Hydrol. Earth Syst. Sci. Discuss., 11, 7169–7188, 2014
www.hydrol-earth-syst-sci-discuss.net/11/7169/2014/
doi:10.5194/hessd-11-7169-2014

Hydrology and Earth System Sciences
Discussions
Open Access

Non-market valuation supporting water management: the case study in Czestochowa, Poland

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Received: 2 June 2014 – Accepted: 4 June 2014 – Published: 1 July 2014

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

Water resources in Poland continue to be under stress despite systematic efforts to safeguard ground and surface water quality and quantity. Groundwater protection from nitrate pollution of human origin requires the development of sewerage systems. Such investments are often financed from public funds that must be formally appraised. The appraisal should be done by a comparison of benefits and costs of investment measures – not only financial but also environmental and social. A significant challenge is the monetization of the effects on the environment. In this paper we use non-market valuation to examine residents' preferences and estimate their willingness to pay for improving drinking water quality. This paper also contributes to the narrow literature on valuation of benefits of measures for groundwater quality improvement by presenting an application of the choice experiment method in the Czestochowa Region of Poland. To the best of our knowledge this is the first study estimating the value of benefits of the groundwater quality improvement in Poland.

1 Introduction

Groundwater is the main source of potable water, in Poland, accounting for more than 70 % of consumption volume. The last national assessment (in 2013) of the groundwater quality was done on the basis of observations in 589 measurements points by the Polish Hydrogeological Survey (Cabalska et al., 2014). Results indicate the poor chemical status in 23 % of the examined points. Groundwater quality was also evaluated according to the fulfilment of quality requirements for drinking water. In 22% of the measuring points (in 170 points) the exceedance of concentration of nitrogen compounds was observed. Nitrogen compounds that occur in groundwater have largely come from the leaks of liquid wastes from households that are not connected to the sewage system. Those households usually use leaking septic tanks from which the sewage seeps into groundwater.

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Measures aiming to achieve the good quantitative and chemical groundwater status have to be evaluated in terms of their economic efficiency. According to the Water Framework Directive measures should be assessed by cost-effectiveness and cost-benefit analysis. So far, in Poland sewerage investments were evaluated only by cost-effectiveness analysis (by a cost per one person connected to sewerage). Cost-benefit analysis must take into account both the financial costs as well as indirect effects such as environmental and resource costs. The estimates of economic costs and benefits should be also incorporated in an analysis of cost-recovery of water services and other water management plans (Chung and Lee, 2009).To the best of our knowledge this is the first study estimating the value of benefits of the groundwater quality improvement in Poland.

Non market valuation has been used for the monetization of benefits of groundwater improvement. Several attempts have been made to value groundwater (Hasler et al., 2005, 2007; Jordan and Elnagheeb, 1993; Koundouri et al., 2012; Martinez and Prantilla, 2007; McClelland et al,. 1993; Rinaudo, 2008; Stenger and Willinger, 1998; Tempesta and Vecchiato, 2013; Tentes and Damigos, 2012; White et al., 2001). The contingent valuation method has been used to assess among others people's willingness to pay (WTP) for improvements in nitrate-contaminated groundwater (Jordan and Elnagheeb, 1993), the economic value of groundwater aquifer (Martinez and Prantilla, 2007), the national benefits of cleaning groundwater contaminated by landfills (McClelland et al., 1993), the benefits of the protection of the over-exploited groundwater aquifer (Rinaudo, 2008), WTP of households living in polluted areas and households having access to preserved quality of groundwater (Stenger and Willinger, 1998), the environmental damage to groundwater, WTP for restoring the aquifer (Tentes and Damigos, 2012), the economic value of groundwater to abstractive users (White et al., 2001). Several papers use the choice modeling approach. Among the topics studied are the estimation of benefits of groundwater protection and groundwater purification in Denmark (Hasler et al., 2005, 2007), the economic value generated by groundwater improvements and from scientific research on effects of climate change on groundwater

(Koundouri et al., 2012), and the assessment of benefits of policies aiming to reduce nitrates in groundwater (Tempesta and Vecchiato, 2013).

2 The Czestochowa case study

The case study is located in the southern part of Poland. Administratively it belongs to the Silesian Voivodeship. The case site is the recharge area of the Main Groundwater Reservoir No 326 (MGWB 326) that is called Czestochowa aquifer from the name of the biggest town lying on this area (Fig. 1). Groundwater is connected to rock formations varying in age that compose the Quaternary, Jurassic (MGWB 326), Cretaceous and Triassic multi-aquifer formations. The MGWB 326 aquifer system is divided into two sub-basins: MGWB 326 (S) located S-E of Czestochowa, with documented and approved disposable water resources of 4220 $m^3 h^{-1}$ on the area of 170 km^2, and MGWB 326 (N) located N of Czestochowa, with documented and approved disposable water resources of 8900 $m^3 h^{-1}$ on the area of 570 km^2. (Malina et al., 2007). The Czestochowa aquifer serves as the main source of drinking water for the local population (335 000 inhabitants) and the local economy (800 factories and enterprises).

MGWB 326 has a very low resistance against pollution coming from the terrain mainly because of lack of an insulation Quaternary layer. The reservoir (generally unconfined aquifer) is exposed on a considerable area and thus it is vulnerable to even small pollution resulting in quick degradation of water resources. The increase of nitrate concentrations in number of wells of MGWB 326 exploited by drinking water supply company is observed. The mean annual NO_3^- concentration in extracted water in two wells of Łobodno water works has risen from 40 $mg L^{-1}$ in 1997 to 60 $mg L^{-1}$ in 2008. The permissible value for drinking water (50 $mg L^{-1}$) was exceeded in 2001 and the adverse concentrations of nitrates steadily increase (Fig. 2) (Mizera and Malina, 2010).

This contamination is primarily caused by the limited coverage of the residential sewerage system. In 2012, the population in communities in the area of MGWB 326 (N) was 335 000. Figure 3 shows an equipping in sewerage systems in communities in the case

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study area (Czestochowa, Janow, Klobuck, Konopiska, Miedzno, Mstow, Mykanow, Olsztyn, Poczesna, Redziny). In a majority of communities less than 50 % of population is connected to a sewage system. Almost 100 000 people use septic tanks to collect their wastes.

In order to improve the groundwater quality a number of measures in the field of construction projects in sewerage systems and wastewater treatment plants (WWTP) have been planned in communities in the case study area. Proposed development of infrastructure will allow 34 thousand people to connect to sewerage and to treat additionally 620 m^3 of sewage per day. Capital expenditures of planned investments are shown in Tables 1 and 2.

Evaluation of the effectiveness of these water management strategies cannot be carried out only on the basis of the financial benefits like predicted revenues from connected people. It also needs to be based on environmental the benefits that arise as a result of the infrastructure operation over a longer period. The main environmental effect of a water management strategy in our case study area will be to stop the degradation of the groundwater quality and subsequently improve groundwater quality. A usual approach in economics is to value goods and services using market prices and revealed consumer behaviour in terms of investigating actual demand and supply decisions for the given good. It is common that traditional economic approaches cannot be used for the valuation of goods and services for which markets are not present. This is often the case when the evaluated good is an environmental good. In cases where markets and consequently market prices are not present alternative approaches need to be applied. This paper applies non market valuation to monetize the benefit of water quality improvement.

3 The choice experiment method

To value groundwater quality and management characteristics we use a choice experiment. In a choice experiment, individuals are presented with a series of choice sets.

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For each choice set, respondents are asked to choose their preferred alternative. The choice experiment method is based on the random utility model. According to the random utility model, the utility of respondent *i* from alternative *j* at choice situation *n* is given by:

$$U_{ijn} = V_{ijn} + \varepsilon_{jni} = \beta X_{ijn} + \varepsilon_{jni} \quad (1)$$

The systematic component V contains specific and observable attributes (X) of the alternatives that are defined and presented to the respondents in the form of choice sets (Berninger et al., 2010). The probability alternative *i* is chosen is given by (Adamowicz et al., 1998):

$$P(i) = P\left(V_i + \varepsilon_i > V_j + \varepsilon_j\right) \quad \forall j \neq i,\ i,\ j \in C_n \quad (2)$$

where C_n is the choice set of respondent *n*.

Assuming that the error is Gumbel distributed implies the multinomial logit model (MNL), $\Pr\left(U_{ij} > U_{ik}\right) = \frac{\exp V_{ij}}{\exp V_{ij} + \sum \exp V_{ik}}$. Assuming a linear systematic component of utility, WTP for a non-monetary attribute can be calculated as the ratio of the utility coefficient of the attribute over the coefficient of the monetary attribute.

3.1 The choice experiment design and the survey

The purpose of our choice experiment was to investigate the public's willingness to pay for improving groundwater quality by investing on municipal sewerage.

We characterised the management program in terms of the following attributes: water pollution, time to improvement and the additional monetary charge in the form of an additional lump sum payment on the water bill.

For the definition of the levels of the water quality attribute we relied on the characterisation of good ecological status of water resources according to the Water Framework Directive (WFD). The best possible level of water quality was near zero pollution, while the second best level was pollution at the maximum permissible level by EU regulations, which is currently set at 50 mg L^{-3}. If no measure was implemented to mitigate water pollution, nitrate concentrations would exceed the maximum permissible level by 20 %.

The levels for the time-to-improvement attribute were 15, 20, 25 and 30 years. If no measure is implemented nitrate concentrations would exceed the maximum permissible level by 20 % in 60 years. Due to the nature of water pollution fast improvement of water quality is unrealistic. As a result, we selected the levels for this attribute to indicate improvement in the medium and long run.

The levels for the additional charge attribute were 20, 40, 50, 60, 80 and 100 PLN (EUR 5, 10, 12, 15, 20, 24). We report the attributes and their levels in Table 3.

Based on these attributes and their levels we constructed a d-efficient experimental design. Each respondent was asked to make 7 consecutive choices between 2 opt in and 1 zero cost opt out alternative. To avoid systematic starting point bias we randomized the presentation order of the choice sets (Ladenburg and Olsen, 2008). Table 4 presents an example of a choice card.

The survey started by introducing respondents to the significance of the aquifer for the region's water supply. The survey then described the current status regarding water quality the forecasted situation in the next 10 years and the exact measures to be implemented in order to achieve improvement in terms of the attributes. After presenting valuation scenario and assuring the confidentiality of the results, the respondents were asked to respond to the survey questions while keeping in mind their budget constraints, financial obligations and other payments they make for similar goods and services.

We pretested the survey one week before the actual sampling took place and revised the valuation scenario and surveys accordingly. Data collection took place using face-to-face interviews from trained interviewers. We collected a random sample of 400 respondents. Data collection took place during July 2011.

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3.2 The multinomial logit model

We estimate Multinomial Logit models to analyze the determinants of individual stated choice. Table 5 reports the coefficient estimates. All attributes appear to be significant determinants of individual choice and carry the expected signs. Specifically, respondents are more likely to select alternatives with near zero pollution and pollution at the safe level relative to alternatives with increased pollution. The sign of the time to improvement attribute is negative, indicating that respondents are less likely to select alternatives where the improvement will take place further into the future. The negative sign on the coefficient of the additional charge attribute implies that respondents are less likely to select more expensive alternatives, as predicted by economic theory.

Based on the estimates of the multinomial logit model, we estimate WTP for the attributes and their levels. We report the results in Table 6. Respondents are WTP 54.11 PLN to achieve near zero nitrate pollution. Respondents are WTP 53.66 PLN for pollution to remain at the maximum safe level according to EU regulations. Finally respondents are WTP 1.77 to achieve improve-ment in water quality one year earlier. The results of the choice experiment illustrate the value attached to improving water quality in the Czestochowa region.

4 Conclusions

In this paper we present the results of a choice experiment aiming to evaluate the public's preferences for water quality in the Czestochowa region in Poland. Results of analysis lead to following conclusions:

- Respondents are willing to pay more than their current water bill (WTP 53.66–54.11 PLN (EUR 13.09–13.20)) to secure better water quality.

- On the basis of WTP the aggregate value of improvement measures could be assessed. The aggregate WTP can be calculated by multiplying the estimated

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monthly household WTP by the number of households connected to a water supply system. It exceeds 50 million PLN per year (EUR 12 million per year).

- The aggregate WTP allows to assess that planned measures (capital costs approx. 150 million PLN) are not disproportionately expensive in comparison to pubic willingness to pay (50 million PLN per year).
- The estimated WTP can be used to select economically justified measures in future water management plans and studies.
- In River Management Basin Plan for the Odra River Basin (2011) there is estimated economic cost recovery on a level of 60 %. Water services are still underpriced. The analysis of WTP allows to plan a water price policy taking into account the public acceptance of price levels. It could be also used to set the water prices generating revenue to meet expenditure.

The results indicate that there is substantial WTP for water quality improvements. Our results add to the expanding literature on the valuation of water quality in Europe and can be useful for water management and for the policy debate, especially in the context of the EU's Groundwater Directive.

Acknowledgements. The study was supported by the European Community 7th Framework Project GENESIS (226536): Groundwater and Dependent Ecosystems: New Scientific and Technical Basis for Assessing Climate Change and Land-use Impacts on Groundwater Systems.

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Table 1. Planned investments in sewerage systems in the case study area.

Community or association of communities	Planned sewerage [km]	Increase in population connected to sewerage	Planned ratio of population connected to sewerage [%]	Costs [thousand PLN]
Czestochowa, Mykanow, Redziny, Poczesna, Konopiska	85.5	18 376	86.7	63 158
Redziny	44.0	8 858	100.0	38 280
Kłobuck	29.7	4 578	88.9	35 664
Mstow	20.9	2 503	50.3	14 381
Mykanow	2.5	300	44.7	3 000
Total	182.6	34 615	85.6	154 483

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Table 2. Planned investments in waste water treatment plants (WWTP) in the case study area.

Community	Planned WWTP	Existing capacity [$m^3 d^{-1}$]	Planned capacity [$m^3 d^{-1}$]	Costs [thousand PLN]
Rędziny	WWTP construction	0	300	5 000
Kłobuck	modernization of WWTP	3 200	3 200	7 795
Mstów	extension of WWTP	320	640	2 000
Total		3 520	4 140	14 795

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Table 3. Attributes and levels used in the Choice Experiment (Status quo levels in italics).

Attribute	Levels
Nitrate pollution	three levels: Near zero pollution; Pollution at the maximum safe level; *Pollution 20 % higher than the safe level*
Time to improvement	four levels: 15, 25, 30 and *60 years*
Additional water charge	seven levels: 20, 40, 50, 60, 80, 100 and *0 PLN*

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Table 4. An example of a choice card.

Suppose that the three alternatives below are the only ones that are available for the management of the Czestochowa Aquifer. Which one of those would you choose if you had the choice?			
	Alternative 1	Alternative 2	Alternative 3
Nitrate pollution	at the maximum safe level	1.2 times the maximum	1.2 times the maximum
Time to improvement	30 years	30 years	60 years
Additional charge	60 PLN	50 PLN	0 PLN
I would choose Alternative:	1	2	3

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Table 5. Results of the multinomial logit model.

Attribute		Coefficient	St Error
Nitrate pollution	near zero pollution	1.197*	0.1603
	at safe level	1.208*	0.1341
Time to improvement		−0.039*	0.0063
Additional charge		−0.022*	0.0024

* = Significance at 10 % level.

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Table 6. Willingness to pay estimates.

Attribute	WTP	St error
Nitrate pollution – near zero pollution	54.11 PLN*(EUR 13.20)	7.14 PLN(EUR 1.74)
Nitrate pollution – at safe level	53.66 PLN*(EUR 13.09)	6.24 PLN(EUR 1.52)
Time to improvement	1.77 PLN* (EUR 0.43)	0.24 PLN(EUR 0.06)

* = Significance at 10 % level. Standard errors calculated using the delta method.

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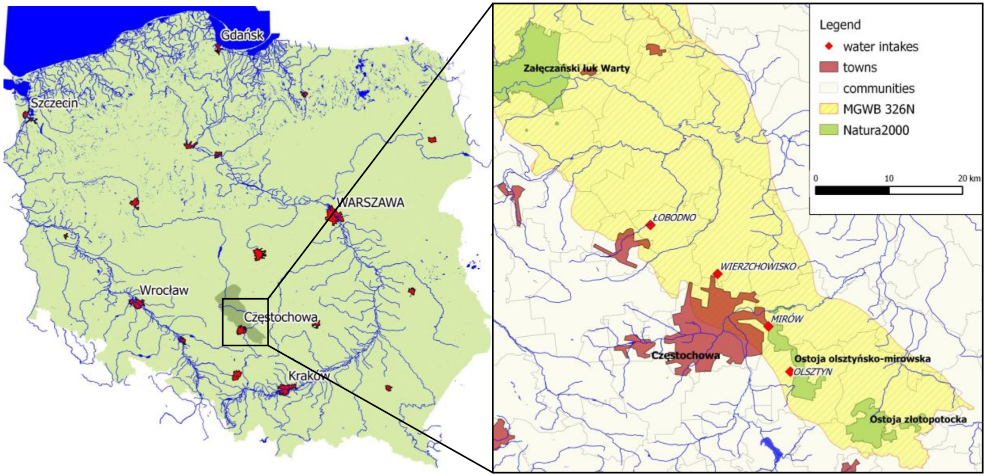

Figure 1. Location of Czestochowa case study – the Main Groundwater Reservoir No 326 (N) (MGWB 326N) with protected Natura 2000 areas and groundwater intakes.

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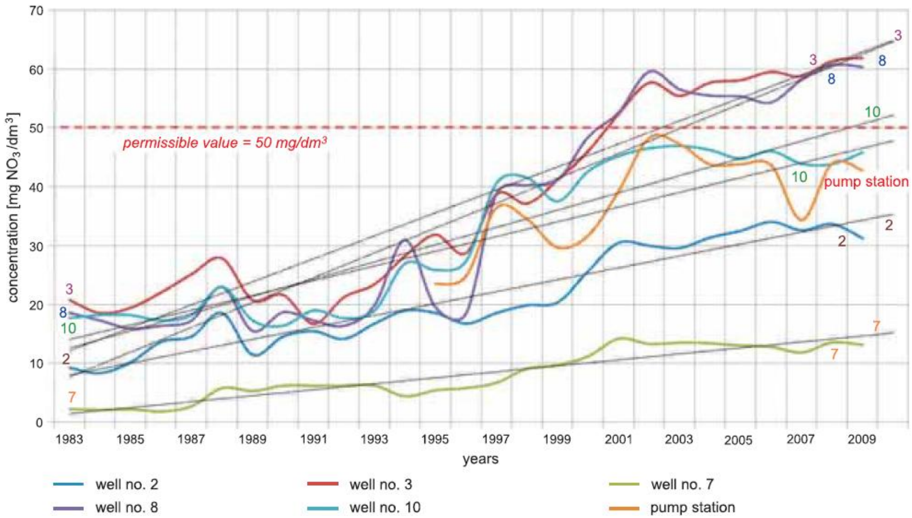

Figure 2. Changes of mean nitrate concentration in wells of the water intake Łobodno (Mizera and Malina, 2010).

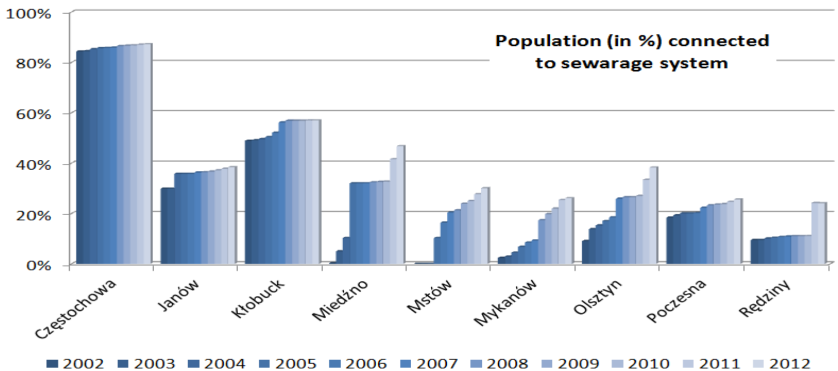

Figure 3. Equipping in sewerage systems in communities in the case study area.

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