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PRIVATE SUBJECT IN WASTEWATER TREATMENT REGIONAL COALITION PROJECT: THE CASE OF CHEMICAL INDUSTRY FACTORY

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Abstract. This paper presents a case study covering the solution to treatment of municipal wastewater originating from small villages located close to each other in a protected landscape area. A high environmental efficiency of treatment is required. Two scenarios of the technical solution are compared. In the first scenario, separate wastewater treatment plants will be built and operated in each of the villages. In the second one, sewerage networks will be built in each village and wastewater will be collected and treated in a wastewater treatment plant of a chemical factory located down the stream; the factory is planning to reconstruct and modernise its wastewater treatment plant. Analyses have shown that the second scenario is environmentally beneficial – ensuring high water quality in watercourses in the protected area, using purified water for industrial purposes primarily, and replenish the water balance and flows in dry periods. The second scenario also appears to be beneficial from a socio-economic point of view. Cost savings, appearing mostly at the side of the factory, creates space for negotiation and an agreement between these entities. The factory image will also improve if implementing the second scenario.

Keywords: cost-effectiveness, public-private collaboration, industrial water pollution, common wastewater treatment plants.

AIMS AND BACKGROUND

The transition from treating wastewater from large and medium sources of surface water pollution to wastewater from smaller sources (municipalities with less than 2000 inhabitants) is related to an increase of costs. Implementation of such projects is usually not feasible without financial support from public sources. Such support can also be justified economically[1], as it concerns securing of a quality drinking water source, increasing purity of bathing waters or in parts of a watershed where a high level of ecosystem protection is required. The last of these options is the case we study.

The distances between smaller sources are often shorter than between the larger ones and therefore it is meaningful to consider so-called coalition projects,

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i.e. when several entities build and operate a joint wastewater treatment plant instead of building individual plants. Such joint projects can result in significant cost savings. For instance, the Rozkos recreational lake in the Czech Republic, where suitable coalitions would be established through optimisation modelling can save over 20% of the average annualised costs compared to the construction of individual Water treatment plants (WTPs) (Ref. 2). This case study worked basically with municipalities as pollution sources only, which means that a factory operating its own WTP was not located in the given area.

Another important aspect to be stressed consists in the fact that in order to achieve the environmental goal, which is typical for a radical reduction of the growth of cyanobacteria, all polluters have to implement the project (individually or in a coalition), otherwise the whole project does not make sense for the reservoir.

This article presents a case study in which a major industrial chemical factory is located in the territory concerned. The idea is being considered whether the planned innovations of its WTP could be used to connect smaller municipal pollution sources in the given basin, i.e. if a joint coalition could be established. This idea is analysed from the ecological, technological and socio-economic points of view. The aims of the case study are: (i) to find out if the idea of a joint WTP can be effective, or under which conditions, and (ii) to determine the participants potential interest in such a project, and in particular, that of the factory concerned. This will enrich practical solutions to similar situations as well as other steps of testing theoretical hypotheses within combinatorial reverse auction theory[3] and simultaneous biform games[4] through economic laboratory experiments[5], where we consider (economic) information asymmetry between those negotiating for a subsidy for a common project.

EXPERIMENTAL

Situation description. The chemical factory CEF, Ltd. (CEF) is located above Valley City, at the Trout River. The annual turnover is € 240–270 mil, the profit is € 35–40 mil; it employs over 1800 workers, mostly residents of the region. It processes coal tar, crude benzole and by-products from coal coking. The main products are basic organic substances intended for further chemical use. With its annual processing capacity of coal tar and crude benzole, it is one of the World leading manufacturers.

CEF operates its own industrial WTP. It is in a situation when its technology is obsolete both economically and technically and, at the same time, the factory wants to create conditions to expand the production and fulfil the required environmental parameters. It is working on a project to be submitted within the application for a change in the integrated permit (IPPC) in order to achieve a high level of protection of the environment as a whole.

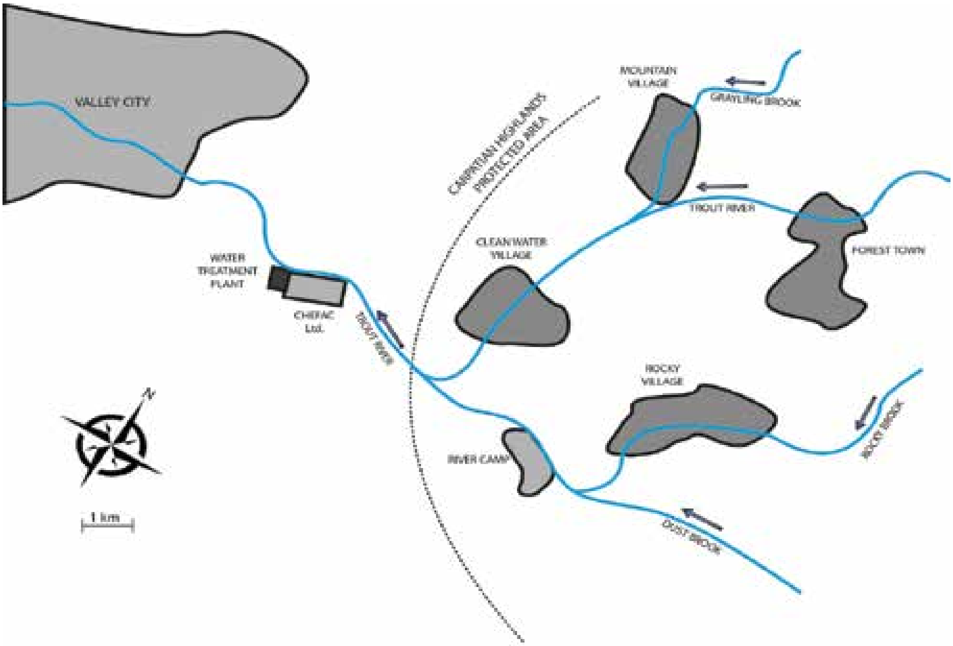

Fig. 1. Case study area – the simplified map was built on a model situation

In the basin of Trout river and its tributaries (Fig. 1), there are 5 smaller settlements with significant recreational facilities (see further Table 2). The area is located on the edge of the protected landscape area Carpathian Highlands which is a vast territory with a harmonious landscape, a significant proportion of natural forest and permanent grassland ecosystems, with abundant representation of tree species, or preserved historical settlements. Economic use of this territory is carried out in accordance with zones of gradual protection in order to maintain and improve their natural state and to preserve and create the area optimum ecological functions. Recreational use is only permissible if it does not harm the natural values of the area.

Municipalities in the Trout river basin produce sewage that is not collected systematically to be treated. Wastewater from local septic tanks is transported to a WTP, treated in several small (domestic) treatment plants, or discharged to infiltrate. Operation of these small WTPs has been affected by frequent power failures. Checking compliance with septic operational conditions is problematic and time-consuming; the costs of pumping sewage from septic tanks, transport to WTPs and treatment are very high. Discharge into subsoil (infiltration) causes groundwater and surface water pollution and promotes the expansion of non-native plant species, which subsequently spread to the protected landscape area. Eutrophication in mountain streams reduces the occurrence and migration of sensitive fish species particularly. There is a long-term effort to solve this situation satisfactorily.

Scenarios of solution. In the above-described situation there are two main scenarios of solutions if we want to address the situation for both CEF and the municipalities:

A – CEF will modernise and reconstruct its WTP. At the same time, municipalities in the Trout River basin will build their own (individual) WTPs.

B – CEF will modernise and reconstruct its WTP in a way which enables to collect sewage from the municipalities in Trout River basin and to connect it to its WTP.

Technology of solution – CEF. In both scenarios (A and B), modernisation of the CEF WTP means that a draft construction plan must be elaborated for the new wastewater treatment plant. The plan also includes the reconstruction of a part of operational facilities in the existing wastewater treatment plant and of the lagoons located outside the factory premises. The new wastewater treatment plant will include (in both scenarios) the following operational elements in particular: sewage regulator, pumping of chemical waste water, wastewater retention, mechanical pre-treatment of sewage, flotation, pumping to the biological stage of wastewater treatment, biological wastewater treatment, tertiary treatment, sludge manipulation including sludge dewatering.

The following facts are particularly important for the idea of creating a wastewater treatment coalition of CEF and municipalities located around the upper Trout river: On the basis of a permit to withdraw surface water from the Trout river, CEF can pump up to 1 750 000 m^3 of surface water and 200 000 m^3 of remediation water annually to ensure its production processes. The water collected is adapted for industrial use in a water processing plant. A part of the water used in the production processes is recirculated and the rest is treated at the WTP and discharged into the Trout river. Fees for water collection and discharge therefore account for a significant part of water management costs at CEF.

The new WTP project is a combination of chemical and biological treatment. In terms of the WTP capacity, the project is designed to allow development of CEF production activities. The water authority, however, rejects the idea of developing production based on increased water consumption and discharges. A limiting feature of the solution consists in the fact that the Trout river is a mountain watercourse with fluctuating flow rates. Under climate change conditions, the watercourse is fluctuating increasingly, with minimum flow rates being typical for the summer half of the year. In practice, this means limiting the discharge of treated water into the watercourse to prevent its point pollution. The factory operation and wastewater treatment technology are currently able to solve this situation up to the residual flow rate of 1 $m^3 s^{-1}$. This flow rate is also limiting for water intake from the watercourse in the profile upstream the Trout river, above CEF site.

In scenario B, CEF will offer the municipalities located in the upper part of the Trout river basin and along its tributaries a connection to CEF WTP. The factory will use about 200 000 m^3 of treated wastewater from the municipalities and it will store the water gradually in a reconstructed lagoon (storage capacity of

235 000 m^3); this water will then be used to cover the shortage of surface water intake in the summer period, when intake from the Trout river is not possible in order to maintain a minimum residual flow rate. Therefore, the parameters for water intake and discharge will not change (we suppose that the water authority would agree with such a solution). The WTP technology and associated equipment designed for scenario A can be prepared easily for an increase of wastewater inflow in case the scenario B is to be implemented. In scenario B, the reconstruction of the CEF WTP is not only a change in wastewater treatment processes but also in the balance of water intake and discharge from/to the Trout river recipient. Table 1 shows the water balance at CEF for scenario A, i.e. in a situation when the municipalities discharge treated water from their WTPs into recipients and CEF manages water from the authorised intake.

Table 1. Basic designed WTP capacities for scenario A and scenario B

Flow rate	Unit	Sewage		Industrial WW	Outflow from WTP	Outflow from WTP into lagoon
		Scenario A	Scenario B	Scenario A, B	Scenario A, B	Scenario B
Q_{indus}	$m^3\ day^{-1}$	400	925	2250	2650	525
$Q_{d,max}$	$m^3\ day^{-1}$	540	1250	3060	3060	710
$Q_{h,max}$	$m^3\ h^{-1}$	60	140	–	270	360

Q_{indus} – daily discharge (average); $Q_{d,max}$ – daily discharge (maximum); $Q_{h,max}$ – hourly discharge (maximum).

As mentioned above, cooperation with municipalities in Carpathian Highlands involves cancelling the current system of partial wastewater treatment in the municipalities and connecting them to the WTP of CEF Company using a central feeding pipe. Sewage water from the settlements (Fig. 1) in the amount of 525 $m^3\ day^{-1}$ (192 000 $m^3\ year^{-1}$) will thus be supplied to the WTP. Table 1 also shows the industrial water balance in CEF in case of scenario B.

Technology of solution – municipalities. Within implementation of scenario A, 5 separate WTPs will be built and operated for individual municipalities and the existing facilities will be cancelled. Their capacities will correspond to the population equivalents of the respective municipalities. Sewerage systems will be built in the municipalities together with the WTPs. Tertiary treatment using pressure membrane modules beyond the WTP ensures the removal of bacteria without using disinfection technologies, high efficiency of phosphorus removal, etc. If scenario B is implemented (only) sewerage systems will be built in all 5 municipalities together with a common wastewater feeding pipe to the CEF WTP in a total length of 16.3 km.

Environmental context of solutions. These solutions include two sets of problems: (i) the impact on water purity in watercourses of the protected landscape area, and (ii) the impact on water balance in the Trout river basin.

Scenario A. The project implementation will fulfil the requirement to increase the wastewater treatment efficiency in the industrial plants and premises of CEF. The limits in the form of maximum amounts of withdrawn and discharged water and the requirement for the maximum residual flow rate in the Trout river will be respected. The advanced technologies used, dual solutions and experienced operators guarantee the risk-free operation of the wastewater treatment plants with high sewage treatment efficiency and sufficient capacity. It is impossible to increase production at CEF because it is not possible to increase the surface water intake and discharge of treated wastewater into the Trout river (the water authority would not agree with such a requirement). The limit consists in small flow rates during the summer months particularly and in general flow rate fluctuations. Protection of aquatic communities takes precedence over the expansion of industrial production.

The construction of five new WTPs in the municipalities around the upper Trout river and its tributaries will ensure compliance with the requirements of environmental legislation and specific requirements of the protected landscape area administration for clean water in mountain watercourses and it will also enable sustainable tourism development in the region.

Scenario B. This scenario will not lead to discharge of treated wastewater into the recipient in the protected landscape area, septic tanks will be removed in villages and the sewage will not be transported to the respective WTPs. Diversion of wastewater to the central WTP and its further management will lead to a reduction in surface water intake from the Trout river by the CEF with favourable impacts on aquatic organisms.

Economic context of solutions. From the economic point of view, it is important to find out how costly both scenarios are in the sum of all social costs, i.e. especially the costs expended by CEF and by the municipalities. It is also important to understand what the economic interests of both entities in each of the scenarios are. Table 2 provides an expert estimate of the costs related to the scenarios A and B in municipalities. Table 3 provides cost estimates for CEF.

Table 2. Costs of the scenarios for municipalities

Municipality	Population	Equivalent inhabitant (EI)	Investment costs (mil CZK)						Operating costs (mil CZK)	
			WTP	sewerage & other		main pipe share	total		total	
			scenario							
			A	A	B	B	A	B	A	B
Clean water	480	600	11	25	25	6	36	31	0.5	0.5
Mountain village	420	700	13	33	33	6	46	39	1	0.7
Forest village	650	1700	27	46	46	5	73	51	1.5	0.8
River camp	50	100	2	24	24	3	26	27	0.5	0.4
Rocky village	250	400	9	25	25	3	34	28	0.5	0.6
Total	1850	3500	62	153	153	23	215	176	3	3

Table 3. Costs of the scenarios for CEF

Scenario	Action	Investment costs (mil CZK)	Operating costs (mil CZK/year)
A	WTPP	279	146
	sewerage system	13	8
	other (reconstructions, etc.)	86	19
	total	378	173
B	WTPP	312	157
	sewerage system	15	9
	other (reconstruction, etc.)	89	24
	total	416	190
Difference		38	17

A certain disadvantage of wastewater treatment solutions using individual WTPs consists in ensuring their operation, as individual municipalities have difficulties to provide qualified attendants and their budgets are burdened with running costs. Inflow to a partial WTP is very uneven, especially in periods of lower interest in accommodation capacities and this can cause operational problems. Reduced water consumption increases the sewer rates disproportionately and the WTP operation cannot be guaranteed without subsidies from the municipal budget.

RESULTS AND DISCUSSION

It is clear from the economic point of view that investment cost expended by the municipalities will be by CZK 39 mil lower in the case of scenario B. At the same time, investment cost expended by CEF would be higher by CZK 38 mil. The municipalities annual operating costs will not change basically if the common project is implemented; they will only be transferred onto piping maintenance for which the municipalities are much better prepared (both technically and in terms of qualified staff) than they are for running their own WTPs.

The CEF annual operating cost will grow by CZK 17 mil (mainly for electricity consumption, wages and chemicals). Annual fees for wastewater discharge will remain unchanged in fact but in case of using lagoons to store water it will not be necessary to pay the watershed administration for surface water intake (about CZK 0.9 mil annually). After the planned increase of the fees for surface water intake, this amount will be approximately CZK 1.7 mil per year. At the same time, it will be possible to expand production at CEF and, in terms of crisis management, situations will be limited when water intake from the Trout river is reduced to maintain the minimum flow rate in the watercourse which results in reducing the existing production. These failures, which were quite regular in the last 5 years cause financial loss of tens of millions CZK per year.

Other social contexts of implementation of scenario B. In addition to the above environmental benefits and (direct) economic benefits for CEF, implementation of scenario B has the potential to: (i) increase CEF reputation among the population in the area as the factory which is known as a major polluter can improve its environmental image, and (ii) improve cooperation with the public sector, especially with adjacent municipalities, but also with regional and other authorities.

On our model situation we tried to show that the idea to treat industrial water pollution with municipal one could bring interesting solutions from technological, environmental and social-economic point of views. The results of the financial analysis indicate that both scenarios are similar in term of total expenditures. Both scenarios are connected with relatively high costs, which municipalities would not be able to bear and some form of external contribution to these costs would be important. For CEF, the scenario B seems to be significantly better, i.e. there is a space for negotiation with the municipalities and regional or/and central government. Of course, these results must not be generalised – every practical situation must be analysed case-by-case.

Co-financing the expenditures of the municipalities from public sources would be a result of political decision. An analysis of the solution (overall) socio-economic benefits could help in the decision-making. There is a vast literature concerning quantification of such benefits; let us mention at least the review by Bergstrom and Loomise[6]. The project benefits also include new contacts which can facilitate negotiations about other projects which require cooperation among the private and public sectors, such as flood prevention measures[7], better water retention in landscape, etc.

Practical implementation of an otherwise interesting and effective solution will require administrative modification of the water permit and changes in processes related to water management. The concrete conditions of the project can be negotiated between the municipalities and CEF, and end with an (environmental) agreement and a contract. The article is of academic character. Institutional settings enabling practical implementations of such ideas may be different in different countries. At least on the academic level it is possible to discuss so-called weather derivatives, in this case for rainfall in a given locality and period, which could be a possible, so far theoretical, tool contributing to a solution in the Czech Republic, but it is true for the other EU countries as well[8].

A wider use of potential cooperation among industrial companies and municipalities in the solution brings about a broader debate. For instance, there is an increasing importance of research in indicators of sustainable corporate performance and reporting[9], indexes of water quality in watercourses and sediments[10], research to deepen the concepts of suitable policies and conditions for better environmental performance of companies[11].

CONCLUSIONS

Our analyses have shown that the scenario where the industrial factory cooperates with the municipalities in wastewater treatment is environmentally beneficial. It ensures high water quality in watercourses in the protected area, purified water is used for industrial purposes primarily and replenishes the water balance and/or flows in dry periods. This scenario is also beneficial from a socio-economic point of view. Cost savings, which appears mostly at the side of the industrial factory, together with the chance to improve factory image, creates space for negotiation and an agreement with the municipalities. Practical implementations of such scenarios require more research on well-functioning institutional settings.

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