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Social innovations in the field of wastewater treatment in rural areas

Społeczne innowacje w odniesieniu do oczyszczania ścieków na obszarach wiejskich

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Abstract

In order to meet social needs and create new social relations, the EU Commission classified under the concept of social innovations, development and implementation of new ideas (products, services, models). In rural areas, this kind of social needs is represented among others by the need of solving the issue of domestic wastewater treatment. The paper describes the implementation of sewerage development program in Poland, as well as problems derived from large value variation of factors encountered characterising the domestic sewage contamination. In view of the current state, the environmental risks due to improper use of domestic wastewater treatment technologies were specified.

Streszczenie

Komisja Europejska UE pod pojęciem innowacje społeczne zakwalifikowała rozwój i wdrażanie nowych pomysłów (produktów, usług, modeli) w celu spełnienia potrzeb społecznych i tworzenia nowych relacji społecznych. Tego rodzaju potrzeby społeczne na obszarach wiejskich m.in. manifestują się potrzebą rozwiązania problemów oczyszczania ścieków bytowych. W pracy opisano jak jest realizowany w Polsce program rozwoju kanalizacji oraz jakie problemy stwarza stwierdzona duża zmienność wartości parametrów charakteryzujących zanieczyszczenie ścieków bytowych. Wobec istniejącego stanu wskazano na zagrożenia wynikające dla środowiska z tytułu zastosowania niewłaściwych technologii oczyszczania ścieków bytowych.

1. INTRODUCTION

According to the definition adopted by the European Commission (EC), that is included in the “2013 Guide to Social Innovation”, social innovation is the development and implementation of new ideas (products, services, models) in order to meet the social needs and creation of new social relationships and cooperation. As a result, the social innovations from the point of view of the EC serve also to build trust and social interactions that are the basis for creation of network structures in the economy, among others, clusters.

According to the EC, these innovations are a process in which four actions can be distinguished:

a. identification of new/unmet/under-met social needs;
b. development of new solutions in response to these social needs;
c. assessment of the effectiveness of new solutions responding to social needs;
d. dissemination of effective social innovations.

There is no doubt that one of the essential social needs in rural areas in the context of the aforementioned definition is a solution to the problem of domestic wastewater treatment.

Despite the dynamic expansion of water and sewage systems, the existing imbalance between rural residents' water supply and collection and treatment of domestic sewage is still significant.

By analysing the afore mentioned actions in relation to the development of the sewage systems, it should be stated:

a. Rural areas are not sufficiently equipped with effluent treatment systems, so the social needs are not met.
b. In rural areas, although new technologies of wastewater treatment are devised and implemented, they are not always rational from the economic, environmental and energy point of view.
c. The effectiveness of the introduced solutions raises legitimate concerns for their durability and reliability.

d. Even in these modern times, Poland lacks effective forms of dissemination of good, proven individual wastewater treatment solutions.

2. THE IMPLEMENTATION OF OBJECTIVES CONCERNING WASTEWATER TREATMENT IN POLAND

Although Poland has signed the Accession Treaty to the European Union (EU) (01.05.2004), it does not mean that the requirements for collective sewage system and municipal wastewater treatment resulting from art. 3, 4, 5, (2) and 7 of Directive 91/271/EEC will be fully applied before 31 December 2015. At the same time, in accordance with article 7 of Council Directive 91/271/EEC, on the date of Polish accession to the EU, urban wastewater from agglomerations of less than 2000 population equivalent (PE) that are equipped with sewage systems and are discharging wastewater into inland surface waters and estuaries should undergo appropriate treatment before being discharged into these waters.

Regardless of the aforementioned EU directive, the need for wastewater treatment was recognised in the "Regulation of the Minister of the Environment [2006]". This regulation distinguishes one of the possible ways of purification, treatment within the limits of the land owned by the person introducing, under appropriate conditions (§ 11, section 5, section 6 and § 12 para. 1).

To implement the commitments of the aforementioned Treaty, Ministry of Environment prepared the National Program for Municipal Wastewater Treatment (KPOŚK) covering 1577 agglomerations with a PE of more than 2000. At the same time, the National Water Management Board developed a program with the aim to equip agglomerations below 2000 PE with sewage treatment plants and sewage systems. That program covers 600 agglomerations.

These programs do not include most of the rural areas due to low PE numbers, and dispersed building system of holdings, which is documented by the following information:

- 15% of villages have a population of fewer than 100 inhabitants; assuming 3–4 persons per household, one can estimate the number of holdings to be between 25 and 35.
- 60% of villages count between 100 and 500 inhabitants, which, can be estimated at 25–166 households.
- 13% of the villages have 500 to 1000 inhabitants, therefore, 125 to 333 holdings.
- Only 6% of villages are inhabited by more than 1000 inhabitants, which can be expressed as 250–300 farms.
- According to CSO data (1996), compact settlements with the distance between farms up to 45 m represent 32.02% of all rural areas. Villages with scattered buildings make up for 27% (over 200 m distance between households), whereas villages with the intermediate dispersion of households fit in the remaining 40.98%.

The existing household dispersion in most villages in Poland significantly impedes the construction of collective sanitation and water supply systems. It should be emphasised that the construction of collective water supply is much easier from the technical and investment point of view.

The compiled data shows that the sewer systems solutions for the aforementioned areas should be different from areas with a larger population and more compact settlements, that is, urban areas or urban–rural areas [Bruszewska, Eymontt, Wierzbicki 2013]. The same applies to water supply systems.

Confirmation of the above statements is contained in the Opinion [2004] of European Economic and Social Committee on actual state and perspectives of appropriate environmental protection technology in the countries acceding to the EU concerning the length of the sewerage network channels. That length should range from 0.5 to 2 m per capita. In case of dispersed settlements, these lengths can range from 5 to 10 m.

Assuming the above calculations on the number of inhabitants (max. 4) on a farm, no village with distance between holdings ≥ 45 m qualifies for gravity collective sewage.

Other systems such as pressure or vacuum can be used with adequate economic justification.

Such justification is necessary to protect future users from excessively high charges resulting from investment and operating costs. Cases where users resigned due to the exploitation costs of the sewage collecting systems are described in publications covering the areas of the former GDR [Riga 2000; Neemann, Kunst 2000]. This was due to high exploitation costs resulting from dispersed settlement development.

In Poland, in areas of dispersed development, some common problems encountered in the operation of gravity sewer are clogging of the channels or odors arising from sewage. These phenomena are caused by insufficient volume of sewage flowing into the collecting channel, resulting in the absence of required flow rate.

This gives rise to the question of how to choose the right innovative wastewater treatment technology in rural areas with, in general, dispersed development.

The above statement is closely related to the implementation of the EU common agricultural policy and the principles of "sustainable development", and also how Polish farms, often deprived of the opportunity to join the collective sewerage system, may implement all the investment and modernisation requirements included in the Cross-Compliance document determining the need for the necessary investments.

3. CHARACTERISTCS OF DOMESTICS SEWAGE AND CAUSES OF LARGE VALUE VARIATIONS OF INDICATORS REFLECTING THE PURIFICATION PROCESS

Concise characterisation of the aforementioned sewage was given by Sikorski [1994], defining them as multiphase organic and inorganic systems, in which phases of solid, liquid and gas can be distinguished, with different degrees of dispersion in water. Large parts of the solids, fine suspensions, emulsified and colloidal particles, as well as the dispersed substances are present in the aforementioned type of wastewater.

Depending on the contents of the aforementioned wastewater components, their indicators may greatly vary, so under the same name, we have to deal with very different liquids.

This is one of the reasons that even with the same technology of wastewater treatment, we get different results depending on the wastewater origins. In large metropolitan areas, averaging of wastewater components will be beneficial for the treatment processes.

Jucherski [1999] synthesised the problem of small wastewater volume lining up in Table 1 and determined indicators and components of contamination of raw domestic sewage, according to various sources of literature.

The summary of the data in Table 2 [Tomczuk 2008] is also interesting. It indicates the influence of different domestic activities on concentration of impurities in the raw domestic sewage in relation to inhabitant and per day.

If we assume 4 as the most common number of residents in the household and compare the data presented in Table 1 and 2, we can observe significant differences arising from the conversion

Table 1. Selected indicators and components of raw domestic sewage pollution, according to various sources of literature

pollution index	Variability ranges or average values based on test results							
	U.S. (1980, 1991)	French (1992)	Dutch (1989)	Polish				
				Kalisz and Sałbut (1993)	Kuczewski (1993)	Sikorski (1994)	Hus (1993)	Jucherski, Walczowski (1994÷1998)
BOD_5 (mgO_2/l)	210–530	270–400	246–787	240	114–510	719	140–740	256–900
COD (mgO_2/l)	680–780	n.a.	668–1983	660	349–845	n.a.	253–1262	447–1020
Suspended solids (mg/l)	300–600	300–400	134–519	557	n.a.	735	91–723	129–196
Total nitrogen Nc (mg/l)	35–100	100–150	77–222	86	70–101	n.a.	45–145	n.a.
Ammonium nitrogen $N–NH_4$ (mg/l)	7–40	60–120	n.a.	39	43–76	32	38–124	30–50
General phosphorus P (mg/l)	10–27	10–40	n.a.	15	n.a.	n.a.	7–23	n.a.
Phosphates PO_4^{-3} (mg/l)	n.a.	n.a.	n.a.	n.a.	n.a.	24	n.a.	n.a.
Number of faecal coliform bacteria in 100 ml	106–1010	106–108	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

*/ Based on IBMER Krynica framework research and implementation control studies of settlers, between 1994–1998.
n.a. – not available

Source: Jucherski,1999.

per inhabitant as well as from the range of value variations given in Table 1. At the same time, it should be emphasised that laundry has a significant impact on general phosphorus concentration in wastewater, and this contamination is difficult to eliminate in the purification process.

Such a large variation of the parameters characterising the domestic wastewater undoubtedly influences the effectiveness of the treatment in different types of small sewage treatment plants. It was documented in Table 3 elaborated by Mazurkiewicz [2007] based on the German publications from the years 1995–2000.

Furthermore, Belejton [1996] points out that the degree of purification of domestic sewage in sewage treatment plants with soil–plant vertical flow filters depends on the type of the sewage. For example, the degree of purification of the wastewater from a house without a bathroom is larger than that recorded for the wastewater from houses equipped with bathrooms. The largest differences were noted in cases of phosphorus of approximately 36% and nitrogen approximately 85%.

Szpindor and others [1999], in accordance with English researchers, provide the following degrees of concentration reduction of basic pollution indicators in the household wastewater treatment plants with supported population of 8. Table 4 was compiled based on that data.

The analysis of the data from Table 4 shows that with use of filter surface of 42.25 m^2, 5.28 m^2 falls per capita. While in the second case, with filter surface of 20.25 m^2, 2.53 m^2 falls per capita.

The size of the surface and the resulting hydraulic load of 37 $dm^3/m^2 \cdot d$ in the first case and 79 $dm^3/m^2 \cdot d$ in the second case, significantly affects the reduction of general nitrogen and phosphorus. As opposed to suburban areas, in rural areas, doubling the surface of the bed of this type of wastewater treatment plant is generally not a problem.

Table 2. Pollutants concentrations in the effluents from the various aspects of household's activities in relation to inhabitant (M)

Activity	BOD5 [$gO_2/M \cdot d$]	Suspended solids [$g/M \cdot d$]	General nitrogen [$g/M \cdot d$]	General phosphorus [$g/M \cdot d$]
Dishwashing	12.60	5.27	0.49	0.82
Using the sink	8.34	4.11	0.42	0.42
Laundry	14.80	11.00	0.75	2.15
Personal care	3.09	2.26	0.31	0.04
Toilet flushing	10.72	12.52	4.14	0.55
Total	≈ 50	≈ 35	≈ 6.1	≈ 4

Source: Tomczuk, 2008.

Table 3. Comparison of different types of small wastewater treatment plants (including household wastewater treatment plants)

Technology	Average concentrations at the outlet [mg/dm³]			Work stability	Handling difficulty	Costs	Space required	Com-ments
	COD	NH_4 -N	NO_3 -N					
Activated sludge	120	30	10	low	very high	very high	low	for >15 M
Sprayed (biofilter) filters	100	20	10	average	high	high	low	-
Circular filters	75	20	25	average	high	high	low	-
Submerged aerated filters	110	55	20	low	high	high	low	-
Vertical reed filters	70	10	40	high	low	average	average	-
Horizontal reed filters	90	30	5	average	low	average	average	-
Sand filters in the trenches by DIN 4261	160	40	10	low	low	low	average	-
Sand filters in the trenches, Renner system	46*	1*	56*	high	low	low	average	little data
Wastewater ponds	80	25	5	high	very low	low	high	-
Drainage system	-	-	-	insecure	very low	low	high	-

Source: Mazurkiewicz, 2007.

To compare the effectiveness of domestic sewage treatment plants to collective sewage treatment systems, results from periodically performed tests in Sokoły village were used. The tests were carried out by the Voivodeship Inspectorate of Environmental Protection in Bialystok from 23.03.2005 to 29.10.2007. Three pollution indicators were tested both in raw and treated sewage. These indicators are BOD5, COD determined by a bichromate method, and the overall suspended solids. Test results are presented in Table 5.
The analysis of data from Table 5 shows significant differences in the parameters of raw sewage, inflowing volume from canals network to the treatment plant was variable during test period:

– 44,000 m³ (2005), 62,000 m³ (2006), 73,500 m³ (2007), and delivered waste water:
– 2120 m³ (2005), 2540 m³ (2006), 2720 m³ (2007).

It can therefore be concluded that in both individual and collective wastewater treatment plants located in rural areas, there are significant differences in the values characterising the degree of contamination of wastewater.
Differences in the volume, as well as disproportions between inflowing wastewater from urban and rural areas to collective sewage treatment plants from the collective network are shown in Fig. 1.

In view of the above inequalities and the need to increase rural sanitation, the number of domestic sewage treatment plants (Fig. 2) increased over a year by 23,241 units. If we assume that each of the domestic sewage treatment plants support 3 people that use 100 dm³ of water per day, we can estimate that 126–167 domestic sewage treatment plants in year 2012 treated 136–260.36 hm³ of wastewater. In comparison, the total volume of treated wastewater from the collective sewerage system in rural areas amounted to 172.2 hm³. Therefore, about 800 times greater volume of wastewater is treated in domestic wastewater treatment plants located in the vast majority of rural areas.
While the collective sewage treatment plants during operation are under periodic sanitary surveys, the domestic wastewater treatment plants are not subject to any control during their lifetime.
In many embodiments of domestic wastewater treatment plants, the sewerage, after partial removal of pollutants, is discharged into the drainage system. It is particularly dangerous if we take into account a few thousand uncontrolled domestic sewage treatment plants in one municipality [Eymontt A., Rogulski B. 2006].
This system is evaluated, for example, according to Table 3, that is low handling difficulty and uncertain work stability; however, in most cases, if the solution is technically simpler and cheaper, the purification efficiency is lower [Eymontt A., Gutry P. 2006]. Also

Table 4. Concentration reduction of selected indicators in relation to vertical filter surface with a tributary of 1,6 m³/d of sewage, study period April 1993 – June 1994

Clearance rate Indicator	Concentration reduction in %		Differences in % reduction
	Filter surface F = 42,25 m²	Filter surface F = 20,25 m²	
BOD_5	96.3	92.1	+4.2
COD	91.6	80.6	+11.0
Suspended solids	89.0	77.2	+11.8
Ammonium nitrogen	92.2	96,0	−3.8
General nitrogen	61.8	15.8	+46.0
General phosphorus	70.0	14.2	+55.8

Source: Szpindor and others [1999] with revised calculations by Zajkowski [2008].

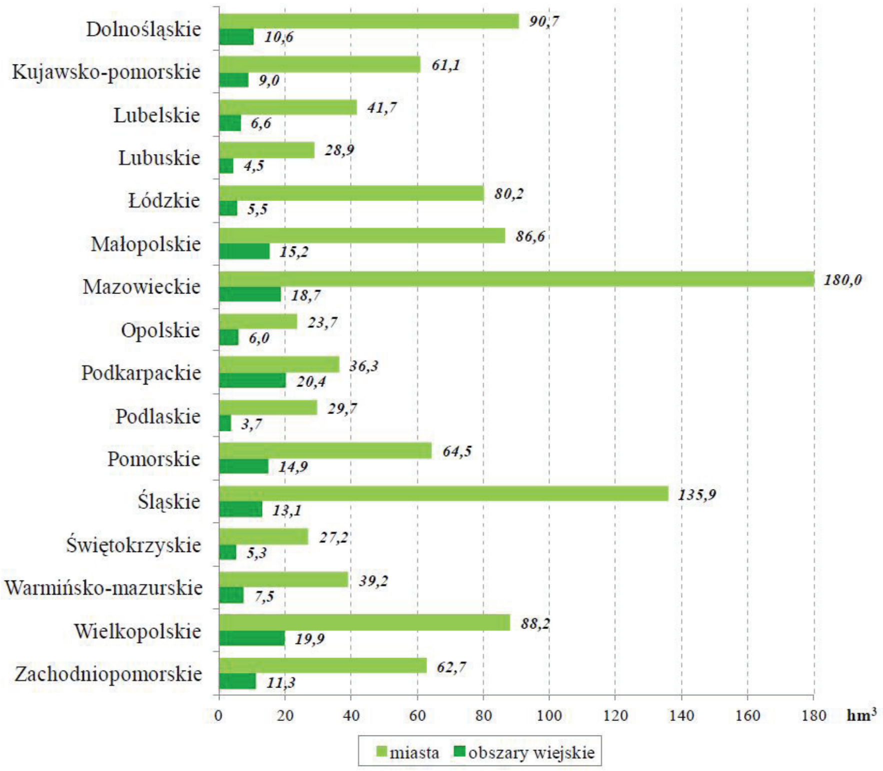

Fig. 1. Wastewater discharged into the sewage system by Voivodeship in 2012 [hm³]
Source: Municipal Infrastructure w 2012 r. [CSO 2013].

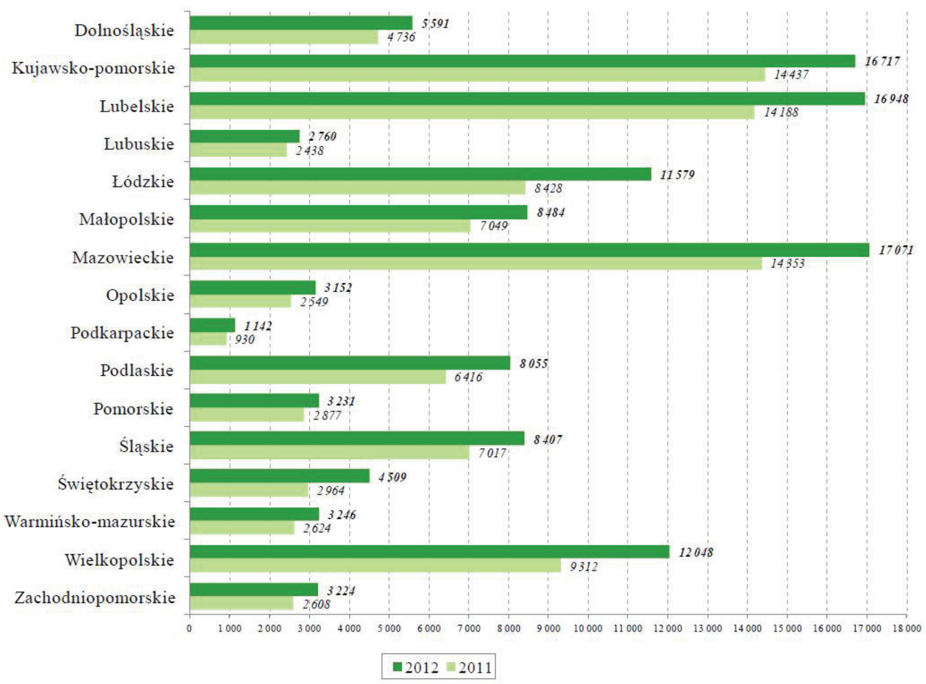

Fig. 2. Household wastewater treatment plants in years 2011–2012 [pc]
Source: Municipal Infrastructure w 2012 r. [CSO 2013].

Table 5. The efficiency of wastewater treatment plant made by the company EKOLAND in Sokoły

Indicator		Raw sewage	Treated sewage	Required value	Concentration reduction [%]
BOD_5 [mgO_2/dm^3]	minimum	170	1.0	40	95.76
	average	463.5	3.83		98.75
	maximum	1550/540 1)	8.8/7.2		99.94
COD – Cr [mgO_2/dm^3]	minimum	410	26.0	150	86.28
	average	937.7	56.2		92.01
	maximum	3048/818 1)	87.0		98.56
Suspended solids [mg/dm^3]	minimum	97	5.0	50	80.21
	average	505.6	8.98		94.48
	maximum	3416/276 1)	19.2		99.74

Attention: 1) - Maximum values, two values are indicated, the bigger one appeared once, and the smaller one is the maximum value for the whole sample period. No substantive justification for such a large difference in the maximum values was found.

take note that the inlet values of pollution concentration are not shown in Table 3.

Development of a universal wastewater treatment technology is difficult (especially domestic), as documented in this publication, because of the large differences in the concentration of pollutants in wastewater from rural areas. A large number of this type of wastewater treatment plants (Fig. 1) with low efficiency can be a major threat to groundwater quality, which is increasingly being used to supply collective water supply systems. Some direction when choosing a domestic sewage treatment plant can be found in the set of norms PN-EN 12566 parts 1 to 7. Parts 1 and 3 are currently mandatory and are the basis for the evaluation of bids at tenders [Eymontt A. 2004, 2005]. However, please note that Part 1 applies to the physical properties of prefabricated septic tanks, which cannot be considered as domestic wastewater treatment plants.

4. THE RECAPITULATION

Conducted analysis and evaluation of current state of wastewater treatment in rural areas using the definitions of the EC concerning social innovation allows to state the following:

- Significant delays in the development of sewage systems in rural areas compared to urban areas.
- The wastewater from individual households has a much larger variety of pollutants concentration compared to municipal sewage. As a result, domestic wastewater treatment plants must meet more requirements to obtain the performance required by regulations.
- In 2012, the volume of wastewater treated in domestic wastewater treatment plants was about 800 times higher than the volume of effluents treated by the collective sewerage systems in rural areas. At the same time, collective sewage systems are under constant supervision, as opposed to domestic sewage treatment plants, the efficacy of which is never controlled. Moreover, the sewage outflow from these domestic wastewater treatment systems is characterised by very variable concentrations of pollutants.
- Hence, the conclusion is the need to verify the effectiveness of domestic sewage treatment plants based on different technological and design solutions, after few years of exploitation, as they may pose a threat to the quality of groundwater.
- This verification will eliminate unsuitable technologies for rural area conditions, which are different in terms of inflow continuity and sewage pollution concentrations.
- Rural areas require special care to restrict potential sources of contamination of surface and groundwater. Water treatment costs are higher and higher. As a result, the selling price of water and wastewater treatment increased in some areas of Poland by almost 100% in the last 10 years, and is comparable to the price of energy.

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Rozporządzenie Ministra Środowiska z 29.11 2002 r. w sprawie warunków, jakie należy spełniać przy wprowadzaniu ścieków do środowiska oraz w sprawie substancji szczególnie szkodliwych dla środowiska (Dz. U. Nr 212, poz. 1799 z 16.12.2002).

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