Supporting Information

Cost-benefit analysis of the Swiss national policy on reducing micropollutants in treated wastewater

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Summary: 10 pages, 1 figure, 2 tables

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Criteria for upgrading sewage treatment plants

Recent changes in the Swiss water protection law (in force since 21 March 2014) imply that MP loads from STPs will be reduced. The concrete implementation of the law (e.g. a decision on which STPs need to be upgraded) will be regulated by the water protection ordinance. The ordinance draft has been developed by relevant stakeholders (state authorities, professional associations, industry representatives, and scientists) and will be subjected to a public consultation by the end of 2014. The criteria for the selection of STPs that should be upgraded are likely to be similar to the ones that were used for the cost estimation (see Table 1).[1] Ultimately, the exact number of STPs that will be upgraded depends on the specific situation and future planning of the cantonal authorities (e.g. connecting two STPs to one bigger STP or exceptions with justified negligible ecosystem benefit in relation to required investment).

Cost assessment

The cost estimates used in this paper are based on two reports, compiled on behalf of the Swiss Federal Office for the Environment.[1,2] The exact cost estimates of the upgrades depend primarily on two decisions, namely the final number of STPs that will be upgraded and the choice of upgrading technology that will be implemented in each STP (activated carbon versus ozonation). In this study, exceptional cases (criterion 4 in Table 1) are included in the cost estimates and in the CBA. Furthermore, cost estimates presented here are based on the assumption that the proportion of activated carbon and ozonation technology is 67% and 33% for STPs that will be upgraded on the basis of the first criterion in Table 1, whereas the proportion of technologies for STPs that will be upgraded under all other criteria is assumed to be 50% and 50% respectively.

The right-hand side of Table 1 presents annual costs (both total and disaggregated by various cost categories) for upgrading STPs under each criterion. These values are exclusive

of value-added tax. Total annual costs comprise amortisation costs (i.e. discounted investment costs distributed over the expected life span of the investment), operating costs and interest expenses. The total investment costs of upgrading the 123 STPs are estimated at 1.12 billion CHF. They consist of costs of construction, mechanical equipment, electrical system, automation and control technology, heating, ventilation, air condition, sanitary facilities, engineering fees, and reserves for unforeseen expenses. The expected average life span of the STP upgrades is assumed to be 33 years. The amortization costs hence amount to 34 million CHF annually. Operating costs include salaries for labour, electricity, maintenance, analysis, material (activated carbon, liquid oxygen, flocculant, and precipitant), and extra sludge disposal costs for the activated carbon treatment. Finally, the interest costs are based on an interest rate of 2%.

Choice experiment theory and choice model specification

The underlying conceptual framework for CE is random utility theory.[3,4] It assumes that preferences of an individual *i* for an alternative *j* reflects utility *U* that he or she obtains by choosing that alternative. A decision maker is assumed to select the alternative which provides him or her the highest utility. In a random utility model, this utility is decomposed into a deterministic (V_{ij}) and a stochastic component (ε_{ij}):

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \quad (1)$$

The deterministic part of utility V_{ij} is usually specified as βX_{ij}, where X_{ij} are attributes of the alternative j presented to an individual i, and β denotes the associated coefficients.

The choice model used for analyzing respondents' choices in this study is the mixed logit model. This model allows greater flexibility than the conditional multinomial logit model as it accounts for possible correlation between choices inherent to the panel data structure underlying CE and preference heterogeneity. In the choice models the probability of

observing a sequence of choices y_i for an individual i is calculated as the product of conditional probabilities of all choice tasks $t = (1,...,T)$ presented to the respondent. These conditional probabilities are integrated over all possible values of β_i, given their density $f(\beta|\theta)$:[5]

$$P(y_i|\theta) = \int \prod_{t=1}^{T} \left(\frac{\exp(\beta_i X_{ij})}{\sum_{k \in C} \exp(\beta_i X_{ik})} \right) f\left(\beta|\theta\right) d\beta \tag{2}$$

where X_{ij} are attributes of alternatives j chosen by an individual i and X_{ik} are attributes of all other alternatives k from a choice set C. The resulting integral does not have a closed form and is therefore approximated through simulation. In this article, the choice model parameters are estimated using a maximum simulated likelihood procedure and Halton draws with 100 replications. The Halton draws generate more precise results than independent random draws in the estimation of random parameters logit models.[6,7]

In order to account for heterogeneous preferences among respondents, parameters for nonmonetary choice attributes are specified as random terms. A uniform distribution is used for dummy variables and a normal distribution for continuous variables.[8] The price coefficient is fixed to improve the statistical efficiency of the estimated WTP values.[9]

If a monetary price attribute is included in the CE design, parameters estimated in the choice model can be used for valuing changes in a respondent's utility in monetary WTP terms.[8,10] These utility changes are calculated as:

$$MWTP_a = -\frac{\beta_a}{\beta_p}, \tag{3}$$

where $MWTP_a$ is marginal WTP for a nonmonetary attribute, β_p is the coefficient of the price attribute, interpreted as the marginal utility of income, and β_a is the coefficient of the nonmonetary choice attribute.

The average increase in welfare gained from adopting a specific policy scenario compared to the status quo scenario (i.e. the mean WTP) is then calculated as follows:

$$WTP = \frac{1}{\beta_p}\left\{\ln\left[\sum_{k\in C}\exp\left(V_k^1\right)\right] - \ln\left[\sum_{k\in C}\exp\left(V_k^0\right)\right]\right\}, \quad (4)$$

where β_p is the coefficient of the price attribute, $V_k{}^0$ is the utility of the status quo option and $V_k{}^1$ the utility of an alternative option.[10]

Pretesting of the questionnaire

The process of questionnaire design lasted approximately three months. It involved several rounds of questionnaire reviews by experienced stated choice researchers, experts in water and urban water management, eco-toxicologists, and ecologists. Three rounds of pretests that took place between April and May 2012 enabled improving the questionnaire design. In the first two rounds 76 face-to-face interviews were conducted by four professional interviewers, who were hired from a marketing agency specialized in public surveys. The third pretest round included 122 online surveys. Such thorough pretesting of the questionnaire ensured that questions, textural explanations and particularly the CE design used in the survey are easy to understand for the general public, that attribute levels are appropriately defined and that the CE design is efficient. An example of the resulting choice card is provided in Figure 1.

Assumptions made in the benefit aggregation procedure

The total benefit estimate of CHF 155 million relies on two important assumptions. First, the beneficiaries of implementing the national MP policy are only households in the catchment of the STPs to be upgraded, even though other households may also benefit because the potential environmental risk will be reduced in some river sections downstream of STPs that will not be upgraded. Second, it is assumed that upgrading will reduce the potential environmental

risk to a low level in the case of all 123 STPs for most of the time during the year. This is the case for 96 STPs. For river stretches directly downstream of 27 upgraded STPs, the substance exposure model shows that the potential environmental risk can only be reduced to or remains at a medium level (high at 1 STP) during driest weather, i.e. base flow (Q95%, at least 5% of the time during a year). For 24 STPs the potential environmental risk level could not be evaluated unambiguously. In these cases, additional information would have to be obtained for river discharges or to estimate mixing effects in lakes.[11] While the second assumption tends to overestimate the total benefits, the first assumption is expected to underestimate them.

References

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Figure 1. Choice card example

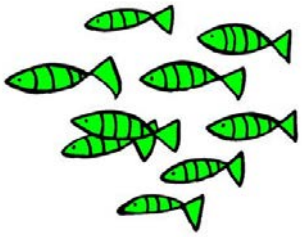
Option A	Option B	NO CHANGE
Low potential risk 	Medium potential risk 	
Whole of Switzerland 	Your Canton 	
 5 years	 15 years	
CHF 100 / year	CHF 50 / year	CHF 0 / year

Table 1. Proposed criteria for upgrading STPs and corresponding cost estimates

	Definition	Number of STPs	Investment costs (CHF/a)	Operating costs (CHF/a)	Interest costs (CHF/a)	Total costs (CHF/a)
Criterion 1	STP >80'000 inhabitants connected	13	9'000'000	28'000'000	6'000'000	43'000'000
Criterion 2	STP in the catchment of a lake if STP >24'000 inhabitants connected	21	7'000'000	16'000'000	5'000'000	28'000'000
Criterion 3	STP at river section with >10% of water in the river that is wastewater not treated for organic MPs if STP >8'000 inhabitants connected and ecologically improved river section >500m	69	16'000'000	29'000'000	10'000'000	56'000'000
Criterion 4	STP at river section with >10% of water in the river that is wastewater not treated for organic MPs if STP >2'000 inhabitants connected and ecologically improved river section >10km	20	2'000'000	3'000'000	1'000'000	6'000'000
Total costs			34'000'000	76'000'000	22'000'000	133'000'000

Note: The cantonal authorities have to provide detailed plans to determine the final number of STPs to be upgraded under criteria 3 and 4.
Source: BG Consulting Engineers et al. (2012).

Table 2. Mean willingness to pay estimates for different policy scenarios

Policy scenario	Time in which new knowledge about the impacts of MPs on human health will become available	Potential environmental risk level	Scale of the potential environmental risk reduction	Mean WTP (CHF/a/ household)	95% confidence intervals
Scenario I	5 years	Low	Switzerland	240	212 ─ 268
Scenario II	10 years	Low	Switzerland	211	186 ─ 235
Scenario III	15 years	Low	Switzerland	181	159 ─ 203
Scenario IV	20 years	Low	Switzerland	151	131 ─ 172
Scenario V	5 years	Low	Canton	189	165 ─ 213
Scenario VI	10 years	Low	Canton	159	139 ─ 180
Scenario VII	15 years	Low	Canton	130	112 ─ 147
Scenario VIII	20 years	Low	Canton	100	84 ─ 116