Assessment of Hydropower Potential in Wastewater Systems in a Lowland Country, Lithuania.

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Introduction

The untapped potential of small, mini, and micro hydropower (MHP) systems in engineered water conduits of urban areas has largely remained unexplored. This alternative energy source is receiving more attention from regulators in several countries [1-4]. While other European countries have widely invested in this technology, Lithuania and other Baltic countries are still behind in their potential development rate.

Assessment of wastewater resources for hydropower generation is a crucial task. Knowing the amount of wastewater and its flow rate and distribution over time is essential. Flow rate frequency analysis must be performed to construct the flow duration curve (FDC), which is a key element for estimating hydropower energy. A big issue is accounting for wastewater flow in the collection network, i.e., upstream of the wastewater treatment plant (WWTP). A methodology is needed to construct the FDC for ungauged sites [4].

Lowland or low-lying areas of a country represent challenges for installing hydro turbines in urban water networks compared with regions with a steep topography surrounded by mountains. The accuracy and completeness of the hydraulic data are crucial, especially when evaluating low- and ultralow-head sites.

The specific objectives of this study were as follows: (1) To review the available best practices of energy recovery in wastewater systems and identify methodology based on local conditions; (2) To search for the potential sites for the installation of hydro turbines and to evaluate wastewater resources for harnessing hydropower; (3) To review and propose tools to facilitate preliminary and/or feasibility analysis of hydro schemes and to review turbines and their installation layouts in wastewater systems; (4) To show best practice in performing multicriteria analysis for the selection of optimal sites.

Materials and Methodology

The study area was the urban water network with potential micro-hydro sites to be deployed in Lithuania. Due to the country's topographic conditions, mostly sewage (wastewater) networks with a free gravitational flow are attractive for harvesting water energy. More than 20 potential sites for installing hydropower turbines were identified [5]. Most of them were located in the sewage network, while only one site was spotted in the drinking water distribution network with a pressure-reducing valve.

This study examined the opportunities for MHP energy recovery at three WWTPs, four wastewater collectors (upstream of WWTPs), and one site in the drinking water network. The layouts of water network systems, their engineering drawings, and spatial information (GIS data) from water companies were analysed [6]. In contrast, the assessment of the head did not present any difficulty.

Sewage volume data were obtained in various temporal formats from WWTPs and water utility companies. Additionally, measurements of wastewater-level fluctuations at the outlets of WWTPs and key structures of the collection network (upstream of the WWTP) were conducted to reveal the pattern of wastewater flow. Spot measurements (from 1 to 3 months) using data loggers at a 30 min intervals were also performed. The recordings obtained were transformed into volumetric discharge values.

The following tools were tested: (1) RETScreen Expert, (2) In-Conduit Hydropower Project Screening Tool, and (3) Business Case Assessment Tool. RETScreen Expert was identified as the most comprehensive tool for assessing the feasibility of eight potential sites.

The multicriteria analysis of siting potential micro-hydro facilities in urban water networks was carried out using the software HYPSE. Collected field data and data generated by RETScreen Expert software were used as the input for a two-dimensional impact matrix, including alternatives or scenarios (e.g., projects or actions) and their criteria according to which the other options must be evaluated

Results

The analysis of the mean annual wastewater flow at the outlets of the 56 collected WWTPs operating in the country showed that it correlates quite well with the population equivalent (PE) and wastewater collection (service) network area (A, km^2). The proposed methodology allowed for establishing a flow duration curve for an ungauged site using only three parameters.

A selection field for classical turbines is relatively narrow in a flat terrain where elevations and flows are relatively low. This can be explained by the low flow rates and small size of turbine units, which increases the unit price of turbines (EUR/kW) compared to the larger capacity of hydro turbines. Only reaction-type turbines can be used at low-head schemes, e.g., propeller, Kaplan, seldom crossflow, and Francis. The development of compact and modular turbines is a recent trend in turbine technology, e.g., a generator unit using a propeller turbine in an axial flow design. A submersible turbine and a generator are combined in one unit; therefore, the need to use a powerhouse is eliminated, and installation costs are reduced. Turbine costs comprise approximately half of the conventional hydropower project development costs. To offset this drawback of conventional turbines, low-cost generators, e.g., pumps as turbines (PaTs), have been suggested. In contrast to an axial propeller (or Kaplan) turbine, PaT units are much more sensitive to clogging issues when operating in effluents charged with suspended particles.

RETScreen software, a conventional hydropower project tool, requires a great deal of engineering preparation before it can be used to assess hydropower schemes in municipal water distribution systems. Its technical level is much higher than other available screening tools; it can be easily adapted to complete feasibility studies and preliminary design of in-conduit hydro schemes.

No studies have been performed in Lithuania on the impact of wastewater quality on the operation of hydraulic machines and their clogging**.** Available data from water companies show that the average concentrations of TSS in raw effluent can reach 500 mg/L. After treatment, they decrease at least 25-fold, down to 20 mg. Large solids, rags, and other fibrous materials from wastewater can be severe for operating turbines if not monitored. This harsh environment can be considered when installing turbines in such locations.

In total, 17 criteria were used for the multicriteria analysis (Table 3). Twelve criteria were to be maximised, while five were to be minimised. Their grouping was as follows: (1) technical-related (TEC; layout, turbine type, design flow, gross head, etc.), (2) economic-related (ECO; investment costs, electricity generated, simple payback, etc.), and (3) environmental-related (ENV; GHG reduction and use of electricity).

The following conclusions were drawn up: (1) While the potential of energy recovery from wastewater systems using micro-hydro plants (MHPs) is an appropriate solution to improve the energy efficiency of the municipal water sector, it has seen no exploitation due to a number of technical and non-technical issues in low-lying countries. Non-technical problems include a lack of awareness about the scale of the existing resources available in water networks; (2) The potential in lowland areas in terms of power capacity resulting from mostly low-head sites cannot be compared to that of elevated topography. In addition, for flat terrain, the selection field for turbines is relatively narrow; moreover, the low flow rates and small size of turbine units increase the unit price of turbines; (3) A methodology was developed to quantify the potential and identify conduit hydropower sites in a lowland country's wastewater systems, including resource assessment, suitable tools to make a preliminary assessment of potential sites, and choice of turbines and their operating parameters in a harsh environment. The lack of in-depth studies on wastewater quality's impact on hydro turbines, particularly the risk of clogging them in sewage networks upstream of WWTPs, can be a severe problem; (4) A conventional multicriteria analysis can help select the most appropriate site for constructing MHPs in urban water areas to achieve energy recovery. There are plenty of multicriteria tools available on the market for solving any real-world issue. However, at least preliminary site assessments and design procedures must be accessible beforehand for this analysis.

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