Integrating microturbines into sewage systems of lowland areas

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Introduction

The untapped potential of small, mini, and micro hydropower (MHP) systems in municipal sewage systems, including wastewater treatment plants (WWTP), has largely remained unexplored. This unconventional hydropower source (or so-called in-conduit hydro) is receiving more attention from regulators and hydro engineers in several countries [1-5]. However, no such hydro plants are operating in Lithuania and other Baltic States. This „sleeping" hydropower potential has seen no exploitation due to a number of technical and non-technical issues in low-lying countries. A significant cause of not harnessing this potential in this region is relatively low power capacities due to flat topography resulting in low or moderate drop in elevation. It's expected that the ongoing LIFE Nexus project activities [6] will significantly improve the database of the potential sites and provide valuable information for water utilities and potential investors.

Materials and Methodology

The study area was municipal sewage systems, including wastewater treatment plants (WWTP) with a free gravitational flow operating in Alytus town (A), Kaunas (K) and Vilnius (V) cities in Lithuania (Table 1). The sewage systems consisting of the collection network upstream of WWTP (U/S) and downstream of WWTP (D/S) were considered.

Table 1. Potential sites for installing hydropower turbines in urban sewage systems of Kaunas (K), Vilnius (V) and Alytus (A) municipalities.

#	Name	Location[1]	Head (m)	Flow (m^3/s)	Outlet
1.	K1	U/S	35.0	0.3	Main
2.	K2	U/S	27.4	0.18	Main
3.	K3	D/S	4.0	1.2	River
4.	V1	D/S	2	1.5	Conduit
5.	V2	D/S	2.9	1.5	River
6.	A1	D/S	15.0	0.11	Conduit
7.	A2	D/S	10	0.11	River

[1] *Site location relative to WWTP (upstream—U/S or downstream—D/S).*

Some general insights are given into assessing hydropower potential in sewer systems [7]. In order to develop a site pre-feasibility study, RETScreen Expert software (only hydropower module) was used [8]. Some definitions given in this application are not compatible with urban water networks (e.g., run-of-river). But they do not affect the calculations at all. Moreover, the inscription of the turbine type (e. g. Kaplan) changes nothing. The values of PaT (pump as turbines – a low-cost generator) or whatever turbine efficiencies can be entered manually. The realistic cost of the turbine (Euro/kW) and other elements for developing a proposed site (e. g., transmission line, substation, etc.) can also be presented. Beforehand, necessary initial data was collected from water utilities and *in situ*. This included measurements of wastewater flow fluctuations at the outlets of WWTPs and key structures of the collection network (upstream of the WWTP) to reveal the pattern of sewage flow. A tailwater effect or reduction of the working head at the sites of treated wastewater outlets (receiving water body – river) was also considered.

Results

For each site, the following items are presented:

- Water resources.
- Energy model.
- GHG emission reduction.
- Cost analysis and economic viability of the investment.
- The economic viability of the investment and risk analysis.
- Preliminary layouts, civil engineering.

Key findings for each site were extracted from the RETScreen Expert application (Table 2). Graphs, tables, and basic information for potential investors and decision-makers support them.

Table 2. Key findings. Micro hydropower plant at the outlet of Kaunas WWTP (K3)

Design flow	Gross head m	Power capacity kW	Electricity MWh	Revenue k€	Initial costs k€	Simple payback yr	GHG red. tCO2	Pre-tax IRR %
1.0	4	28	185	18.5	76.3	5.5	50	19.5

Some preliminary layouts are provided to get a general insight into the conception (Fig. 1).

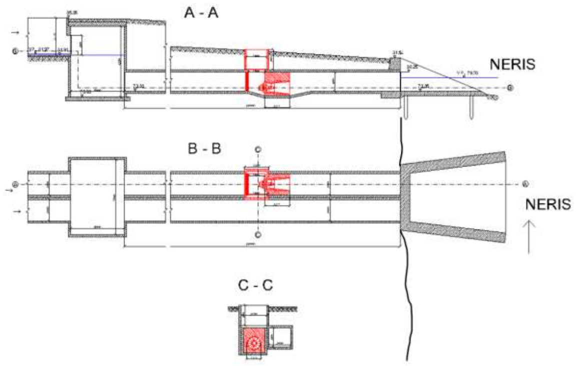

**Fig.1. Preliminary layout of installing a submersible, modular turbine into an underground concrete chamber. Vilnius WWTP (V2).
Receiving water body – the Neris River**

Concluding remarks

RETScreen application, a conventional hydropower project tool (only a module), requires a great deal of engineering preparation before it can be used to assess hydropower projects in water distribution systems. It can be easily adapted to complete feasibility studies and preliminary design of in-conduit hydro schemes.

Sewage water quality poses significant challenges for the operation of power generators, especially for radial or mixed-flow types of machines (e.g. PaT). It is evident that turbines should be designed explicitly for raw wastewater and operate without clogging or fouling caused by material in the fluid under any operating conditions within the range of service specified. This harsh environment can be considered when installing turbines in such locations. For hydropower systems using untreated wastewater, a trash rack chamber must be installed at the inlets of the penstock. It's a significant restriction for the scheme since the operation costs are likely high.

At the outlets of WWTPs, depending on the layout of the scheme, a conventional hydro turbine or PaT can be set up. In a sewage collection network (upstream WWTP) with existing inspection chambers on the mains, a more convenient way is to set up a PaT. The so-called bypass configuration is a classical layout for installing a turbine in a sewage pipeline system.

The potential residing in sewer systems of lowland areas in terms of power capacity resulting from mostly low-head sites cannot be compared to that of elevated topography.

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