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Questioning investment decisions on the city level: Is it sustainable to upgrade wastewater treatment plants?

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Investment decisions do have long-lasting consequences and thus impact sustainability goals in the long-term. In the context of wastewater treatment plants (WWTPs), they have not only direct financial impacts on the organization itself but also on the environment and society. The fourth purification stage represents such an investment decision that would change existing wastewater treatment processes, cost structures and wastewater quality. We analyse whether and how such an investment is valuable and contributes to society. Sustainability can be analysed on several stages. The results reveal that so far the decision for the introduction of this additional purification stage builds only on information from the organizational level. More integrated thinking is necessary comprising further information from other levels. The gained results can be transferred to similar decision-making processes especially in public service organizations, but also beyond.

I. INTRODUCTION

WWTPs are public service organizations that are responsible for a safe, reliable and efficient treatment of community wastewater. They operate with public money and, thus, have to justify their investments to society. Such investments include for example extension and rehabilitation of sewerage system, construction of a cogeneration plant, or the introduction of a fourth purification stage [1]-[5]. Infrastructure investment decisions generate sunk costs as they cannot be reversed without high financial effort and, thus, represent long-term capital commitments.

Investment costs can be determined at manageable efforts by conventional investment appraisals. However, those appraisals strongly focus on monetary issues at the organizational level and do not evaluate all associated consequences. Non-monetary issues such as environmental and social topics are usually not taken into account [6]-[8]. However, in order to avoid bad investments long-term financial and non-monetary aspects should be integrated into decision-making from the very beginning [2], [6].

In this paper, we investigate the fourth purification stage as an example for a technological process innovation in municipal WWTPs. This decision whether to upgrade the existing wastewater treatment in order to eliminate micropollutants is an example for an infrastructure investment decision. On the one hand, by means of such a technology (i.e. additional treatment downstream via ozonation, powdered activated carbon or granulated activated carbon), improvements in wastewater quality can be achieved [9]-[11]. On the other hand, high and long-lasting investments, unclear evidence on evolving by-products, and effects on humans and the natural environment represent reasons for skepticism [12], [13]. So far, a clear recommendation for or against this additional treatment stage is lacking. The question whether the decision for a fourth purification stage really contributes to society is not answered yet [13]. Therefore, we examine which costs and non-monetary issues are and should be considered for WWTPs' decision. We derive determinants that influence decision-making. Furthermore, we compare our findings for a fourth purification stage - that clearly represents an end-of-pipe solution - to alternative measures at the sources of pollution. Hence, we provide a more holistic view on this specific investment decision that does not only include the apparent investment costs occurring in WWTPs but also associated long-term impact on society.

II. WWTPS' CONTRIBUTION TO SUSTAINABILITY

The task of WWTPs is to mitigate environmental impacts caused by organizations and households. They are responsible for fulfilling services of general interest and contribute to a circular economy [14]. Despite their positive influence on water quality, WWTPs' operations have also negative impacts on the environment [13], [15]. WWTPs consume large amounts of resources such as operating materials, energy, and freshwater. They contribute to emissions into air as well as soil. The quantification of WWTPs' environmental impacts has been done via life cycle assessments by researchers [4], [16]. However, so far, it is not clear whether the introduction of a fourth purification stage represents an actual improvement in environmental performance or just a shift of burdens.

International and national institutions promote the creation of sustainable societies (e.g. Water Framework Directive [17] UN Sustainable Development Goals, esp. 6.3 and 6.b [18]) and all actors are expected to contribute to this development. In this way, public service organizations such as WWTPs are supposed to act as role models that can be more easily influenced by state authorities than private organizations [19]. They should consider the associated consequences of their actions for society [14], [20]. Hence, the task of WWTPs is not only set for wastewater treatment but also for creating valuable infrastructures and, thus, contributing to a sustainable society [4], [21]. The difficulty for managers lies in transferring this thinking into action and in including not only financial but also other sustainability aspects in their decisions.

III. Method

We perform a systematic literature review according to Fink (2010) [22] and Tranfield et al. (2013) [23], in scientific databases (Academic Search Complete, Business Source Complete) in order to detect previous studies dealing with the introduction of a fourth purification stage in WWTPs. To gain a broader scientific picture and include findings that have not been published yet within scientific literature, we search research databases such as CORDIS and GEPRIS[1]. Those databases include final project reports of national and international research projects. We analyze the material in order to determine concrete costs for this treatment, determinants, assessment and valuation methods as well as values and benefits of micropollutants' removal from wastewater.

IV. Results

The systematic literature research shows that the number of previous studies within the scientific databases is very low. Only six studies analyze cost aspects regarding the fourth purification stage. However, we detected ten research reports of research projects with costs analysis, all from German speaking countries and mainly from Germany. Altogether the oldest study was from the year 2007 and the newest one from 2016. The considered costs are mainly capital costs and operating costs. Only some studies integrate depreciation. Nearly every study reports the specific annual costs. The cost ranges observed for the fourth purification stage are very high. They are influenced by the size of the WWTPs, number of inhabitants connected, the dose level of ozone and carbon, the influent and effluent quality of wastewater, additional polishing steps, energy costs, interest rate, operating life and further local circumstances. In sum, clear recommendation cannot be given for WWTPs or countries regarding the configuration of a fourth purification stage on the basis of previous research. This is not only because the costs are highly dependent on specific cases and the applied treatment technology (the associated costs vary for treatment with granulated activated carbon, powdered activated carbon or ozone) but also because of the difficulty of long term orientated thinking considering other issues than the established costs in investment appraisals.

Only few studies or research reports investigate environmental aspects, e.g. energy efficiency [24], carbon footprint [25] or life cycle assessment [10], [26]. Our results reveal, that so far, only few studies deal with the fourth purification stage and its costs or attributed benefits and environmental aspects. We detect that no study of a fourth purification stage performs a holistic sustainability evaluation.

V. Discussion and Conclusion

We see several levels of analysis which are important for investment decisions. Investment costs occur on the organizational level for WWTPs. Those costs are already considered by previous studies. With the help of appraisal methods and other valuation tools, a guideline for application within WWTPs is provided. Obviously, one can determine large spans for costs of a fourth purification stage that are highly dependent on the circumstances. This means the results of previous research can only partially be transferred to new contexts. The adaptation to local circumstances is necessary and challenges WWTPs' managers.

However, from a sustainability view this calculation of costs on the organizational level is too narrow-sighted as it does not represent the "true societal costs". To achieve a more sustainable development external effects should be considered on further levels of analysis. Such effects emerge from WWTPs' (non-) investment decision and comprise monetary issues (such as resulting public fees) or non-monetary issues (such as changed water quality or consumption of materials). Those effects influence stakeholders on a societal level and should be considered for a more holistic decision-making. Especially the non-monetary effects represent a challenge as their true value is often not clear and needs to be monetarized and, finally, internalized.

The internalization of costs represents a challenging task for the future comprising the question whom to allocate the "true costs" for the handling of micropollutants and the (non-)introduction of an additional purification stage. It is not clear whether this purification stage in WWTPs really represents the best solution for society. To properly assess this end-of-pipe solution, it is necessary to compare it to alternative measures. Among such alternatives are source solutions (e.g. in households) as well as decentral solutions (e.g. wastewater pre-treatment in hospitals or industry). In this way, the reduction of discharges at pollution sources could represent a more socially desirable approach.

VI. Recommendation

The following recommendations can be derived from our study for WWTPs' decision-making. In a first step, investments costs and other impacts should be estimated by WWTPs. Within this internal orientation phase, WWTPs can seek support by other WWTPs to learn from best practices or by engineering offices in order to calculate costs and influencing variables. However, non-monetary issues and the holistic view of the Sustainable Development Goals are still not included. This is why a cooperation with scientists from multiple disciplines and political organizations should be fostered for insights into newly developed tools. Those tools should not only analyze data on the monetary and non-monetary impacts of the specific object of interest but also on alternatives taking into account the perspective of all relevant stakeholders. This decision-making process is applicable

[1] See GEPRIS= Geförderte Projekte Informationssystem, Deutsche Forschungsgemeinschaft (http://gepris.dfg.de); CORDIS= Community Research and Development Information Service (http://cordis.europa.eu/home_en.html)

to other disposal companies, the public sector in general as well as other organizations.

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