Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination

Charles W. Abdalla, Brian A. Roach, and Donald J. Epp

ABSTRACT. Public decision-makers require information on the benefits and costs of policies for groundwater protection. The averting expenditures method for valuing environmental improvements is examined and used to approximate the economic costs of groundwater degradation to households in a southeastern Pennsylvania community. Results indicate that households’ knowledge of contamination, perception of risk, and presence of children determine whether they undertake averting actions and that their expenditure levels are higher if young children are present. The estimates obtained through averting expenditures analysis have a sound theoretical basis and are of sufficient magnitude that they merit consideration in groundwater policy decisions.

I. INTRODUCTION

Groundwater quality management has become an important public policy issue. While the extent and severity of groundwater degradation is not currently well documented, public concern over possible human health effects from drinking contaminated groundwater has led 33 states to enact groundwater protection legislation between 1985 and 1990 (U.S. Environmental Protection Agency 1990). Despite the level of concern and legislation relating to groundwater quality, little is known about the economic benefits of groundwater protection. Although previous economic research on groundwater focused primarily on the costs of policies to remedy degraded groundwater, groundwater protection policies can yield a range of possible benefits. These include avoided losses from actual human health effects, such as increased mortality or morbidity from exposure to contaminants, possible ecological damages, and losses of intrinsic values associated with groundwater resources. One area of economic damages that has received relatively little attention in previous work is that of averting expenditures, or the costs incurred by households, firms, or governments to avoid exposure to a groundwater contaminant. This study illustrates how empirical measurement of such expenditures can yield conceptually valid estimates of an important category of economic costs of environmental degradation and how this information may be used in policy decisions.

Theoretical explanations of averting expenditures are based on the household production function theory of consumer behavior. In the context of averting behavior models, the household produces consumption goods using various inputs, some of which are subject to degradation by pollution. The household may respond to increased degradation of these inputs in various ways that are generally referred to as averting or defensive behaviors.

Previous theoretical treatments of averting expenditures have concluded that these expenditures can provide a conservative estimate of the true cost of increased pollution. Courant and Porter (1981) demonstrated that savings in averting expenditures, assuming that pollution abatement does not directly affect utility and holding
the level of personal environmental quality constant, are equal to the benefits of a marginal pollution reduction. In reality, individuals will alter their personal environmental quality level as pollution is reduced. If personal environmental quality decreases with increases in pollution and pollution does not directly enter into the utility function, averting expenditures are a lower bound to willingness to pay. When pollution enters into the utility function directly, Courant and Porter stated that it is more difficult to determine if averting expenditures bound willingness to pay.

Watson and Jaksch (1982) and Harford (1984), in studying the effect of air pollution on personal or household cleanliness, developed theoretical models considering the “price” of a cleaning episode as a function of pollution and cleaning frequency. Their models indicated the need for empirical results to test assumptions of cleanliness and averting expenditure behavior. Harrington and Portney (1987) reported that the sum of changes in averting expenditures and costs of illnesses is likely to be a lower bound estimate of willingness to pay (WTP), assuming individuals do not increase averting expenditures in response to a decrease in pollution. Also, they conclude that the possibility exists in principle to observe exact benefits but obtaining the necessary information regarding market and household behavior normally prohibits the analysis.

Bartik (1988) also stated that theoretically correct measures of WTP could be estimated using averting expenditures if information was obtainable concerning the household’s production technology. In the absence of such information, upper and lower bounds to WTP could be obtained from averting expenditure information for marginal and nonmarginal changes in pollution. Rather than defining the cost of a cleaning episode, Bartik’s model utilizes the defensive expenditure function based on the household’s choice of personal environmental quality. Bartik noted that the capability of averting expenditure estimates to bound WTP is dependent upon the validity of several assumptions. In particular, averting inputs should not exhibit jointness in the production of household outputs and averting expenditures should not involve sunk costs in the purchase of durable goods. If an averting good violates the jointness assumption, expenditures on the good are theoretically divided among the production of each commodity involved. Violation of the sunk cost assumption also implies that the full purchase price of the durable good cannot be attributed to the change in water quality.

Roach (1990) demonstrated that including household time as an input into the production function for personal environmental quality did not change Bartik’s (1988) conclusions about the ability of averting expenditure estimates to bound willingness to pay. Also, graphical analysis indicated that averting expenditures will present a lower bound to compensating and equivalent variation (CV and EV, respectively) based on reasonable assumptions. Shortle and Roach (1989) extended the graphical analysis to demonstrate that averting expenditures are likely to be a lower bound to CV and EV even if pollution enters into the utility function directly. However, the bounds in this case will be less exact than when pollution does not enter into the utility function directly.

Averting expenditure estimates appear to provide a conceptually valid conservative estimate of actual costs or benefits of changes in drinking water quality. However, averting measures may be difficult to define for different types of pollution. For example, Watson and Jaksch (1982) included house painting and window washing as averting measures related to air pollution. These activities are likely to violate the nonjointness assumption since they may also be inputs in the production of “household appearance.” Averting measures related to drinking water are easily defined, such as buying bottled water or a home water filtration system.

Some researchers including avoidance costs in their studies have simulated averting behaviors and expenditures based on the assumption that households did in fact engage in such behaviors in response to pollution. For example, Spofford, Krupnick, and Wood (1989) used prespecified probability distributions to model house-
holds' averting expenditures in a study of groundwater remediation efforts at a federal Superfund site in Massachusetts. Others, including Smith and DesVouges (1986), Harrington, Krupnick, and Spofford (1989), and Abdalla (1989), have provided empirical evidence of household averting expenditures in response to water quality degradation.

In this study, averting expenditures were used to approximate the economic costs to households in a southeastern Pennsylvania community affected by groundwater contamination. The estimates obtained are interpreted given the underlying theory and implications for policy are discussed.

II. PROCEDURES

Criteria for selecting a community experiencing groundwater contamination included a minimum of 500 households connected to a public community water system, an expectation that the contamination incident would continue during the entire study period, and public notification of contamination. The borough of Perkasie in southeastern Pennsylvania, which has an estimated 2,760 households (population 7,877), was selected as an example of a community affected by groundwater contamination. In late 1987, Trichloroethylene (TCE), a volatile synthetic organic chemical, was detected in one of the borough's wells. TCE levels were as high as 35 parts per billion (ppb), exceeding the Environmental Protection Agency's maximum contaminant level (MCL) of 5 ppb. Since no temporary solution was available to reduce TCE levels below the MCL, the county health department required the borough to notify customers of the contamination in June 1988. As of December 1989, no solution had been implemented.

Mail questionnaires were used to elicit information about increases in household averting expenditures taken in response to contamination in Perkasie. Households were asked about specific actions they took to avoid exposure to TCE. This was an attempt to address the empirical estimation problem of including expenditures for unrelated reasons, such as changes in tastes and preferences. Since many of the behaviors for avoiding a water contaminant require a person's time as well as purchased inputs, the amount of time required for averting actions and cash expenditures on averting inputs were sought. The time input was evaluated alternately at the minimum wage and at the estimated wage of the respondent. Information was collected about possible factors influencing averting expenditure changes, such as health perceptions, attitudes, and demographic factors. Also, respondents were asked their quantitative and qualitative cancer risk perceptions associated with the contamination incident. The survey instrument was developed and administered following procedures suggested by Dillman (1978).

Based on Kalton (1983), a random sample of 1,733 was determined to be needed for representative results. A mailing list of residential customers was obtained and the survey was administered in September 1989. After three follow-up mailings, 761 usable questionnaires were received. Adjusting for nondeliverable surveys, the effective response rate was 46.9 percent. The response rate was lower than anticipated and it was felt necessary to investigate nonresponse bias. A telephone interview with a random sample of 50 nonrespondents was conducted to determine if respondents and nonrespondents were similar in key attributes. Two variables from the mail questionnaire sample and the telephone interview sample, awareness of TCE contamination and whether household averting actions were taken in response to TCE, were statistically compared following a method suggested by Snedecor and Cochran (1980). The hypothesis that the two samples were different on these attributes was rejected at the .05 level. Consequently, the mail survey results were concluded to be representative of the Perkasie population.

III. AVERTING EXPENDITURES

Only 43.2 percent of Perkasie respondents were aware of TCE in their water despite mandatory notification of the contamination. Of these, 133, or 43.75 percent,
undertook specific actions to avoid exposure after learning of TCE in their water. The actions included: (1) increased bottled water purchases among households buying it prior to the contamination, (2) bottled water purchases by new buyers, (3) installing home water treatment systems, (4) hauling water from alternate sources, and (5) boiling water. To avoid violation of the jointness in production assumption, respondents were asked to report only those actions taken as a specific response to TCE contamination. The purchase of home water treatment systems violates the nondurable assumption, since the system provides benefits lasting beyond the contamination. To overcome this problem, only a portion of the purchase and installation costs were included in the estimates. The useful life of filtration systems was considered to be ten years. Since the 88-week contamination period under study represented 0.17 of the useful life of the system, only 0.17 of the purchase and installation price was included in the estimates. Averting goods must also not exhibit jointness in production. A possible display of jointness in production is the purchase of bottled water. The water may be purchased for taste as well as health reasons. However, jointness is less likely to exist in studying a contamination incident of a relative short duration. Consequently, the increase in bottled water purchases during the contamination incident is likely to be a direct result of the increased health risks and not changes in tastes and preferences.

The costs of these actions were calculated for the sample and extrapolated to the total population of Perkasie residents (Table 1). The total increase in expenditures from December 1987, when TCE was first detected, to September 1989 ranged from

1 Because costs of the actual groundwater contamination episode were of interest, extrapolation to the total Perkasie population was based on the existing level of households' knowledge of TCE. Thus, the loss estimate does not address the question of what losses would have been if all households had information about contamination. Since we did not know how households that were unaware would behave once informed of TCE, estimation of losses with full information was not attempted. Loss estimates under such a scenario can be expected to exceed those obtained due to the expectation that at least some of the households that were unaware would have increased averting expenditures upon learning of TCE.
$61,313.29 to $131,334.06, depending on the wage rate used to reflect the value of lost leisure time. Given the theory reviewed in Section I, these values are interpreted as a lower bound estimate of the economic losses from TCE contamination. The average weekly increase in averting expenditures per household which undertook averting actions in response to the contamination was $0.40.

IV. DETERMINANTS OF AVERTING EXPENDITURES

Household averting behavior decisions in Perkasie were considered as a two-step process. The household’s first step is to decide whether actions should be taken to reduce exposure to water contaminants. There are two possible outcomes as a result of this step; either the household decides that the contamination is significant enough that actions should be taken or the contamination is not significant enough to warrant action. Logit regression models were used to determine factors influencing decisions to undertake averting actions. The dependent variable was equal to 1 if the household took at least one averting action as a specific response to TCE contamination and equal to 0 if no specific actions were taken (regardless of any previous actions taken). The logit regression results in Table 2 indicate that households were more likely to take averting actions if they received information about TCE, rated the cancer risks associated with the levels of TCE in their water to be relatively high, and children ages 3 to 17 were present in the household.

Only individuals who made the decision to avert considered a second decision step—selection of the intensity of averting actions. The estimated increase in household averting expenditures was used as an indicator of averting behavior intensity. Ordinary least squares regression models were constructed to identify factors influencing averting expenditure increases. The dependent variable was the estimated household averting expenditure directly due to the TCE contamination over the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>-4.47</td>
<td>14.34***</td>
</tr>
<tr>
<td>TCE RISK</td>
<td>0.47</td>
<td>9.79***</td>
</tr>
<tr>
<td>TCE INFO</td>
<td>0.35</td>
<td>8.99***</td>
</tr>
<tr>
<td>CHILD 3-17</td>
<td>0.92</td>
<td>7.21***</td>
</tr>
<tr>
<td>OTHER PROBLEMS</td>
<td>0.37</td>
<td>1.05</td>
</tr>
<tr>
<td>CHILD UNDER 3</td>
<td>0.19</td>
<td>0.45</td>
</tr>
<tr>
<td>GENDER</td>
<td>0.43</td>
<td>2.27</td>
</tr>
<tr>
<td>FAMILIarity</td>
<td>0.30</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Number of observations: 263
R-Value: 0.296
Percent correctly predicted by model: 70.3%

** Indicates statistical significance at the 0.01 level.

Variable Descriptions
TCE RISK: Qualitative rating of the cancer risk associated with the levels of TCE in the water (1 = insignificant risk to 5 = very serious risk).
TCE INFO: Addition of two qualitative integer responses to the amount of information received or obtained concerning TCE (2 = no information to 10 = a lot of information).
CHILD 3-17: 0 if no children ages 3-17 were living in the household, 1 if at least one child age 3-17 was present.
OTHER PROBLEMS: 0 if individual was not aware of problems in addition to TCE, 1 if aware of at least one additional problem.
CHILD UNDER 3: 0 if no children under 3 years of age were present in the household, 1 if at least one child under 3 years of age was present in the household.
GENDER: 0 if respondent was male, 1 if female.
FAMILIarity: Qualitative ranking of respondent’s familiarity with chemical substances (1 = not familiar to 4 = very familiar).

88-week study period. Table 3 shows that households with children less than three years of age spent more as a result of the TCE contamination than those without young children.

While the explanatory power of the mod-

---

2Uncertainty about the cost estimates may be a result of sampling error. The number of observations obtained (761) fell short of the number that were calculated (1,136) for a representative sample of the population. Since this was lower than the desired number of responses, follow-up telephone interviews with a random sample of 50 nonrespondents were conducted to test for possible bias. The hypothesis that nonrespondents’ and respondents’ were different for two attributes was rejected at the .05 level of significance. Despite this evidence that nonresponse bias does not appear to be present, sampling error cannot be completely ruled out.
TABLE 3
ORDINARY LEAST SQUARES REGRESSION RESULTS
FOR INTENSITY OF AVERTING ACTIONS FOR
PERKASIE HOUSEHOLDS AWARE OF TCE
CONTAMINATION

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>t-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>54.33</td>
<td>0.64</td>
</tr>
<tr>
<td>CHILD UNDER 3</td>
<td>64.71</td>
<td>2.21**</td>
</tr>
<tr>
<td>TCE RISK</td>
<td>17.30</td>
<td>1.16</td>
</tr>
<tr>
<td>OTHER PROBLEMS</td>
<td>37.56</td>
<td>1.02</td>
</tr>
</tbody>
</table>

Number of Observations: 113
F-Value: 3.16 (Entire model is significant at 0.01 level)
R-Squared value: 0.12

Note: Variable descriptions are the same as given in Table 2.
** Indicates statistical significance at the 0.05 level.

nels is relatively low, the signs of the statistically significant coefficients were in the expected directions. The results are also consistent with previous work. For example, the positive influence of information about environmental contamination received by households upon averting expenditures was also found by Swartz and Strand (1981).

V. CONCLUSIONS

Data on the averting expenditure increases of households in a Pennsylvania community was collected to estimate the costs of a groundwater contamination incident. Averting expenditures were estimated to range from $61,313.29 to $131,334.06 during an 88-week TCE contamination period. Under specific assumptions, the change in averting expenditures associated with a change in environmental quality provides a conservative estimate of the true cost, or benefit, of the environmental change (Roach 1990). These assumptions appear to be reasonably appropriate to situations involving drinking water contamination.

Qualitative risk perception and knowledge of contamination are important determinants of households’ decisions to undertake averting behaviors, while the factors that influence the level of averting expenditures included the presence of young children in a household and income levels. Results of this study imply that policy analysts should consider using studies to measure averting expenditures when examining policy alternatives. We have shown that measuring averting expenditures to estimate the cost of environmental pollution is conceptually valid and empirically feasible. In certain situations, it may be less expensive to measure averting expenditures than to develop estimates of pollution costs using other methods. Drinking water contamination appears to be such a case. Where a lower bound estimate of costs is sufficient to justify policy action, such as setting an MCL for a drinking water contaminant, there is no need for methods that are more expensive in time and money, even though they may be more inclusive and thus provide a complete estimate of total costs. Failure of policy analysts to consider the use of averting expenditure studies may result in more expensive or less timely decisions.

Another implication for policy that emerges from this study draws on the finding that averting expenditures vary with households’ qualitative perception of the health risk and knowledge of contamination. Risk communication strategies which affect perception of drinking water risks may change the estimates of benefits and costs of environmental policies which affect health.

A surprising finding of this study was that only 43 percent of Perkasie residents were aware of the TCE contamination despite legislation which requires public water authorities to notify its customers of contamination. This significantly differs from the results of an earlier study (Abdalla 1989) in which 96 percent of residential customers were aware of a contamination incident in central Pennsylvania. Thus, existing public notification rules and procedures appear inadequate to inform all affected customers.

Since awareness of contamination influences averting behavior, the policies and procedures for public notification are also
important factors affecting public realization of the costs. The regression results suggest that households may not be equally concerned with health risks posed by contaminants in drinking water. Notification efforts could be intensified towards those groups which appear to be more concerned with water quality. For example, households with young children tend to spend more on averting activities related to water use. Notification programs targeted at parents of young children could be delivered through child care centers or pediatricians' offices.

In light of the few studies documenting the existence and nature of behaviors to avoid environmental contaminants, the results are significant. While the averting expenditure method does not encompass all impacts, this study indicates that the method is capable of yielding conceptually valid estimates of an important category of the costs of environmental pollution.

References


