
Motorcycle and Fuel/Maintenance per Supervisor per Month		$	50
Environmental Health Coordinator Salary		$	6,000
Environmental Health Coordinator Benefits per Year		$	5,000
Total Salary Costs	Per Year	**$**	**47,000**
ADMINISTRATION COSTS			
Number of Workers per Office			50
Number of Offices Required			4
Rent per Office per Month		$	500
Cost of Administrative Staff per Office per Month		$	500
Lighting and Consumables per Office per Month		$	75
Materials, Communications, and Advertising per Office per Month		$	1,000
Total Administrative Costs	Per Year	**$**	**99,600**
GRAND TOTALS			
TOTAL COSTS	Per Year	**$**	**610,280**
TOTAL COSTS PER HEALTH WORKER	Per Year	**$**	**3,317**
TOTAL COSTS PER ELIGIBLE HOUSEHOLD		**$**	**3.05**

5 RESULTS OF APPLYING THE COST-EFFECTIVENESS MODEL

In this chapter the proposed model is applied to compute the cost-effectiveness of the four scenarios shown in Table 1 (Chapter 3) and of an intervention used in Mexico and documented in the *Bulletin of the World Health Organization* (Gutiérrez *et al.* 1996).

5.1 The Cost-Effectiveness of the Four Scenarios

The results of the computations for the four scenarios are discussed in the following subsections and summarized in Table 4.

5.1.1 Base Case: Software Added to Hardware: [HW+,SW-] ➜ [HW+,SW+]

The most realistic scenario is to add software (hygiene) to existing hardware (water supply and sanitation). (As shown in Table 3 above, hygiene is provided at $3 per household x 200,000 households = $600,000.) The effect of hygiene is to reduce cases by 25%, or the difference between 40% effectiveness for hardware and software combined and 15% for hardware alone. Using these figures, the cost per case averted is $2.22, and the cost per death averted is $523, equivalent to $15.71 per DALY saved, using the standard subjective parameters. The gross budgetary impact of the intervention ($600,000) is partly offset by $127,500 savings in ORT costs (which the example assumes are paid for by the health agency).

A version of this scenario based on more pessimistic assumptions increases the cost of hygiene to $6.00 per household per year, lowers pre-intervention incidence to three cases per infant per year, and reduces preventive effectiveness to 20%. This still yields a cost of $78.90 per DALY saved, which is below the $100 cutoff for cost-effectiveness proposed in the *World Development Report*. Likewise, a version of this scenario based on more optimistic assumptions lowers the cost of hygiene to $2 per household per year, raises incidence to 10 cases per infant per year, and raises effectiveness to 30%. In this version, which is not unrealistic or outlandish for a peri-urban environment, the environmental health intervention costs only $1.30 per DALY saved, $43 per death averted, and a tiny 18 cents per case averted.

5.1.2 Hardware and Software Combined: [HW-,SW-] ➜ [HW+,SW+]

The second scenario is to add both hardware and software. In traditional cost-effectiveness analysis for water supply and sanitation as a health intervention both hardware and software are considered to be health-sector costs. The hardware chosen for this example is an intermediate technology which would cost only $72 per household or $14.40 per capita per year. It would be combined with software costing $3 per household per year to yield total costs of $75 per household or $15 per capita. This type of intervention is not cost-effective. The cost per DALY is $320 while that per case averted is $45.28. The cost per death averted of $10,655 is close to the estimate provided by Walsh and Warren: $3,400-$4,000 per infant death averted in 1975 prices. Even with

Table 4
Cost-Effectiveness of the Four Scenarios

Population=1 Million Under-Five 170,000 Households 200,000	**SW added to HW** **(I)**			**HW and SW Combined** **II**	**HW Only** **III**	**SW Only** **IV**
URBAN/PERI-URBAN AFRICA	**BASE:** **[H W + S W -] ➜ [HW+SW+**	**PESSIMISTIC** **H W + S W -] ➜ [HW+SW+]**	**OPTIMISTIC** **[HW+,SW-]➜ [HW+,SW+]**	**[H W - S W -] ➜ [HW+,SW+]**	**[HW-,SW-]➜ [HW+,SW-]**	**[HW-,SW-]➜ [HW-,SW+]**
	Software added to hardware. Incidence=5 episodes/year. Effectiveness= 40%-15%= 25%. SW cost= $3/hh/year.	Software added to hardware. Incidence=3 episodes/year. Effectiveness= 30%-10%=20%. SW cost= $6/hh/year.	Software added to hardware. Incidence=10 episodes/year. Effectiveness= 50%-20%=30%. SW cost= $2/hh/year.	Software and hardware added. Incidence=5 episodes/year. Effectiveness= 40%-0%=40%. SW cost=$3/hh. HW cost=$14.40 capita/year.	Hardware only. Incidence=5 episodes/year. Effectiveness= 15%. HW cost= $14.40/capita or $72/hh/year.	Software only. Incidence=5 episodes/year. Effectiveness= 15%-0%=15%. SW cost= $3/hh. HW cost=0.
Reduction incidence per child	1.25	0.6	3	2	0.75	0.75
Cases averted	212,500	102,000	510,000	340,000	127,500	127,500
Deaths averted	903	434	2,168	1,445	542	542
DALYS from deaths averted	30,068	14,433	72,163	48,109	18,041	18,041
DALYS from cases averted	552	265	1,325	883	331	331
Total DALYS averted	30,620	14,698	73,488	48,992	18,372	18,372
Total cost SW to health sector	$600,000	$1,200,000	$400,000	$600,000	$0	$600,000
Total cost HW to health sector	$0	$0	$0	$15,000,000	$14,400,000	$0
Net cost ORT	($127,500)	($61,200)	($306,000)	($204,000)	($76,500)	($76,500)
Dollar per case averted	**$2.2**	**$11.2**	**$0.2**	**$45.3**	**$112.3**	**$4.1**
Dollar per death averted	**$523.2**	**$2,627.0**	**$43.4**	**$10,654.7**	**$26,433.2**	**$966.1**
Dollar per DALY saved	**$15.7**	**$78.9**	**$1.3**	**$320.0**	**$794.0**	**$29.0**

optimistic assumptions, this intervention is not cost-effective from a child survival programmer's perspective. It is also not a realistic scenario because in most situations, water and sanitation hardware interventions are not paid for from the health-sector budgets.

5.1.3 Hardware Alone: [HW-,SW-] ➜ [HW+,SW-]

Not surprisingly, the least cost-effective of all scenarios is to provide hardware alone. At a cost of $14.40 per capita with preventive effectiveness of only 15%, the costs are $112 per case averted, $26,433 per death averted, and $794 per DALY saved. Providing hardware can be justified by other benefits, not by health alone. Households themselves will pay something for these other benefits.

5.1.4 Software Alone: [HW-,SW-] ➜ [HW-,SW+]

The last scenario is to provide software alone. This is cost-effective but not as much so as the first scenario. The cost per DALY and per life saved are nearly twice that of the first scenario: $29 and $966, respectively. One would hope, however, that health planners would try to coordinate with water supply and sanitation promoters and service-providers to encourage households to invest in appropriate low-cost hardware at $72 per household per year. Investments of this size can be financed by micro-housing-banks that operate like micro-entrepreneur financial institutions but market loan products for housing improvements, such as on-site water supply and sanitation facilities.[5] Promoting this strategy and making participation in the environmental health program contingent on prior improvement of water supply and sanitation facilities would improve health-sector cost-effectiveness by lowering the cost per DALY saved from $29 to only $8 (i.e., using the base assumption for adding software to hardware, the preventive effectiveness from the health sector decision maker's perspective is 40%, instead of 15%, while the cost remains $3 per household).

5.2 The Cost-Effectiveness of a Representative Curative Intervention

The last two columns of Table 3 show the cost-effectiveness of ORT, for comparative purposes. The assumptions are five episodes per child per year, a case fatality rate of 0.25% and a total health-sector cost of $2 per ORT treatment administered. The costs are $24 per DALY saved and $800 per death averted. The cost of a case averted is non-applicable. If the cost of ORT is lowered to $0.50 per treatment, then the cost per DALY falls from $24 to $6 and the cost per death averted falls from $800 to $200. The presence of water supply and sanitation does not affect the cost-effectiveness of ORT; however, it does reduce the total number of cases that have to be treated, and therefore the total budget required to cover the whole population.

5.3 Case Study: The Cost-Effectiveness of Prevention by Regulation and Surveillance

Water supply and sanitation conditions are public health issues that have a critical impact on child survival. However, governments usually choose to promote water supply and sanitation by the judicious use of subsidies and regulation of the infrastructure sector. In Mexico, for example, the development of water supply and sanitation infrastructure has not been financed by the health ministry, but public health officials' advocacy of better sanitation has influenced government policy. A recent article in the *WHO Bulletin* claims that incidence and mortality of diarrhea in under fives was reduced by 40%-50% over a two-year period by regulatory measures: "Fostered by a fear of the devastating effects of cholera, several interventions, such as the widespread chlorination

[5] Details on these financial services may be found in Varley 1995.

of water for human consumption and an effective prohibition on irrigating fruit and vegetables with sewage water, were implemented by the government in June 1991. The results were marked: over the 2-year period 1991-93, the annual mean number of episodes of diarrhoea among under-5-year-olds decreased from 4.5 to 2.2, while the corresponding mortality rate fell from 101.6 to 62.9 per 100,000" (Gutiérrez *et al*. 1996).

Table 5 shows how the cost-effectiveness model can be applied to the Mexico case. With a population of 93 million, a software intervention costing $5 per household per year (for surveillance, regulation, and enforcement of public health regulations), ORT coverage of 70%, and an ORT cost of $5 per case treated (1996 US$), the regulation is not only cost-effective but also has a positive net effect on cash flow for the health sector budget. The costs are all negative values because of the savings in total costs of ORT brought about by the intervention. Cost per case averted was ($0.89), per death averted ($681), and per DALY saved ($20.46). The assumption was that all ORT costs were paid by the health sector, but this may be wrong. Even without the budgetary savings from ORT, the cost-effectiveness of the intervention would be $60.40 per DALY saved. Also, the effect on children over five and adults was excluded. While no claim for great precision can be made, it is not unreasonable that a 50% reduction in cases at a health sector cost of $93 million (for regulation and surveillance) would be offset by savings in treatment costs of $125 million.

When new regulations are imposed, such as those imposed in Mexico, those harmed (e.g., producers) may demand compensation. Ownership rights over the environment then become an equity issue. Both these interventions were a low demand on the health budget, but were insisted upon by public health authorities. In the case of chlorination, the financial burden was passed on to consumers, producers, and workers. In the case of regulations on irrigation, the distributional and production effects on the fruit and vegetable market are difficult to appraise given the openness of Mexico to trade. Regulation and surveillance of water quality and use would be cost-effective from a child survival program perspective, despite the measures being quite indiscriminatory between the under fives and the rest of the population.

Even if the government paid compensation or subsidies to producers, it is far from clear that they should be paid by a corresponding reduction in the gross health budget. The issue is equity, not allocation. Often producers do not bear the costs of external effects on health, as they are difficult to monitor.

Historically, public health improvement in the developed world required political commitment to establish environmental ownership rights, enshrine them in legislation, and then enforce the relevant regulations. Public health interventions have to keep up with the dynamic growth in the water supply and sanitation sector. Increased water supply precedes sanitation: more water consumed means more wastewater to dispose of. The drinking water sector requires no financial assistance from the health sector: demand is nearly always sufficient to cover costs. Sanitation, however, may justify some public intervention in the form of a public health subsidy for *construction* of sewerage systems, although this is not administered by the health agency. To ensure that the water supply and sanitation infrastructure is able to provide substantial health benefits for both children and the general public requires that the health sector devote resources to design, surveillance, marketing, regulation, education and advocacy.

Table 5
Cost-Effectiveness of Regulation and Surveillance in Mexico

	Present	Future	Effectiveness/Cost
	A	B	A-B
Incidence (overall episodes/infant/year)	4.50	2.25	2.25
Cases	71,145,000	35,572,500	35,572,500
Deaths	92,489	46,244	46,244
Loss of DALYs from Deaths	3,079,227	1,539,614	1,539,614
Loss of DALYs from Morbidity	89,649	44,824	44,824
Total DALY Loss	3,168,876	1,584,438	1,584,438
Total $ Cost of SW	0	93,000,000	93,000,000
Total $ Cost of HW	0	0	0
TOTAL $ Cost of ORT	249,007,500	124,503,750	(124,503,750)
		$/case	($0.89)
		$/death	($681)
		$/DALY	($20.46)

6 CONCLUSIONS AND RECOMMENDATIONS

Although program designers may not always conduct a formal cost-effectiveness analysis, they invariably generate some of the data required for one—measures of projected cost and health impact. This paper is a challenge to the view that heath-sector managed water supply and sanitation interventions for preventing childhood diarrhea are not cost-effective. Using conservative assumptions to measure the health impact of hygiene interventions that can be incorporated in child-survival packages, the model finds hygiene to be cost-effective well within the range of cost-effectiveness promoted in the WDR. The conclusions about cost-effectiveness are expressed in terms of dollars per death and case averted, as well as in terms of the newly emergent DALYs.

Three basic assumptions underlie the model:

- The costs of hardware or physical infrastructure are not assumed to be a burden to the health sector budget. Not only are non-health benefits characteristic of water supply and sanitation services but some level of service is commonly financed by a combination of user charges and public health subsidies for construction through public works.
- The indicative cutoff value for cost-effectiveness is $150 per DALY.
- The preventive effectiveness of the public health "software" will be the additional health impact from adding "software" to "hardware." Therefore, situations in which independently financed water supply and sanitation infrastructure is available or planned should be viewed as opportunities for environmental health interventions.

Program planners should not feel they have to formally incorporate economic costs and benefits in a cost-effectiveness calculation. This is not demanded of investments in other sectors and should be seen as an "ideal," which is rarely achieved in practice. At the sectoral planning level, a measure of dollars per unit of impact is an appropriate measure of performance. In cases where a sound cost-benefit analysis has been conducted, its results will be an important input to the selection or exclusion of particular interventions in a program. In many cases cost-benefit analysis will strengthen the case for environmental health interventions since the positive health impact is associated with indirect effects whose costs are valued at less than benefits (e.g., time savings and increased productivity). Social cost-benefit analysis will give monetary value to the egalitarian nature of environmental health interventions—everyone benefits, rich and poor alike.

It is recommended that the broader range of environmental health interventions described in the prevention paper be incorporated in USAID and other donor agency programs for child survival. As an initial step, environmental risk factors and epidemiological indicators of major childhood diseases should be collected while programs are formulated.

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