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Research Article

INNOVATIVE SYSTEM OF SIMULTANEOUS TRANSPORTATION AND TREATMENT OF SANITARY WASTEWATER IN SCATTERED DWELLING AREAS

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ABSTRACT
The work presented the possibility of implementing an innovative system of simultaneous transportation and treatment of sanitary wastewater in scattered dwelling areas. Small-bore sewerage with a balanced flow enables simple and inexpensive simultaneous disposal and pre-treatment of fluid with from vast, undeveloped areas.

Keywords: innovative system, transportation and treatment of wastewater, small-bore sewerage

INTRODUCTION

In Poland, more than 80% of people living in rural areas have no access to sewerage, which constitutes approximately 3 million households. About 87.6% of agglomerations have no sewerage infrastructure whatsoever, 5.1% boasts a partial infrastructure, whereas only 7.3% have a complete sewerage infrastructure [Raport GUS, 2014]. Sewerage network in large settlement units is developed adequately; however, poorly urbanized areas are lacking in that respect. According to the Central Statistical Office data [Witkowski (ed.) 2014], in 2013 more than 87% of people living in urban areas and roughly 31% of people in rural areas had access to sewerage network (Graph 1). As far as the access to water supply network is concerned, the figures were 95% for urban areas and almost 77% for rural areas, respectively. Water supply network in non-urban areas was over twice as long as the sewerage network. This is due to the fact that the construction and exploitation of vast sewerage networks in rural areas is unprofitable because of scattered dwellings and low population density. [Suchorab et al. 2015]. The comparison of the percentage of people in Poland with access to sewerage network in urban and rural areas on the example of year 2013 is presented in Figure 1.

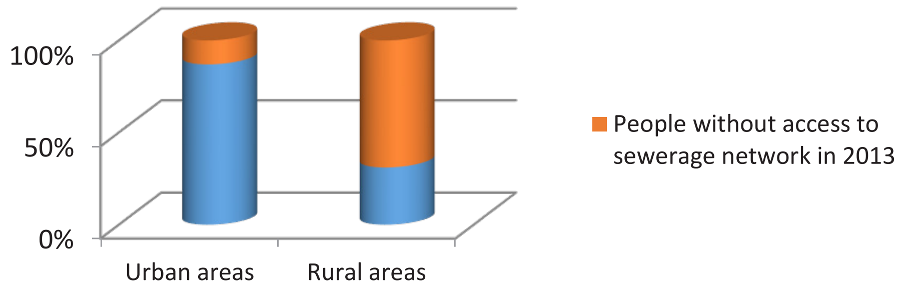

Figure 1. Percentage of people in Poland with access to sewerage network in urban and rural areas [on the basis of GUS Infrastruktura Komunalna 2013]

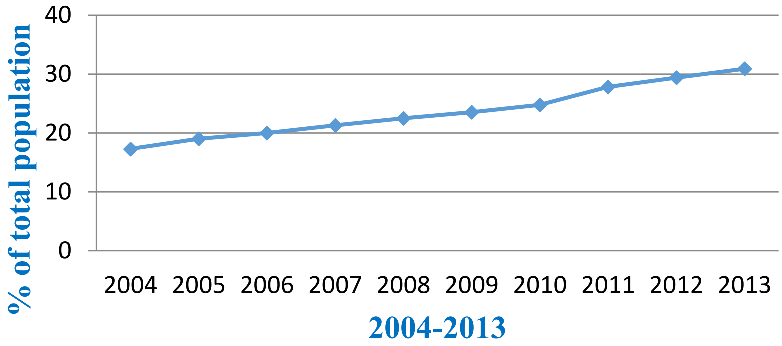

Figure 2. Percentage of people in rural areas with access to sewerage network in the years 2004–2013 [on the basis of Central Statistical Office data and GUS Infrastruktura Komunalna 2013]

As a result of the accession of Poland into the European Union, devising new solutions guided by the principle *think global – act local*, became a necessity. This principle requires elaborating new methods of managing water resources, including sewage management.

Each day, the number of settlements built outside the city limits – which too are poorly urbanized and have no sewerage infrastructure – grows [Jarzyna et al. 2014]. Therefore, the issue of sewerage infrastructure in non-urban or poorly urbanized areas is a complex mechanism. Figure 2 shows changes in the percentage of people living in Poland with access to sewerage networks in rural areas, throughout the years 2004–2013.

The treatment and wastewater disposal systems include: sewerage networks, pre-treatment devices, pumping of wastewater and drainage facilities responsible for the drainage of wastewater into ground or waters. An appropriate system setup is made up of basic technological structures aimed at disposal and treatment of wastewater, as well as management of sewage sludge. Apart from these basic facilities, the mechanisms involved include: power production; control of technological processes; monitoring of these processes [Goleń et al. 2011].

These issues are still relevant both in regard to the improvement of life standard of scattered dwelling areas inhabitants, as well as environmental protection. Therefore, new innovative solutions are in demand, including the choice of appropriate materials.

Disposal of liquid pollutants in non-urban areas with scattered dwellings is based on different systems than in the case of cities. Depending on the conditions in an area, individual or collective systems of wastewater disposal can be employed. The analysis of system operation and their operation costs allows selecting the most suitable solution for the given topographical conditions [Heidrich et al. 2008].

TECHNOLOGY DESCRIPTTION

Small-bore gravitational sewerage network is a solution enabling disposal of wastewater when treatment in the settling tank is impossible, and the construction of a conventional gravitational network is unprofitable. Small-bore sewer system network ensures a constant disposal of supernatant waters. Channels are constructed with pipes of much smaller diameter – up to 90 mm – than in a conventional gravitational network, which are arranged in less steep angles. Similarly as in the case of local sewerage, the sludge is disposed of every 6–12 months [Szulżyk-Cieplak et al. 2015].

Simplified wastewater treatment technology is an advantage of this sewerage system, as the settling basin and mechanical part are not required. However, wastewater has to be transported to a treatment plant which is equipped such technology [Niedzielski 2003].

Reduction of the diameter of pipes from at least 200 mm to 75 mm in the case of sewers and limiting the angle of their geometric slope was done for economic reasons. These savings are especially noticeable in areas characterized by quicksand and shallow ground waters [Kalenik 2009]. An unconventional solution is to install a trap in each plot where poorly biodegradable items appear, while the treated wastewater reaches collective sewerage system. This method greatly increases the flow rate of wastewater and removes the need of installing grinder pumps. Figure 3 presents the scheme of a small-bore gravitational sewerage system.

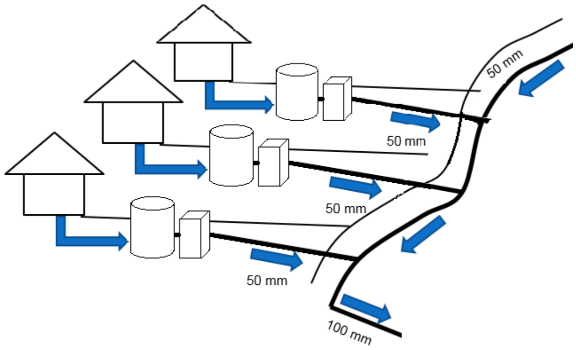

Figure 3. Scheme of a small-bore gravitational sewerage system

As far as sanitation management is concerned, one can observe a constantly increasing demand for systems enabling efficient and economic disposal and treatment of wastewater. Such systems of sewage disposal and pre-treatment include the small-bore sewerage and innovative solutions employing rotating biological contactor with rotor for fluid aeration.

This kind of sewerage system does not require the construction of a connecting chamber, which lowers the investment costs. Moreover, the small-bore sewerage system is built at a smaller depth and with less steep drop angles than the traditional one. In the case of the small-bore gravitational sewerage with balanced flow, the financial outlays needed for the construction and operation of the device for pumping treated wastewater is lower than in the case of tools for pumping raw sewage [Goleń et al. 2011].

The small-bore gravitational sewerage is characterized by low investment costs and low or comparable operation costs in relation to other sewerage systems. Most of all, it is cost-effective for rural settlement units.

Research stand

One of the devices used in the process of biological treatment of liquid pollutants in small-bore sewerage is a rotor. It works very well in non-urban areas with few dwellings. The use of a rotor enables to lower financial outlays thanks to innovative solutions which allow simultaneous transportation and treatment of wastewater. A properly constructed and operating rotor provides surface for the development of microorganisms. Its rotational motion creates suitable conditions for the process of wastewater aeration [Lenik et al. 2015]. Patent application was filed for the rotor design and principles of its operation (Application number W.119065 of 31.05.2010, number RWU.066284).

Rotor construction

The studied rotating biological contactor with bi-directional longitudinal flow is one of the innovative solutions for the systems concurrently draining and purifying the fluid in the residual units. The use of such rotor-based technologies implies that they play de facto the role of the bioreactors for mineralization of organic compounds. Consequently, well designed, constructed and working rotor permits the existence of the conditions for the microorganisms to settle on the rotor surface.

Rotor is constructed of multiple corrugated pipes made of plastic (Fig. 4). The layers of pipes are wound around the device axis housing the shaft with a float in a cylindrical fashion, as evident from the cross-section (Fig. 5). Corrugated pipes are wound in alternating directions (clockwise and counter-clockwise), and are additionally secured with bands.

Rotor constructed in this way ensures efficient aeration of liquid pollutants with their simultaneous recirculation throughout the longitudinal axis of the device and activated sludge tank chamber [Lenik et al. 2015].

METHODS

In the course of field studies on the sewerage system operation, data pertaining to the actual conditions and issues of sewerage system functioning in the area of ten communes of Lubelskie

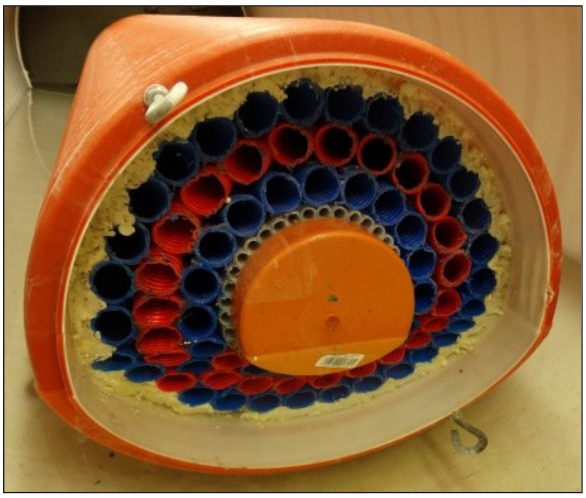

Figure 4. Interior of the rotor

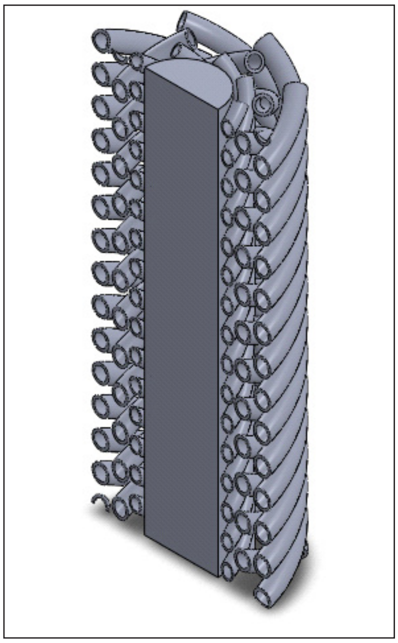

Figure 5. Cross-section of the rotor [Duda et al. 2014]

Voivodeship were collected. Figures 6–9 contain photos depicting the condition of manholes in the analysed wastewater disposal systems.

The data collected from the existing and operating sanitary sewerage systems and assessment of their condition enables to determine the most frequently occurring problems arising during their operation.

Typical problems include:

- malfunctions of vacuum valves and blocking of pump impellers caused by the infiltration of large pollutants and related with inadequate use of sanitary systems,
- accumulation of fat on floats,

Figure 6. Condition of a manhole

Figure 7. Visible degradation of internal manhole elements

Figure 8. Manhole cover with float system being controlled

Figure 9. Wastewater drainage

- malfunctions of electronic elements, related with the creation of gases and chemically aggressive environment which degrades materials and devices of the sewerage system.

As part of the study, a research installation with a model of rotating biological contactor and instrumentation was constructed at the Faculty of Fundamentals of Technology of Lublin University of Technology in a laboratory scale (Fig. 10, 11) and pilot plant scale (under actual model conditions) (Fig. 12). This enabled to carry out studies leading to the preparation of guidelines for the construction of a prototype demonstration model.

Figure 10. Fundamentals of Technology Department Laboratory – rotating biological contactor with bi-directional longitudinal flow

RESULTS AND DISCUSSION

The work discussed the issue of the use of different systems of sewage disposal with traditional by means of methods and small-bore sewerage system. Table 1 depicts the comparison of traditional (gravitational) system and small-bore sewerage.

Construction of collective systems in rural areas is very often unjustified due to economic reasons. Therefore, discussing alternative solutions is important. On the basis of the selected statistical data from Central Statistical Office – Environmental Protection and online database Bank Danych Lokalnych (Bank of Local Data), as well as authors' own research, an assessment of situation was performed in regard to the disposal and treatment of wastewater in rural communes of Lubelskie Voivodeship throughout several recent years. Studies have shown that wastewater management in rural areas still relies mainly on the drainless system. Table 1 presents the data pertaining to the justification of utilizing small-bore sewerage system. It especially concerns a significant reduction of the costs related to building pipelines (pipeline diameter – 50 mm with minimal flow rate limited to 15 m/s), which enables appropriate aeration of wastewater and biodegradation to occur.

Figure 11. Fundamentals of Technology Department Laboratory – control panel of the rotating biological contactor with bi-directional longitudinal flow

Figure 12. Research installation built in pilot plant scale

Table 1. Comparison of gravitational and small-bore sanitary sewerage systems

Small-bore sewerage system	Gravitational sewerage system
Minimal pipe diameter – 50 mm	Minimal pipe diameter – 200 mm
Minimal flow rate – 0.15 M/s	Minimal flow rate – 0.6 ÷ 0.7 M/s
Pre-treatment of wastewater in connection junctions in which non-biodegradable waste is separated	No pre-treatment
low risk of infiltration and exfiltration	High risk of infiltration and exfiltration
Possibility of utilizing curved tubes in horizontal and vertical planes	Necessity of utilizing straight tubes in horizontal and vertical planes

CONCLUSIONS

The issues discussed in the article pertain to the efficiency of applying various systems of wastewater disposal in scattered dwelling areas and the purpose of implementing an innovative wastewater disposal system with rotating biological contactor. Utilization of small-bore sewerage system with balanced flow for wastewater disposal is rational both in the case of rural areas and city outskirts with scattered dwellings. Following conclusions were drawn on the basis of conducted research:

- In the case of sanitation management, an increasing demand for devices allowing efficient and economic conditioning of wastewater can be observed,
- Realization of projects involving construction of large wastewater treatment plants in areas located remotely from urban agglomerations is difficult and time-consuming,
- The technology of simultaneous transportation and treatment of wastewater will improve the living standard of residents, as well as the natural environment protection,
- A solution to the problem of high costs of constructing sewerage infrastructure in urban and rural areas is a competitive small-bore sewerage system with balanced flow, which is cheaper and easier in operating,
- Results of field studies enabled to verify the application of comparative operational parameters of the devices for the requirements of innovative sanitary sewerage system operation.

The obtained results concern the possibility and purposefulness of employing and designing a rotating biological contactor with bi-directional longitudinal flow, an example of which was presented in this work. They stem from the comparison of two sewerage systems: gravitational and small-bore.

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