*Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2010, 7, 374–381*

# ECONOMIC ANALYSIS OF OPTIONS FOR SEWAGE TREATMENT PLANT[1]

Iwona Skoczko

Department of Technology in Engineering and Environmental Protection, Białystok University of Technology
Wiejska str. 45A, 15-351 Białystok, i.skoczko@pb.edu.pl

**Summary.** The aim of the study is economic analysis of options for sewage treatment plants for single houses or small groups of houses that will ensure proper treatment of domestic sewage and will not constitute a threat to the environment, i.e. water or land. The paper presents several variants of domestic sewage treatment systems. Their proper functioning requires several conditions: proper design, proper construction and correct operation. The selection process for the purification of sewage by individual consumers is mainly dictated by the amount of economic investment and operating costs.

Installations for the disposal of wastewater from individual homes must treat wastewater to levels specified in the Act of the Minister of Environment of 24 July 2006 (revised January 28, 2009), and be affordable to investors.

According to an analysis, the best effects of wastewater treatment are obtained with activated sludge and biological filter, but these are the most expensive systems to build and maintain. Low investment costs are incurred when installing a septic tank, but the future operating costs are higher and, unfortunately, the effect of treatment is very low. Slightly more expensive investment is the constructed wetland system, where the risk of pollution is very low. Environmentally conscious, therefore, the investor should choose a balanced solution to its wastewater treatment plant to ensure the best results of purification at optimal investment and operational expenditures.

**Key words:** domestic sewage treatment plant, costs, expenditures

## INTRODUCTION

Solving of the problem of wastewater disposing discharged from individual homes or small clusters of houses can be implemented according to one of the following options:

1. Wastewater disposing by the use of household sewage treatment plant and discharge of treated sewage into the water or soil [Heidrich 2007].

[1] The paper is written by project S/WBIIŚ/24/08.

2. Collection of wastes in sealed containers, followed by their PG transport to wastewater treatment plants.

According to Błażejewski [2003] the cost of sewerage system construction consists of the following elements: investment in the sewerage system, investment in wastewater treatment plant, operating costs.

The basis for choosing a solution of drainage system and sewage disposal are indicators of the effectiveness of technical and economic investment [Village.. 2001]. Capital expenditures and operating costs are still the first criterion for the selection process for the purification of sewage by individual consumers. Due to low public awareness, less important are solutions that offer a high degree of purification of sewage. Considered here are simple ways of wastewater purification, low-input and cheap to operate, as well as those for which you can apply for funding.

An investor who owns a detached house with difficult access to a public sewerage system usually takes into account the following types of treatment: Septic tank, septic tank 3-chamber, drainage, sand filter, wetland, biological filter or sludge reactor [Village... 2001].

## METHOD OF CALCULATION OF BUILDING COSTS

Building costs of sewage treatment plants are difficult to determine because they are set individually by the equipment suppliers. the present study attempts to determine the costs of constructing and operating various equipment options.

**Septic tanks** of varying capacity and made of different materials are offered by numerous domestic and foreign companies. The result of the considerations is the relationship to determine the approximate average construction costs ($I_{0G}$) as a function of the number of inhabitants ($M$). The model is based on tariffs of the Mirax and Intech companies,

$$I_{OG} = 499 \cdot M + 1120, \text{ PLN}$$

Increase in the number of residents using a tank determines the increase of construction cost per capita with a reference:

$$I_{OG}^{M} = 499 + \frac{1120}{M}, \text{ PLN/M}$$

**Drainage**. The basis for determining the cost of a filtration system construction were data collected from several domestic and foreign companies, offering services in this area. The overall relationship to determine the capital expenditure incurred on the construction of a filtration drainage system is [Recommendation ATV... 1998]:

$$I_{DR} = a \cdot M + b \text{, PLN}$$

$M$ – number of inhabitants,
$a$, $b$ – factors depending on kind of soil.

The costs of filtration drainage construction are presented in Table 1.

**Sand filter.** When we are dealing with an impermeable soil or low permeable and high water table it is recommended to use sand filters. Capital expenditure incurred on the construction of vertical sand filters and unit investment costs, determined on the basis of detailed cost estimates, can be determined from the formula (Tab. 1):

$$I_{FP} = 800 \cdot M + 6400 \text{, PLN}$$

$$I_{FP}^{M} = 800 + \frac{6400}{M} \text{, PLN/M}$$

**Wetland.** Wastewater treatment processes occur in semi-natural conditions or with the participation of heterotrophic microorganisms. The conditions necessary for the development of this type of micro-organisms are made possible by the presence of wastewater (containing nutrients) and are stimulated by the presence of plant roots and rhizomes. Of the various types of constructed wetlands the most commonly used are soil-plant filters with subsurface horizontal flow of sewage [Heidrich and Witkowski, 2005]. National experience associated with the use of constructed wetlands has become the basis for the determination of the relationship between capital expenditure and unit investment costs and the number of supported residents, expressed by formulas as presented in Table 1:

$$I_{OH} = 2980 \cdot M^{0,664} \text{, PLN}$$

$$i_{OH}^{M} = 2980 \cdot M^{-0,336} \text{, PLN/M}$$

**Biological deposit**. Calculations of the costs of sewage treatment plants using biological resources were based on equipment available on the Polish market. The devices allow for full biological decomposition of organic pollutants, a high degree of nitrification and denitrification in partial fulfilment of hypoxic parts of the bed. Treated sewage complies with existing law or findings of the licenses [Heidrich 1998].

You can find offers of many companies which will undertake the installation of such a plant. The objects consist of tank, biological bed, sand filter, drain or soak. Prices of sewage treatment systems depend on many factors (Tab. 2) and it is very hard to compare them and to clearly identify the model. The prices

Table 1. The total and unit costs of construction of different kinds of sewage treatment plant

| Number of inhabitants | 4 | 8 | 12 | 16 | 20 |
|---|---|---|---|---|---|
| Septic tank | | | | | |
| Construction cost, $I_{OG}$, PKN | 3160 | 5112 | 7108 | 9104 | 11100 |
| Unit cost $I_{OG}^{M}$, PLN/M | 790 | 639 | 592 | 569 | 555 |
| Sand filter | | | | | |
| Unit cost, $i_{FP}^{M}$, PLN/M | 2400 | 1600 | 1333 | 1200 | 1120 |
| Drainage | | | | | |
| Capital expenditure, $I_{DR}$, PLN | | | | | |
| Sand | 970 | 1710 | 2450 | 3190 | 3930 |
| Mud | 1750 | 3230 | 4710 | 6190 | 7670 |
| Wetland | | | | | |
| Unit cost, $i_{OH}^{M}$, PLN/M | 1870 | 1480 | 1293 | 1174 | 1089 |
| Number of inhabitants | 5 | 10 | 15 | 20 | |
| Biological filter | | | | | |
| Construction cost, PLN | ok. 9509 | ok.13530 | 18100 | 22500 | |
| SBR | | | | | |
| Construction cost, PLN | 6500 | 12000 | 19900 | 27000 | |

Source: Heidrich 2007 and Catalogues of Esos i Delfin, Aquamatic, Ekopol, JPR System, Bioires companies

Table 2. Dependence treatment price of a biological fluid from the individual indicators

| The price of sewage treatment plant depends on: | The kind of dependence |
|---|---|
| Number of permanently residing residents or estimated water consumption | The size of the septic tank and drainage system depends on the average water consumption in the household. |
| Kind of soil and ground water depth | Exchange of soil for drainage is required in the case of poorly permeable soil. Investor orders gravel. In the case of a sewage treatment system for 4 people about 30 tons of gravel should be ordered. In addition, a drainage collector is mounted (400 PLN for 4 people) and a collector well (300 PLN). |
| Depth of installation | The depth of the septic tank and drainage determines the height of the well superstructure and of the collector well. The materials accounted for on „as used" basis. |
| Distance between home, settling tank and drainage | Settling tank is connected with drainage by pipes and joints; their number depends on distance and layout in the garden. |
| Installation system | Installation by an assembly team (cost of 2000 PLN) or by the investor under the supervision of one employee (cost from 300 PLN, the investor hires an excavator and provides two helpers). |

Source: Own elaboration based on Catalogues of Aquamatic, Ekopol, JPR System companies

of materials used for the construction of the systems largely depend on the Euro exchange rate and this is the fundamental criterion of valuation. On the basis of economic analyses of the companies Aquamatic, Ekopol, JPR the author suggests a simplified model that allows individual approximation of the total cost of construction of a sewage treatment system with biological fluid:

$$I_{OB} = 788 \cdot M + 6490 \text{ , PLN}$$

The costs in Table 1 are the arithmetic mean of several wastewater treatment systems and therefore do not agree with the model.

**Active sludge.** Wastewater treatment with active sludge is still not widely used in Poland, although the effects are entirely satisfactory. Individual prices discourage potential buyers of the equipment, as does the need for periodical maintenance, which also involves costs, and is the condition to ensure a relatively steady flow of sewage. One of the most important selection criteria is readily available servicing, which disqualifies many companies at the stage of the review, because many businesses, despite the attractive prices offered, are still under-developed as to the range of services they provide. The present study examines the economy options for sewage treatment systems offered by the companies Sanitech, Bioires, Turbojet, Nebraska.

Type SBR system from Ekoprogress Bioires, for 1–24 inhabitants, works with primary settling tank and active sludge. Expenses incurred in the construction of the sewage treatment system indicate that an increase in sewage volume increases the unit cost of investment (Tab. 1).

TurboJet offers sewage systems developed for 3–30 inhabitants, with different throughput levels: EP-1, EP 2, EP-3, EP-4. Systems EP-1 and EP-2 operate with a primary settling tank, EP-3 and EP-4 with a primary settling tank and storage reservoir, but in the EP-4 the sludge chamber is separated from the secondary settling tank.

Capital expenditure and unit investment costs incurred on the construction of a TurboJet sewage treatment system, including the purchase and installation costs, can be expressed by the formulas:

$$I_{TJ} = 1110 \cdot M + 1145, \text{ PLN}$$

$$i_{TJ}^{M} = 1110 + \frac{1145}{M}, \text{ PLN/M}$$

The costs in Table 1 are the arithmetic mean of several wastewater treatment systems and therefore do not agree with the model.

## RESULTS AND SUMMARIES OF INDIVIDUAL TECHNOLOGICAL SOLUTIONS FOR THE TREATMENT OF DOMESTIC SEWAGE

An overview of the types of sewage treatment systems available on the Polish market for sanitary purposes can be found in the proposal of the media industry. The proper functioning of these types of wastewater treatment systems must meet the following conditions: proper design, the type of system must be matched to the proposed conditions of its use, proper installation and correct operation.

Table 3. Comparison of costs of construction and operation

| Year | Septic tank | | | Drainage, wetland and biological treatment plant | | | | | Sewerage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | outlay | annual cost | total cost | outlay | ann. cost | total cost | | | outlay | ann. cost | total cost |
| | | | | | | drainage | biol. | wetl. | | | |
| 1 | 1825 | 2628 | 4453 | drainage | | 3675 | 6900 | 10060 | 5000 | 1075 | 6075 |
| 2 | | | 7081 | 3575 | 100 | 3775 | 7100 | 10160 | | | 7150 |
| 3 | | | 9709 | biological | | 3875 | 7300 | 10260 | | | 8225 |
| 4 | | | 12337 | 6700 | 200 | 3975 | 7500 | 10360 | | | 9300 |
| 5 | | | 14965 | wetland | | 4075 | 7700 | 10460 | | | 10375 |
| 6 | | | 17593 | 9960 | 100 | 4175 | 7900 | 10560 | | | 11450 |
| 7 | | | 20221 | | | 4275 | 8100 | 10660 | | | 12525 |
| 8 | | | 22849 | | | 4375 | 8300 | 10770 | | | 13600 |
| 9 | | | 25477 | | | 4475 | 8500 | 10860 | | | 14675 |
| 10 | | | 28105 | | | 4575 | 8700 | 10960 | | | 15750 |

Table 4. Summary of advantages and disadvantages of each type of sewage treatment system

| Kind of treatment plant | Advantages | Disadvantages |
|---|---|---|
| Drainage | – simple construction,<br>– low purchase costs of facilities<br>– does not require specialized knowledge,<br>– high resistance to non-uniformity of wastewater flow,<br>– low operating costs,<br>– long life span,<br>– low failure | – relatively large land area,<br>– lack of control over the efficiency of the plant,<br>– required regular use of biologicals in order to maintain the quality of bacterial flora,<br>– possibility of oversizing at the design stage |
| Sand filter | – simple construction,<br>– low purchase costs of facilities<br>– does not require specialized knowledge,<br>– high resistance to non-uniformity of wastewater flow,<br>– low operating costs,<br>– possibility of economic use of treated sewage | – relatively large land area,<br>– higher costs and increased workload,<br>– necessity of protection against damage to the sand filter |
| Wetland | – simple construction,<br>– very high efficiency,<br>– possibility of using the filter as a decorative element in the plot,<br>– possibility of using local swamp vegetation,<br>– high resistance to flow non-uniformity of plant,<br>– possibility of economic use of treated sewage | – relatively large land area,<br>– high cost of film, pump, fill the filter,<br>– need to purchase plants for planting on the filter |
| Biological filter | – high resistance to non-uniformity of wastewater flow,<br>– high resistance to changing outdoor temperatures,<br>– high reduction of pollution,<br>– lack of expert knowledge needed,<br>– long life span,<br>– low operating costs,<br>– small size of sewage treatment installation | – need for cleaning, flushing, reservoir filling,<br>– replacement of mechanical parts potentially most exposed to wear |

As a part of this study, based on data contained in the final analysis, a simulation was performed of the economic investment and operating costs for a wastewater treatment system for a single family house with four people, based on the following assumptions (Tab. 3):

– number of inhabitants: 4 people,
– average daily water consumption: 150 litres per person = 0.15 $m^3$,
– total daily water consumption: 4 people × 0.15 $m^3$ = 0.6 $m^3$,
– total annual water consumption: 365 days × 0.6 $m^3$ = 219 $m^3$,
– cost of 1$m^3$ of domestic sewage: 4.91 PLN,
– annual cost of domestic sewage for 4 people: 219 $m^3$ × 4.91 = 1075.29 PLN.

Comparison of the analysed household sewage treatment technologies is summarised in Table 4.

## REFERENCES

Błażejewski R., 2003. Village sewerage (in Polish). Wydawnictwo Polskie Zrzeszenie Inżynierów i Techników Sanitarnych. Odział Wielkopolski. Poznań.

Heidrich Z., Stańko G., 2007. Lexicon of household wastewater treatment systems (in Polish). Wyd. Seidel-Przywecki, Warszawa.

Village sewage treatment plants – examples of solutions (in Polish). Fundacja Wspomagania Wsi, Warszawa 2001.

Heidrich Z., 1998. Household sewage treatment systems, A Guide (in Polish), Centralny Ośrodek Informacji Budownictwa, Warszawa.

Heinrich Z., Witkowski A., 2005. Sewage treatment systems (in Polish). Wydawnictwo Seidel-Przywecki. Warszawa.

Regulation of the Minister of Environment of 24th July 2006 on the conditions that have to be met when draining wastewaters or water to the ground and on substances that are particularly noxious to the water environment (in Polish). Dz. U. Nr 137, poz. 984, 2006 r.

Recommendation ATV-H262P. Household sewage treatment in vegetation filter systems (in Polish). Wyd. Seidel-Przywecki, 1998.

Product Catalogue of Esos.

Product Catalogue of Aquamatic.

Product Catalogue of Ekopol.

Product Catalogue of JPR System.

Product Catalogue of Bioires.

Product Catalogue of Turbojet.

Product Catalogue of Nebrasca.

## EKONOMICZNA ANALIZA WARIANTÓW PRZYDOMOWYCH OCZYSZCZALNI ŚCIEKÓW

**Streszczenie.** Celem pracy była charakterystyka przydomowych oczyszczalni ścieków dla pojedynczych domów lub niewielkich ich zgrupowań. Uwzględniono urządzenia gwarantujące właściwe oczyszczenie ścieków, tzn. takie, dzięki któremu ścieki nie będą stanowić zagrożenia dla

środowiska, a przede wszystkim dla odbiorników ścieków oczyszczonych, niezależnie od tego, czy będzie nim woda czy ziemia. Przedstawiono kilka wariantów przydomowych oczyszczalni, porównano ich wady i zalety i przeprowadzono ekonomiczną analizę.

Urządzenia do unieszkodliwiania ścieków z pojedynczych domów muszą oczyszczać ścieki do poziomu określonego w Rozporządzeniu Ministra Środowiska z dnia 24 lipca 2006 r. w sprawie warunków, jakie należy spełniać przy wprowadzaniu ścieków do wód lub do ziemi oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego.

Według przeprowadzonej analizy najlepsze efekty oczyszczania ścieków charakteryzują oczyszczalnie z osadem czynnym i złożem biologicznym, jednak są to obiekty najdroższe w budowie i utrzymaniu. Najmniejsze nakłady inwestycyjne ponoszone są przy montażu osadnika gnilnego, jednak wysokie są dalsze koszty eksploatacji, zaś efekt oczyszczania bardzo niski. Najtańszym rozwiązaniem pod względem kosztów utrzymania okazała się oczyszczalnia z drenażem, która jednak nie gwarantuje wysokiej sprawności oczyszczania. Nieco droższą od niej inwestycją jest oczyszczalnia hydrofitowa, gdzie ryzyko zanieczyszczenia środowiska jest bardzo mały. Świadomy ekologicznie inwestor powinien zatem wybrać odpowiednio wyważone rozwiązanie, gwarantujące najlepszy efekt oczyszczenia przy optymalnych nakładach inwestycyjnych i eksploatacyjnych.

**Słowa kluczowe:** przydomowe oczyszczalnie ścieków, koszty, nakłady