To Invest Or Not To Invest? – A Valuation Of Mine Water Recirculation Comprising Private And Public Benefits In Ha Long, Vietnam

Hao Hong Do[1], Viet Quoc Trinh[2], Oliver Frör[1]

[1]*Institute of Environmental Sciences, Department of Environmental Economics, University of Koblenz-Landau, Fortstraße 7, D-76829 Landau, Germany, hao_do@uni-landau.de*

[2]*Institute of Environmental Engineering and Ecology, Faculty of Civil and Environmental Engineering, Ruhr-University Bochum, Universitätsstraße 150, D-44780 Bochum, Germany*

Abstract

Whilst pursuing profitable targets in business, environmental protection and conservation activities by mining companies are hardly pursued. This study aims to reveal the feasibility to gain benefits while investing in water treatment to recycle and reutilize mine water and achieve an efficient and environmentally benign water management in the Ha Long coal mining region in Vietnam. A cost-benefit and payback period analysis are conducted to provide a framework for the investment decision. Furthermore, a survey based on contingent valuation is adopted to estimate the willingness to pay for clean rivers in urban areas nearby the mining operations.

Key words: cost-benefit analysis, contingent valuation, ecosystem services, mine water, developing country

Introduction

Water resources are becoming increasingly scarce, albeit its essential role for human life. It has been one of the most widely overused and polluted natural commodities on our planet. Besides, coal mining causes not only severe pollution of surface and groundwater but also hazards to the surrounding nature and ecosystem. Nonetheless, available literature concerning economic concepts of the solutions of these mine water-related issues is mainly about the economic efficiency of a technological application within the private investment of mining companies (Haibin & Zhenling 2010; Dharmappa et al. 2000); the potential effects to society are rarely considered thoroughly. Thus, this paper attempts to identify and associate the positive welfare gained from an efficient mine water management in two ways: the mining company on the one hand and society on the other hand, or in other words, the internal and external benefits. First, it provides a cost-benefit analysis of the investment in water treatment plants for recirculation and reuse within the coal mining industry in Vietnam. Thence, it employs an economic valuation of the external benefits of such an investment in improving the river aquatic environment, hence the ecosystem, in the vicinity of the hard coal mining region in Ha Long peninsula, Vietnam.

In Vietnam, the coal mining industry has experienced a long history of 178 years. It is located mostly in the northern regions of the country. In 1994 the Prime Minister enacted the establishment of Vietnam national coal and mineral industries holding corporation limited (Vinacomin), with one hundred percent of the charter capital coming from the State. Contributing the largest portion to the economic structure of Quang Ninh province, the hard coal mining industry proves to be an important sector. Whilst Ha Long Bay has been a UNESCO world natural heritage site twice, coal exploitation comprises nearly 50 percent of the city's total economy (Vietnam Institute for Urban and Rural Planning 2013), severely adding to the pollution of this tourism city – the centre of the province with rapid economic development. Although the mining companies have continuously enhanced equipment for purification of mine water, the vulnerability still remains in the current system. Each day, mining activities

in Ha Long release about 95,000 cubic meters of mine water. By 2016, 51 percent of mine water volume was not properly treated but directly discharged into the environment, causing pollution for adjacent rivers. On account of the scarcity of this natural resource and the economic growth, Ha Long is forecast to be in a shortage of freshwater at 28,000 cubic meters per day by 2030. For the above reasons, the WaterMiner project, funded by the German Federal Ministry of Education and Research (BMBF), focuses on improving the efficiency and effectiveness of mine water management within Ha Long peninsula through the material flow analysis (Brömme et al. 2018), the technical concepts (Ulbricht et al. 2018), and the economic concepts. The remaining structure of the paper is as follows: the next section presents the cost-benefit analysis of mine water recirculation and reuse for an individual mining company; the following section analyses the social benefits by a non-market valuation technique; finally, the paper discusses and concludes.

Estimation of internal benefits – an investment cost analysis

Nui Beo Coal joint stock company, a subsidiary of Vinacomin which we use as a case study, exploits both open-pit and underground mining, of which the latter consumes extensively more water during operation than the former. The implementation of underground mining since 2017 has led to a sudden tremendous demand for clean water. Currently, the provision of clean water relies upon the water company of the province (Quawaco), meanwhile, a vast amount of mine water is discharged into the environment after partial treatment. With the expansion of coal mining, the gap between demand and supply of acceptable water quality for different use purposes is increasing and thus raises awareness for the potential of recycling and reusing mine water.

For that reason, this study focuses on the approach of recirculation and reuse of mine water. Mine water treatment in all coal mines is managed by Vinacomin environment company, to which each subsidiary mining company pays fees for the services. The mine water treatment plant in Nui Beo company reaches the capacity of 1,200 cubic meters per hour, generating output water satisfying the national standard for industrial wastewater. This water is reused for such as coal selecting, dust control, road washing, machine washing whilst water with higher quality for domestic use needs further treatment. Thence, a newly supplementary water treatment station advances the treated mine water to the water qualifying the national standard.

Mine water from the underground pit is less likely to depend on the season and is thus more stable in volume than the open-pit mining. 200 litres per day is the average amount of needed water per worker for regular operation such as washing work clothes and equipment, bathing after work and cooking. Currently, the total number of workers of the company is 1500 persons projected to be doubled by 2025. In reality, the amount of consumed water is higher than the projected amount due to the currently low consciousness of saving water of workers. From this circumstance, a flexible treatment capacity is

Table 1 *Quantity and costs of water supply for domestic use.*

Pos.		Amount/day (m^3)	Amount/year (m^3)	Unit cost (VND/m^3)	Cost/year (VND)
1	Produced water	400	146,000	6,618	966,228,000
2	Water bought from clean water supplier				2,204,600,000
	The first 200 m^3/day	200	73,000	12,500	912,500,000
	The next 200 m^3/day	200	73,000	17,700	1,292,100,000
3	Variable cost saving				1,238,372,000
4	Initial investment				6,885,333,146

necessary. Altogether, after thorough consideration, an investment into an automatically supplementary water treatment system with a capacity of 400 m^3/day is plausible to recirculate mine water for domestic use.

In the economic and technical report of water treatment plant for domestic use (VITE-Vinacomin 2016), the list of supplementary treatment costs includes (i) chemical ingredients: pH balancing, nano iron(0), NaClO, (ii) electricity, (iii) labour, (iv) maintenance, which are transformed into 3,120; 2,680; 808; and 10 VND per cubic meter, respectively. In summary, the unit cost yields 6,618 VND (US$ 0.292/m^3). The supplementary plant locates in the adjacent area of the existing one to acquire the advantage in water delivery. Table 1 exhibits the cost-benefit analysis of an investment in a supplementary water treatment facility. Benefits stem from the monetary saving from further treatment and recirculation of water instead of buying from external suppliers.

Based on the results of table 1, the net present value (NPV) is calculated towards 2030 under the current plan of coal mining in this company. The NPV of an investment in 2017 at about 6.885 billion VND (pos. 4) following with about plus 1.238 billion VND saved annually cash flows (pos. 3) in a duration of 13 years yields about 5.291 billion VND, given that the discount rate is proposed by the State Bank of Vietnam (2017) at 4.25% (The use of a discount rate in this analysis depends on the expected price changes of purchased water. If we expect a price change in the range of the assumed discount rate, the rate should be ignored. Conversely, if price changes are expected to be very low, the discount rate should be used.). Another technique to evaluate the economic feasibility of the supplementary water treatment is the payback period, which is estimated at 5.56 years, whereas the discounted payback period using the same discount rate as in NPV extends to 6.48 years. Since the underground mining of Nui Beo is projected to continuously function for a long time, at least beyond 2030, the positive profit for the investor is unambiguous by comparison.

Estimation of external benefits - a contingent valuation study

Method

Ecosystem services typically represent non-market goods since they are provided free of charge by nature. Usually, property rights to them are not assigned, therefore, they cannot be included in the market mechanism. As mentioned above, investments into water recirculation and reuse require more advanced water treatment technology so that water discharged into the rivers will be much cleaner and will allow those downstream river ecosystems to provide better services to society. In this paper, we aim at valuing these external benefits by the non-market valuation technique contingent valuation which has become one of the standard methods for the economic assessment of ecosystem services. However, it has only rarely been applied in Vietnam and so far not at all in the context of mine water.

It is standard technique in environmental economics to use contingent valuation (CV) and choice experiments (CE) as stated preference methods for valuing non-market ecosystem services. In these methods, a representative survey is used to establish a hypothetical market and describe scenarios of an environmental improvement for which respondents can then state their personal willingness to pay (WTP). CE is employed to measure marginal values of various independent ecosystem service changes, whereas CV is used for directly measuring the value of a fixed combination of such ecosystem service changes. Which of the two methods to adopt follows from the specific research purpose.

Mine water pumped from open-pit and underground mines is not the only concern of the WaterMiner project. Further focus is placed on the management of surface water runoff which is contaminated by very much impurities such as coal, coal sludge, coal gangue, rock, and soil. While upgrading the collection and treatment of mine water and surface runoff, the positive spill-over effects on the adjacent ecosystem of discharging rivers are noticeable. These ecosystem services

are classified as public goods by reason of the naturally non-excludable and non-rivalrous characteristics. The first aim of the study was to assess the overall value of the generated environmental public goods in a pilot survey serving as initial steps to understand the research object. To this end, the CV method was employed. Subsequently, the implicit WTP, thus the utility, of the households towards the entirely non-market improvement in the currently polluted river is uncovered by their stated preference. The second aim of the study was to determine the budget constraint of the residents in such a hypothetical market experiment. This led to the adoption of a double-bounded dichotomous choice elicitation question format. After the first closed-ended question about WTP, the follow-up bid is contingent upon the initial response. I.e., the second bid would be higher or lower whether the first answer is 'yes' or 'no', respectively. There are four possible pairs of outcome: (i) yes-yes, (ii) yes-no, (iii) no-yes, and (iv) no-no. Then, the estimation of results relies on the Maximum likelihood approach laid out by Hanemann et al. (1991). The influence of bids on the probability of willingness to contribute is tested using probit models.

To investigate the value of these environmental changes, a pilot survey of 30 door-to-door in-person interviews was implemented in November 2017 with households living along and nearby Lo Phong river. Before this survey, several expert interviews to understand the locality, current environmental problems, future plans, and appropriate payment amounts have been conducted with the regional authorities from DONRE, DOC, Quawaco, heads of residential quarters, members of Farmers Union and inhabitants of relevance. Further, in the WaterMiner project, environmental economists worked closely with ecologists, engineers, and specialists from Vinacomin.

The Lo Phong river is 7.11 km long, located in the Ha Phong ward. On the one hand, the Lo Phong river receives water from two large surface mines, namely Ha Tu and Tan Lap. Besides, it had played a role as a transferring channel for mine water pumped from the Ha Tu mining workshop to the treatment plant only until 2017 when a pipeline system was constructed instead. Mine water discharged in the river has not always been totally collected to be treated in the treatment station. Typically, a huge amount of surface water from mining workshops containing an abundance of coal, rock, and soil runs directly to the river in the rainy season. On the other hand, municipal wastewater from adjacent residential areas flows directly to the Lo Phong river. Eventually, the river is highly polluted, which triggers various environmental threats, harms the riparian vegetation and leads to health-related risks (Hendryx and Ahern 2009). Altogether, the concerns regarding polluted water caused by acid mine water, coal sludge and municipal wastewater as well as water flow disturbance triggered by rock, soil, and solid waste and risk of flood in the rainy season have become quite strong.

According to the contingent valuation technique and the NOAA Panel guidelines (Arrow et al. 1993), a questionnaire was designed with four parts: (i) an introduction of the WaterMiner project and the survey, (ii) questions about the connection of the river and its ecosystem services with participants' livelihood used as a warm-up, (iii) attitudinal questions, scenario description and the WTP elicitation question and (iv) socio-demographic questions. To obtain the constraint in monetary contributions, two bids were raised regarding the monthly WTP in a three-year period. The first bid was fixed at 40,000VND (US$ 1.8), then the second bid depended on the answer to the first question. If the answer was 'yes', the follow-up bid increased to 50,000VND (US$ 2.2); otherwise, in case it was 'no', the follow-up bid decreased to 25,000VND (US$ 1.1). The response rate was 100%.

Data description and regression results

On average, the participants' age is 48.9, of which 58.6% are female. A majority of them have lived there for a long period; the mean is 28 years, which implies that they have witnessed considerable changes of the river and its ecosystem services over time. High school or vocational training is the average education level. The mean income of the participants is quite low, ranging between 2 and 5 million VND/month (US$ 88–US$ 220/month). Un-

der the circumstances of living on the outskirts of Ha Long and the reference from the classification of income tax in Vietnam, the participants' income is categorized into 5 levels. The attitudinal questions follow a five-level Likert scale. The mean participant assesses their own awareness of environmental protection to be fairly good. Plus, they feel fairly confident that other inhabitants would be willing to pay as well.

Table 2 reports the summary regression results of 5 models: double-bounded regression, interval regression, ordered probit, probit with pooled data, and probit in panel data. To control over heteroscedasticity in standard errors, the Huber-White procedure is applied in all regressions except model 1. Regardless of numerous attitudinal and socio-demographic questions in the enquiry, all regressions involve only regressors that significantly explain the probability and amount of WTP and produce higher log-likelihood values to mitigate consuming the degrees of freedom of the models. Income, gender and personal self-awareness of environmental protection significantly affect the WTP of inhabitants in the vicinity of Lo Phong river in the same direction across 5 models. The dependent variables in model 1 and 2 are bid values offered to respondents. The former uses a command developed by López-Feldman (2012) and the latter is based on the interval regression command with controlling over heteroscedasticity in Stata. In respect of the 4 possible outcomes mentioned above, the true utilities of respondents fall into 4 ranges: [0; 25,000], [25,000; 40,000], [40,000; 50,000], and [50,000; +∞]. Outcomes indicate no divergence in coefficients between these two models. If the respondent's income increases to the next level, *ceteris paribus*, the monthly WTP will increase statistically significantly by 20,040 VND. Instead of ranging the respondents' WTP into intervals, the dependent variable is coded into 4 corresponding orders: 1, 2, 3, 4. Model 3 illustrates results of an ordered probit model as expected. An upgrade in income level reduces significantly the probability of refusing the project, in the meantime raising significantly the probability of supporting the project at the highest bid. Overall, the estimated mean WTP is 44,256 VND/month, being statistically significant at 0.1% with the 95% confident interval [38,409; 50,103].

To capture the cost effect on the probability of support for the project, probit models are employed. The individual responses to three bid-levels are transformed into the binary variable with 1 implying in favour and

Table 2 *Regression results.*

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
	Double-bounded	*Interval reg.*	*Ordered probit*	*Probit*	*xtProbit*
	Coeff. (s.e)	Coeff. (s.e)	Coeff. (s.e)	ME (s.e)	ME (s.e)
Income	20.04***	20.04***	1.663***	0.659***	0.613***
	(4.864)	(5.429)	(0.390)	(0.123)	(0.134)
Gender	16.51***	16.51**	1.356***	0.506***	0.474***
(M=0, F=1)	(6.063)	(6.760)	(0.504)	(0.147)	(0.166)
Self-awareness	-6.934**	-6.934*	-0.566*	-0.206**	-0.203**
	(3.464)	(4.088)	(0.318)	(0.099)	(0.098)
Bid level				-0.025***	-0.025***
				(0.005)	(0.005)
Constant	17.74	17.74	-	-	-
	(12.48)	(16.423)	-	-	-
Log-likelihood	-29.19	-29.19	-28.93	-	-
Wald Chi-square	18.12***	14.20***	19.65***	49.14***	46.27***
McFadden R2	-	-	0.286	0.456	-

*** Significant at least at 1% level; ** Significant at least at 5% level; * Significant at at least 10% level.

0 implying opposition. The number of observations is thus artificially augmented to 90. Under this arrangement of the data set, it is essential to control on cluster-robust standard errors. Specifically, model 4 is a pooled probit model with the cluster effect on individual meaning 30 clusters. Model 5 uses the panel data format on the basis of probit regression with the heteroscedasticity–robust and the population–averaged effect. Since the estimation in panel data accounts for the dependence over time, or bid in this case, the potential efficiency increases. For better interpretation, table 2 demonstrates outcomes of model 4 and 5 in marginal effects (ME), which are consistent with results of three previous regressions. Higher income people are significantly more likely to say 'yes' to the offer than the counterparts with lower income. Females are significantly more willing to contribute than males. In contrast, people considering themselves having a higher awareness of environmental protection are less likely to support the project than the counterparts. Notably, as the bid increases by 1000 VND, *ceteris paribus*, the probability of support decreases statistically significantly by 2.5%.

Discussion and conclusions

Facing the increasing demand for water and the shortage of water supply in the future in Ha Long in general and in the mining company in particular, the water treatment technology for domestic water use in Nui Beo partly solves the problem. Additionally, it offers the company the considerable autonomy in water provision for its regular operations, which brings various merits and not just economic advantages. As demonstrated using the example of Nui Beo coal mining company, the investment in a treatment station with a capacity of 400 m^3/day involves a 5.56-year payback period or 6.48-year after discounting. Moreover, the NPV indicator lasting in 13 years shows a positive number at about 5.291 billion VND. Considering the long-term mining activity of the company, an investment is clearly preferable.

From the survey results, detrimental impacts on the ecosystem of Lo Phong river primarily triggered by mine water and municipal wastewater lead to the high willingness of inhabitants along the river to financially support the project to generate ecosystem services. As expected, the budget constraint is significantly of crucial importance in the WTP of respondents. Likewise, the monetary amount of bids significantly affects the support of the program in an adverse direction. Females and those with lower self-awareness of environmental protection are more likely to be in favour of the project. Perhaps people who are more willing to pay for the environmental improvement regard it as a means to compensate for their not–yet well environmental consciousness. Remarkably, the ratio of the mean monthly contribution to the average income of the participants is rather large, about 1%-2%, albeit at a low absolute value (US$ 1.95) compared to the WTP in developed countries.

Altogether, this study reveals that not only internal benefits for the mining company itself but also the external benefits spilling over to society as a whole are the notable rewards of an efficient and effective management of mine water for recycling and reuse. The measurement methods bring transferable and applicable prospects to other mining companies in Vietnam and in other developing countries with similar features. Notwithstanding, the recycling possibility of mine water to direct drinking water is not covered in the paper. Because the study relies solely on monetary values, it lacks the resolution to cope with the limit of stating positive values due to households' budget constraints. In poor nations, typically in rural or suburban regions, household income is extremely low so that people can hardly afford any monthly extra expense. Regardless of the significant WTP in terms of money from this study, further research with new approaches to capture the comprehensive WTP, hence the social benefits, of the very low-income group is needed and expected to shed new light on valuing those external benefits.

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References

Arrow K, Solow R, Portney PR, et al (1993) Report of the NOAA Panel on Contingent Valuation. Fed Regist 58:4601–4614. doi: 10.1258/095646202760029804

Brömme K, Trinh VQ, Greassidis S, Stolpe H (2018) Material flow analysis for spatiotemporal mine water management in Hon Gai, Vietnam. In: Proceedings 2018 of the International Mine Water Association Congress IMWA. Pretoria, South Africa

Dharmappa H., Wingrove K, Sivakumar M, Singh R (2000) Wastewater and stormwater minimisation in a coal mine. J Clean Prod 8:23–34. doi: 10.1016/S0959-6526(99)00309-1

Haibin L, Zhenling L (2010) Recycling utilization patterns of coal mining waste in China. Resour Conserv Recycl 54:1331–1340. doi: 10.1016/j.resconrec.2010.05.005

Hanemann M, Loomis J, Kanninen B (1991) Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. Am J Agric Econ 73:1255–1263. doi: 10.2307/1242453

Hendryx M, Ahern MM (2009) Mortality in Appalachian coal mining regions: the value of statistical life lost. Public Health Rep 124:541–550. doi: 10.1177/003335490912400411

López-Feldman A (2012) Introduction to Contingent Valuation Using Stata. MPRA. doi: 10.1258/095646202760029804

The State Bank of Vietnam (2017) Decision No.1424/QĐ-NHNN

Ulbricht A, Bilek F, Brömme K (2018) Development of a technical concept of spatial and temporal coordinated mine water recycling exemplified by a mining area with urban influence. In: Proceedings 2018 of the International Mine Water Association Congress IMWA. Pretoria, South Africa

Vietnam Institute for Urban and Rural Planning (2013) Adjustments of Masterplan for Ha Long city – Quang Ninh province to 2030, vision towards 2050 *[in Vietnamese]*

VITE-Vinacomin (2016) The economic and technical report of water treatment plant for domestic use *[in Vietnamese]*