Averting expenditures and valuation of damages: two methods for assessing the benefits of water filtration in Israel

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Abstract

This paper presents an economic benefit analysis of constructing a filtration plant to serve the Israeli National Water Carrier. The main focus of the paper is a comparison of two methods for evaluating the benefits of the filtration plant: direct valuation of damages caused by consumption of unfiltered water, and assessment of consumers’ willingness to pay for high quality water by analysis of averting expenditures. We also compare the benefit estimates, as derived by the two methods, with the costs of constructing and operating the filtration plant. The central result is that according to both methods of benefit analysis, the benefits of filtration significantly outweigh costs. Another important result is that total public willingness to pay (WTP) for improved water quality is higher than the total damage costs of consumption of unfiltered water. In the last section of the paper, a proposal for dividing the financial burden of constructing and operating the plant between relevant parties is presented.

Keywords: Averting cost; Damage valuation; Water filtration; Willingness to pay

1. Introduction

Many areas in Israel suffer from a scarcity of water. In 1964, construction of the National Water Carrier (NWC) was completed, extracting water from Lake Kinneret (the Sea of Galilee) and conveying it to the central and southern parts of the country (for a detailed description see Becker & Lavee, 2002). During the early years of its operation, the NWC provided most of its water for agricultural purposes (around 90%) and only a small part went to households and industry. Over the years this situation was reversed and today 70% of NWC water goes to households and industry, and only 30% to agriculture. Today, the NWC annually delivers about 330 million m³ of water to the different parts of the country, accounting for about 35% of all potable water in Israel; 90% of water consumers in Israel receive at least part of their water supply through the NWC.

Over the years Lake Kinneret water quality has deteriorated while, at the same time, international water quality standards have become stricter. Amongst other things, it was discovered that several types of

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pathogenic parasites, which cannot be eliminated by chlorination or other standard methods of disinfection, are found in the water; these parasites can only be removed by filtration (Rebhun, 2000). In 1992, a professional committee was formed to investigate this issue. Following extensive discussion, the committee recommended that NWC water be filtered. The committee’s recommendations were based on water quality standards in developed countries that require filtration of all surface-water used for drinking. Critics of the recommendation pointed out that Lake Kinneret water was meeting World Health Organization standards as it was, and thus concluded that there was no need to undertake such a significant investment. The debate continued for many years until, in 2001, the government decided to approve the construction of a central filtration plant for the NWC (Lavee & Daniali, 2007). Through utilization of the plant, water quality in Israel will meet the strict standards of the world’s most developed countries.

2. Literature review

Economic literature has examined the benefits of improving water quality through a number of different approaches. Courant & Porter (1981) examine, from a theoretical perspective, consumers’ willingness to pay for water quality through analysis of averting expenditures: ‘the costs of measures undertaken in efforts to counteract the consequences of pollution’. Their central result is that averting expenditures cannot be used to accurately assess public willingness to pay for water quality, nor even to estimate a lower bound for WTP.

Harrington & Portney (1987) evaluate the benefits of introducing stricter health regulations. The authors claim that it is necessary to take into account not only savings in medical expenditure due to the decline in morbidity (as was done in the past, such as in Cooper & Rice (1976)), but also savings made in averting expenditures. Households exposed to health risks spend money in an attempt to avert the dangers and disutility of disease, and when stricter regulation leads to a lower level of exposure, less expenditure of this sort is needed; this point has also been made in Courant & Porter (1981) and Harford (1984). Harrington & Portney (1987) find that, in most cases, the sum of direct costs and averting expenditures underestimates total benefits from stricter health regulation; however, the paper is theoretical and does not provide empirical evidence.

Harrington et al. (1989) attempt to valuate the costs of a water contamination event. The authors first present a theoretical model, and then test the model using empirical data from a water contamination event that took place in 1983–4 in Pennsylvania. Their analysis included the direct costs of the event (medical expenditure), indirect costs (loss of work days, leisure hours, etc.) and averting expenditures following the detection of the contamination.

Abdalla et al. (1992) empirically examine the averting expenditures of households exposed to water contamination. Their results are based on a survey of residents of Perkasie, Pennsylvania, a small community which in 1987 suffered from groundwater contamination, namely Trichloroethylene (TCE) levels exceeding the EPA’s maximum contaminant level. They find that the use of averting expenditures to estimate a lower bound for willingness to pay has a sound theoretical basis and provides policy makers with a good tool for decision making. A further point that arises in the paper concerns the awareness of consumers to water quality issues. According to the paper, a significant part of the population is not normally aware of existing water quality, but in cases when awareness grows, averting expenditures may increase considerably. Furthermore, households with children are willing to pay a much higher price for ensuring high water quality.
Abrahams et al. (2000) compare two types of averting measures: purchase of bottled water and purchase of home water filters. Through development of a theoretical model, the authors test the conditions under which individuals choose different averting behavior options. The tested conditions include information level and perception of risk, as well as personal characteristics (age, race, etc.). Following development of the theoretical framework, the authors conducted a survey in the state of Georgia, in 1995. The survey results reveal that whereas expenditure on bottled water may overstate willingness to pay for clean water by about 12% (as it incorporates issues such as taste preference and convenience), expenditure on home water filters may indeed accurately reflect willingness to pay.

Hite et al. (2002) examine public willingness to pay for higher water quality in Mississippi, through support of pollution reducing investment in the agricultural sector. Um et al. (2002) show that the key parameter determining averting behavior is subjective perception of water quality, and not actual water quality. Rinaudo et al. (2005) estimate the costs of water pollution in the upper Rhine (in France) between the years 1988 and 2002, through valuation of avoidance costs. Stenger & Willinger (1998) evaluate willingness to pay for high quality water amongst residents of Alsace, through a contingent evaluation study.

Pattanayak et al. (2005) look at willingness to pay for high quality water in Katmandu, Nepal; based on a survey of 1,500 consumers, the authors estimate the costs of coping activities of a population that has to deal with a polluted water system. The authors compare coping costs with the price of water as charged by the water company, and also with stated willingness to pay for improved water services.

Dasgupta (2004) evaluates the costs of damage caused by drinking polluted water in Delhi, taking into account both costs borne by the public health system and private costs such as loss of workdays. Dasgupta & Dasgupta (2004) use a contingent valuation approach to assess damages and costs from consumption of contaminated water, also in Delhi. Regli et al. (1999) present a cost benefit analysis regarding the expected medical costs of water pollution in the US, an analysis which served as the basis for new water regulation. Gurian et al. (2001, 2004) evaluate different water regulation alternatives.

In summary, many studies have examined the costs borne by society due to water pollution, as well as the benefits of reducing pollution levels. Methods for measuring such benefits include valuation of the damages caused by water pollution, surveys directly questioning willingness to pay for improvement of water quality, and monitoring of the behavior of households following news of drinking-water contamination. Most studies suggest that despite the clear limitations to each of the different methods, policy makers should indeed make use of economic research as a decision-making tool, when considering both new water regulation and investment in water quality improving infrastructure.

Our research, which served policy makers in Israel in their decision to begin construction of a water filtration plant for the National Water Carrier, consisted of two benefit analysis methods, and a comparison of the costs of construction and operation of the new plant with the estimated benefits. Our study took into account all limitations and difficulties noted in the above-mentioned papers.

3. The theoretical framework

In order to valuate consumers’ willingness to pay for high quality water, we first develop a basic theoretical framework, and then examine the empirical data. In this section, we present the theoretical model.

The NWC supplies water to households on a continuous basis. Water in the NWC is contaminated to some degree such that the probability of contracting an intestinal disease by an individual consuming...
this water over a year is \( q \). The government needs to decide whether to construct and operate a filtration plant which will improve the quality of the water such that the probability of contracting a disease will decrease to \( p \). If the government chooses to construct the plant, households will have to fund the construction and operation of the plant, so that the price of water will increase. In order to evaluate the economic feasibility of constructing the plant, the government needs to know consumers’ willingness to pay (WTP) for filtered water. If WTP is higher than the cost of constructing and operating the plant, the government should construct the plant; otherwise, it should refrain from constructing the plant. Our analysis will be based on the theory of expected utility, as developed by von Neumann & Morgenstern (1947). The model presented here is based on the model presented in Hanley et al. (2007).

Each household consists of a single individual with an annual income of \( W \) which is used to buy a wide range of products. If the individual is ill, they do not work for a given period and lose an income of \( L \). A household is willing to pay an annual amount of \( r \) for improved water quality. Let us assume that the expected utility of the household is given by:

\[
EU = qU(W - L) + (1 - q)U(W)
\]

Let us now examine the maximum price a household will be willing to pay for improved water quality; \( r \) is that level of payment which will bring the following equation into balance:

\[
pU(W - L - r) + (1 - p)U(W - r) = qU(W - L) + (1 - q)U(W)
\]

Therefore, \( r \) is also the option price that the household is willing to pay (Cook & Graham, 1977). Assuming the change in probability of illness is marginal, willingness to pay is given by:

\[
\frac{dW}{dq} = \frac{U(W) - U(W - L)}{qU'(W - L) + (1 - q')U(W)} = \frac{\Delta EU}{EU'} > 0
\]

where the numerator represents the difference in household utility between a year in which the individual does not contract a disease and one in which he does; the denominator represents the marginal difference in utility from annual income.

4. The empirical analysis

In this section we examine the empirical data concerning both the costs of construction (and operation) of the filtration plant and the benefits obtained by filtration. The cost analysis was undertaken in a previous study and the result is provided here in order to compare the costs with the benefits. This paper will focus on estimating the benefits of filtration via two independent methods.

4.1. Benefit analysis

Benefits were estimated according to two independent methods:

1. Valuation of contamination damage. This method evaluates the damages caused by consumption of unfiltered water. These damages concern the health of individuals exposed to contaminated water.
(the risk that such individuals will contract intestinal diseases). This approach involves comparing the costs of water contamination damages under a business-as-usual scenario with expected damage costs following the introduction of water filtration (though filtration will not of course entirely eliminate health risks). The difference represents the benefit of filtration. We based our analysis in part on the findings of a survey conducted in Pennsylvania in 1983–4, reported by Harrington et al. (1989). Since the study was conducted in a different country and in a different year, certain adjustments were required, as will be described.

2. The averting expenditure method. This method assesses the price that households are willing to pay for improvement in drinking water quality through analysis of actual expenditures in the marketplace, in this case, expenditure on home water filters. Critics of this method raise the question as to whether individuals possess the information required to accurately assess the potential damages of drinking contaminated water.

It should be noted that filtration has other benefits of a more direct nature. These consist of savings to Mekorot Water Co. (the national water corporation) and to the municipal water systems in areas such as purification materials, disinfectants, storage tank cleaning, less system wear, etc. However, overall savings in these areas are estimated at only about US$1 million, and clearly cannot justify the construction of the plant on a cost-benefit basis by themselves.

1. Valuation of damages. Figure 1 shows the process of evaluating contamination damage. The upper three boxes on the right-hand side of the figure represent the process of estimating the effect of filtration on lowering the incidence of intestinal diseases. The left-hand side represents the calculation of the size of the population exposed to NWC water contamination (on a yearly basis). Taking the outcomes of the two sides together, we arrive at the economic benefit of lowering the incidence of intestinal diseases through water filtration. The different stages of our calculations were as follows:

![Fig. 1. Methodology for evaluating benefits from contamination reduction.](image-url)
The relation between filtration and turbidity—this stage is relatively straightforward as measurement is simple. On the basis of laboratory tests performed at similar plants (Mekorot Water Co. data, 1997, unpublished data) it is possible to determine the benefit from filtration in terms of reduced turbidity. The proposed plant reduces turbidity from 1 NTU to 0.2 NTU.

The relation between turbidity and contamination—first of all, it needs to be clarified that turbidity does not constitute contamination as of itself, but rather serves as an indicator of the level of contamination. Accordingly, for untreated surface-water, a turbidity level of 1 NTU or higher usually indicates contamination at a given and known level. According to studies conducted in Europe and in the US (LeChevallier et al., 1991a, b; Huck et al., 2002; Gitis et al., 2005; Weiss et al., 2005; Karanis et al., 2006), the contamination level will decrease by at least 99.9% (3 log) following sand filtration, which lowers the level of turbidity from 1 NTU to 0.2 NTU. All above mentioned studies conducted actual tests for water contamination levels (of different contaminants) following filtration by relevant technologies.

The relation between contamination level and incidence of disease—according to LeChevallier et al. (1991a,b) the incidence of intestinal disease in the population receiving water filtered to reach a turbidity level of 0.2 NTU was 12% lower than in the population receiving water with turbidity level of 1 NTU. On the basis of Levin & Kleiman (1999), the decrease in incidence of disease is estimated at 10%; a full breakdown is shown in Table 1.

The economic cost of disease—we based our analysis of the economic cost of illness on two sources: data from the Israeli Ministry of Health (Israel Ministry of Health, 2000), and data from a survey conducted during an outbreak of Giardiasis in Luzerne County, Pennsylvania in 1983–4, as reported by Harrington et al. (1989). The survey examined the behavior of people who contracted the disease, paying attention both to direct costs (a visit to the doctor, hospitalization, drugs, etc.) and indirect costs (loss of work days, leisure, lower productivity after return to work). The survey also examined the costs born by households of trying to prevent the spread of the disease (averting activities, such as boiling water and purchasing bottled water).

Since the survey was conducted in a different country and in a different year, it was necessary to adjust the data from the study site to the policy site. For this purpose, we made use of a benefit function transfer: we follow the valuation of behavior as appears in Harrington et al. (1989), but adjust for the different characteristics (and specifically, socio-economic characteristics) which exist in Israel. In this, we follow the transfer protocol suggested by Kask & Shogren (1994), and also take into consideration the limitations of the benefit transfer function method as discussed in Muthke & Holm-Mueller (2004).

Table 1. Decrease in incidence of disease following filtration (%) (Source: based on Levin & Kleiman, 1999).

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Decrease in number of cases (%)</th>
<th>Decrease in number of deaths (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>8.44</td>
<td>0.00044</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>0.55</td>
<td>0.00017</td>
</tr>
<tr>
<td>Giardiasis</td>
<td>0.34</td>
<td>Almost 0</td>
</tr>
<tr>
<td>Bacterial</td>
<td>0.78</td>
<td>0.001</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>0.0016</td>
</tr>
</tbody>
</table>
As far as possible, we made use of data available from the Israel Ministry of Health. Where Israeli data was not available, we based our analysis on data from Harrington et al. (1989), making adjustments where necessary so as to reflect conditions in Israel.

Many of the cost components evaluated in Harrington et al. (1989) relate to the outbreak of the disease. In our case, however, we were dealing with the issue of continuous exposure to the risk of disease. Therefore, costs in areas such as raising public awareness, disinfection and prevention were not relevant to our study.

All relevant data regarding medical treatment and costs of medical treatment were available from Israeli sources. This included characteristics of people who contracted diseases, number of hospitalization days per illness, number of doctor visits, prescription drugs, time spent in emergency room, etc., as well as all relevant costs (cost of a visit to the doctor, cost of emergency room treatment, cost of hospitalization, cost of prescription drugs, laboratory tests etc.).

All data regarding costs relating to individuals’ behavior (loss of work days, decline in productivity and loss of leisure time) were based on Harrington et al. (1989). However, prices were adjusted to Israeli costs (average wage, the value of an hour of leisure, the value of the decline in productivity and the value of human life). Table 2 shows how the different behavioral elements were evaluated so as to arrive at the economic cost of a single case of Giardiasis.

As regards the risk of contracting an intestinal disease, exposure to contamination has an immediate, non-accumulating effect. An accumulating effect means that as the time period of exposure to contamination grows, the damages accumulate and intensify—the effect is non-linear (most types of cancer fall under this category). On the other hand, an immediate, non-accumulating effect is linear in nature—two people exposed to contamination 50% of the time ‘equal’ one person exposed to it 100% of the time. For this type of disease, it is possible to aggregate cases of partial exposure so as to arrive at the equivalent number of cases of full exposure.

Although 90% of the population in Israel receives at least of some of its water through the NWC, NWC water constitute only 38% of potable water in Israel and so it may be said that 2.4 million (out of a population of 6.2 million in 1999) drink NWC water. Accordingly, Table 3 shows the decrease in incidence of disease as a result of NWC water filtration.

### Table 2. Valuation of the economic cost of a case of Giardiasis.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (US$)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor visits</td>
<td>27</td>
<td>3 visits, at $9 per visit</td>
</tr>
<tr>
<td>Hospitalization days</td>
<td>97</td>
<td>0.5 hospitalization days, at $194 per day</td>
</tr>
<tr>
<td>Prescription drugs per patient (four types)</td>
<td>30</td>
<td>Price of prescription drugs provided for patients of the disease in Israel</td>
</tr>
<tr>
<td>Emergency room visits and laboratory tests</td>
<td>87</td>
<td>0.75 visits per patient, at $116 per visit</td>
</tr>
<tr>
<td>Direct loss of workdays</td>
<td>411</td>
<td>By average lost workdays (including loss of workdays due to child’s illness)</td>
</tr>
<tr>
<td>Reduced productivity</td>
<td>270</td>
<td>Applies to employed persons, on the basis of average wages</td>
</tr>
<tr>
<td>Time spent on way to get treatment</td>
<td>12</td>
<td>3 hours multiplied by the average cost of an hour of leisure ($4)</td>
</tr>
<tr>
<td>Loss of leisure hours</td>
<td>128</td>
<td>Applies to all persons, on the basis of occupational status distribution</td>
</tr>
<tr>
<td>Total</td>
<td>$1,062</td>
<td></td>
</tr>
</tbody>
</table>
On the basis of the valuation of the costs associated with contracting Giardiasis, similar valuations were performed for other diseases. Multiplying the costs associated with each disease by the number of cases presented in Table 3 (that is, by the number of cases assumed to be saved following filtration) gives the overall annual cost savings achieved by NWC water filtration (Table 4). Overall benefits reach US$62 million annually. In order to calculate savings per m³, we divided this figure by the amount of water supplied by the NWC to households (231 million m³) and arrived at the figure of US$0.27 per m³; to calculate savings per person, we divided by 2.4 million and arrived at US$25.8 per person.

2. Evaluating benefits through analysis of averting expenditure. The second method we employed was based on analysis of households’ averting expenditures. This method aims to estimate households’ WTP for high water quality by looking at their expenditure on different measures of prevention. Abrahams et al. (2000) claim that home water filters provide a good indicator of households’ WTP. They also demonstrate that, other than awareness to the risks of drinking contaminated water, the only significant parameter affecting the probability that a household will purchase a home water filter is household income (Abrahams et al., 2000: 433). Our methodology in this section is as follows:

i. First, we use data on purchase of home water filter equipment in Israel to identify two points along the curve depicting the relation between WTP and household income.

ii. We then use these two observations to identify households’ utility function, based upon the theoretical model described earlier in the paper.

iii. Finally, we used the identified utility function to find the WTP of the average Israeli household for high water quality.

Through a survey conducted among companies that sell home water filter equipment, we found that in the year 2000, approximately 200,000 Israeli households had water filter systems in their homes. Home water filters can be divided into two main groups: the first consists of basic filters employing U.V. technology or carbon filters, both of which lower the probability of contamination

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### Table 3. Decrease in incidence of disease following filtration (number of cases).

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Decrease in number of cases (thousands)</th>
<th>Decrease in cases of death (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>202</td>
<td>10.5</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Giardiasis</td>
<td>8.2</td>
<td>Negligible</td>
</tr>
<tr>
<td>Bacterial</td>
<td>18.7</td>
<td>24</td>
</tr>
<tr>
<td>Overall</td>
<td>242</td>
<td>38.5</td>
</tr>
</tbody>
</table>

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### Table 4. Economic value of decrease in incidence of disease following filtration of drinking water.

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Decrease in number of cases (thousands)</th>
<th>Economic value of decrease in incidence of disease (US$ million)</th>
<th>Decrease in cases of death (units)</th>
<th>Economic value of decrease in cases of death (US$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>202</td>
<td>14.25</td>
<td>10.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>13</td>
<td>3.5</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>Giardiasis</td>
<td>8.2</td>
<td>8.7</td>
<td>Negligible</td>
<td>–</td>
</tr>
<tr>
<td>Bacterial</td>
<td>18.7</td>
<td>20</td>
<td>24</td>
<td>9.6</td>
</tr>
<tr>
<td>Overall</td>
<td>242</td>
<td>46.5</td>
<td>38.5</td>
<td>15.4</td>
</tr>
</tbody>
</table>
to a level similar to that obtained by a central filtration plant, at an annual cost of approximately US$60; the second group consists of more advanced systems (using Reverse Osmosis technology) that lower the probability of contamination essentially to nil, with annual costs of about US$87.

**Home water filter use in Israel.** We conducted a survey among 88 households who purchased one of the two types of water filter equipment (basic or advanced) and examined the income level of each household. We found that 96% of households who purchased the basic water filter equipment belonged to one of the two upper household income deciles; 92% of those who purchased advanced filtering systems belonged to one of the three uppermost percentiles. In this way, we were able to arrive at two points along the curve depicting the relation between WTP and household income. We will presently use these two observations to identify the households’ utility function.

Based on our previous results, we know that damage costs for a person who contracts an intestinal disease due to contamination are about US$258 (our valuation showed savings of US$25.8 per person for a 10% reduction in probability of contracting a disease; therefore damage costs to a person who actually contracts a disease are 25.8/0.1 = US$258). In Israel, the average number of persons per household is 3.4 (Israeli Central Bureau of Statistics, 2000), so average costs per household are US$877. Some of these costs are not borne by the household: hospitalization, doctor visits, etc. These costs are covered through the national health insurance system and so the individual does not pay for them directly. That individual is concerned only with those expenses borne directly by the household (loss of workdays, leisure time, time of travel to receive treatment, etc.). These direct expenses constitute 77.3% of total damage costs and therefore, from the perspective of the average household, damage costs are US$678 (77.3% of US$877). As these costs depend on wages, they differ according to household income. Accordingly, damage costs are US$1,119 for households in the 9th decile and US$3,051 for households in the 97th percentile.

**Identifying households’ utility function.** Using this information, we can identify households’ utility function according to the economic model. We assume a risk-averse utility function of the form:

\[ U(x) = ax^b \]

We can identify the parameters of the utility function (\(a\) and \(b\)) based upon the theoretical model presented in the first section of this paper. Specifically, we make use of the following equation:

\[ WTP = \frac{(ax^b) - (a(x-L)^b)}{q-p} \quad (4) \]

This equation presents the relation between WTP and the utility function and, as we have data for all parameters (except for \(a\) and \(b\)) for two observations, we can solve for the unknown parameters. The known parameters for the two observations are:

\( q-p \) = The decrease in probability for contracting a disease is 10% using a basic system and 12% using an advanced system.

\( W \) = Average annual household income is US$49,300 for households in the 9th decile and US$130,000 for households in the 97th percentile.
WTP = $60 for households in the 9th decile and US$87 for households in the 97th percentile.

$L = $1,119 for households in the 9th decile and US$3,051 for households in the 97th percentile.

We now estimate the unknown parameters by inserting the known parameters for our two observations into Equation (4):

\[ WTP = \frac{(\alpha X^\beta) - (\alpha (X - L)^\beta)}{q - p} \Rightarrow \alpha = 0.9 \quad \beta = 0.5765 \]  

Having found the utility function, we can plug in the data for the average Israeli household (with an annual income of US$30,000) and arrive at an average household WTP value of US$45, or US$13.23 per person. This value is lower than that obtained in previous studies, as can be seen in Table 5, reproduced from Abrahams et al. (2000); the first four rows are taken directly from Abrahams et al.; the fifth we added based upon the findings described in Abrahams et al. (2000) itself. However, it should be remembered that average income in Israel is significantly lower than in the US (average wages in the US are about 250% higher than in Israel).

As 90% of households in Israel consume NWC water, it may be estimated that the total 1.82 households would be willing to pay US$81.9 million (45*1.82 million) for constructing a filtration plant. If we divide this number by the amount of water delivered to households through the NWC we get a WTP of US$0.3545 per m³.

4.2. Cost analysis

We evaluated the costs of constructing and operating a central filtration plant at the Eshkol site in northern Israel, through which all NWC water passes. After filtration, the water is supplied into a number of conveyance systems, transporting water to the different parts of the country.

The central filtration plant was chosen over other alternatives based on a comparison of net present cost. That is, expected expenditures over the entire lifetime of the plant (or plants) were discounted, and the alternative with lower net present cost was identified. In calculating expenditure flows, different quality parameters, such as lifetime, environmental effects, flexibility to adjust to unexpected changes, reliability, timetable for construction, and water security, were also taken into account.

The net present value of expenditures for the central filtration system was estimated at US$245 million. Construction costs were estimated at US$130 million; annual maintenance expenditure was estimated at US$4.4 million (Balash Ayalon & CDM, 1995). At a 7.5% discount rate, overall annual costs are thus estimated at US$21.5 million, or US$0.065 per m³.

4.3. Comparison of the results

Table 6 shows a comparison between the costs of constructing and operating the central filtration plant and the benefit estimates as derived by the two different methods: valuation of damages, and averting expenditures.

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1 The details of the calculations are provided in the technical report submitted to the government committee for the assessment of the need for filtration. See Mor Tamuz (2000).
As can be seen in Table 6, willingness to pay as estimated by the averting expenditures method is somewhat higher than the value of benefits according to our calculation of reduced damage costs. This result is reasonable, as households are assumed to be risk averse and are thus willing to pay a premium to minimize the probability of contracting a disease (a premium of US$0.0845 per m³). However, this result must be treated cautiously due to questions regarding the level of public awareness both to the probability of contracting a disease and to the costs of disease. As has been discussed in many papers (such as Abdalla et al. (1992) and Abrahams et al. (2000)) the level of public awareness to health risk has a significant effect upon willingness to pay for high water quality. This issue is not dealt with in this paper.

According to both methods of benefit analysis, the benefits to the public far outweigh the costs, by a factor of at least 4 to 1. The difference between benefits and costs is indeed significant enough so that it may be safely concluded that the bottom-line of this analysis—namely, that constructing the plant is economically worthwhile—would be unaffected by any minor change in the underlying assumptions of our analyses.

Beyond the public’s WTP, we need to take into account savings to the public service systems as well. Construction of the plant will achieve savings in the following areas:

i. direct operational savings to the Mekorot Water Corporation and to the municipal water systems of US$1 million;
ii. savings to the public health system (doctor working hours, hospitalizations, etc.) of US$10.5 million.

In fact, then, it is enough for the public’s WTP to equal US$10 million for the construction of the water filtration plant to be worthwhile (overall annual costs being US$21.5 million). Accordingly, it would be enough for 165,000 households to be willing to purchase home water filter equipment for the

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2 It should be noted that households are willing to pay, on average, US$45 for a home water filter, when only part of the drinking water supply comes from the NWC (the rest of the water is from groundwater sources, where contamination is much rarer). Therefore, a household’s averting expenditure is actually relevant for 38.5% of the water supply. This explains why averting expenditures turn out to be higher than damage costs.

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Table 5. Estimates of WTP for water safety, per person (Source: Abrahams et al., 2000: 436).

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Valuation</th>
<th>Valuation method</th>
<th>Estimated WTP (in US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzar &amp; Cosse (1998)</td>
<td>Δ in water quality</td>
<td>CV open-ended</td>
<td>77.00</td>
</tr>
<tr>
<td>Kwak et al. (1997)</td>
<td>Δ in drinking water</td>
<td>CV open-ended</td>
<td>39.36</td>
</tr>
<tr>
<td>Laughland et al. (1993)</td>
<td>Δ in water safety</td>
<td>Averting expenditure</td>
<td>46.00–275.00</td>
</tr>
<tr>
<td>Abdalla et al. (1992)</td>
<td>Δ in water safety</td>
<td>Averting expenditure</td>
<td>14.25</td>
</tr>
<tr>
<td>Abrahams et al. (2000)</td>
<td>Δ in water safety</td>
<td>Averting expenditure</td>
<td>47</td>
</tr>
</tbody>
</table>

Table 6. Comparing the costs of constructing and operating a water filtration plant with its expected benefits, as estimated by the two methods.

<table>
<thead>
<tr>
<th>Cost of filtration plant</th>
<th>Valuation of damages</th>
<th>Averting expenditures: home water filters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value in US$ per m³</td>
<td>$0.065</td>
<td>$0.27</td>
</tr>
</tbody>
</table>
investment in the filtration plant to be worthwhile. Already in the year 2000, about 200,000 households owned home water filter devices, and so, even if we ignore the rapid growth of the home water filter industry, construction of the plant is clearly worthwhile.

The question of how the benefits are shared between the different parties led us to examine another interesting question: how should the burden of financing construction and operation of the plant be divided between the different groups?

5. Dividing the financial burden

Economic theory often advocates the ‘polluter pays’ principle. According to this principle, whenever the source of pollution can be identified, the party responsible for the pollution should be the one to pay for minimizing its effects (see, for example, Baumol & Oates, 1988). However, what should be done when it is impossible to identify the polluter, or when the pollution occurs naturally?

In our case, water is produced from an open lake, and the source of its pollution cannot be identified easily. In this case, the ‘polluter pays’ approach is not applicable and does not aid us in finding a solution to the financing problem.

So, how should the financing burden be divided? Intuitively, it was proposed that the price of drinking water be increased so as to pass all costs of construction and operation of the filtration plant to water consumers. However, we present an alternative proposal here, based on criteria of simplicity, transparency, implementability and fairness. The principle at the heart of this methodology is what we term the ‘beneficiary pays’ principle.

We looked at all parties who stand to benefit from utilization of the water filtration plant: the Mekorot Water Corporation, municipalities, hospitals (through less hospitalizations and doctor visits, etc.) and, of course, households. We examined how benefits would be divided between the different parties (percentage-wise) and then split construction and operation costs according to the same ratio (see Table 7).

The table shows that, by this method, most of the financing burden should fall on households (82%), as they stand to benefit most from the introduction of the filtration plant. The health system’s share of total benefits is 16.6%, resulting from savings gained by the decrease in incidence of disease. Direct benefit to municipalities and to the Mekorot Water Co. is rather small: only 1.6% of the total value of benefits.

As we are interested in constructing a simple and straightforward assessment mechanism, it is proposed to avoid taxing municipalities and instead divide the burden between its two main beneficiaries: households and the Ministry of Health. The Ministry of Health should have a total of US$3.65 million subtracted from its annual budget; the rest of the costs should be borne directly by households, through a US$0.054 per m³ increase in the price of drinking water.

Table 7. Dividing the burden according to the ‘beneficiary pays’ principle.

<table>
<thead>
<tr>
<th>Benefiting party</th>
<th>Value of benefits (US$ million)</th>
<th>Share of overall benefit (%)</th>
<th>Share of financing burden (US$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health system</td>
<td>10.5</td>
<td>16.6</td>
<td>3.65</td>
</tr>
<tr>
<td>Municipalities and water corporation</td>
<td>1</td>
<td>1.6</td>
<td>0.35</td>
</tr>
<tr>
<td>Households</td>
<td>51.5</td>
<td>81.8</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>100.00</td>
<td>22</td>
</tr>
</tbody>
</table>
6. Conclusion

This paper presented an economic benefit analysis of constructing a filtration plant to serve the Israeli National Water Carrier, and a comparison of the estimated benefits with the costs of constructing and operating the plant. The study found a clear net benefit in constructing the plant.

Benefit analysis was carried out according to two independent methods: direct valuation of damages and assessment of households’ WTP through evaluation of averting expenditures. We found that the price that households are willing to pay for improved water quality is higher than the actual benefits expected from reduced illness damage costs. This may seem reasonable, as households are risk averse and are willing to pay a premium for lower risk. However, this result must be treated cautiously due to questions regarding the level of public awareness both to the probability of contracting a disease and to the costs of disease.

Finally, we have proposed a methodology for dividing the burden of financing plant construction and operation, on the basis of what we term the ‘beneficiary pays’ principle. This principle is not widespread in the literature, but in cases where it is impossible to identify the polluting parties, it may serve as the most sensible and justifiable solution to the financing problem.

References


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