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NEW TECHNOLOGIES OF SMALL DOMESTIC SEWAGE VOLUME TREATMENT APPLIED IN POLAND

Summary

Numerous firms dealing with widely understood natural environment protection offer various solutions for domestic sewage treatment plants. While choosing the suitable variant of such installation, an investor is driven in the first place by economic factors, easy operation and high operational reliability.

The article presents and assesses four domestic sewage treatment systems working on the basis of activated sludge technology, biofilter and combinations of these two methods, selected in view of the results they achieved.

Because of the specific character of sewage produced in the areas with dispersed buildings, sewage treatment plant installations must prove highly reliable under variable operating conditions, they should be cheap to construct and utilize and not require complicated service. It seems that Sequencing Batch Rectors (SBR) treatment plants meet these requirements, as well as combined installations which join a classic activated sludge method and submerged or mobile biofilter systems. In case of SBR reactors, the whole process of sewage treatment occurs in a single tank where individual phases of the working cycle are controlled by computer. Regulation of supplied air quantity allows to modify the bioreactor work cycle in the way making possible additional reduction of biogenic compounds from sewage.

Technical solutions which combine activated sludge and biofilter methods are becoming increasingly more popular. Such treatment plants incorporate advantages of both methods. They are especially recommended in holiday resorts where considerable irregularity of sewage inflow and storage occurs. During the period of low hydraulic loading or when no sewage outflow is registered, biocenosis in the form of activated sludge will not die back fast because the substrate necessary for microorganism development will be obtained from forming biofilm covering the biofilter.

The examples of domestic sewage treatments plants presented in the article are characterized by high reduction of organic and biogenic pollutants as has been revealed by the tests conducted in the operated installations. Because of that they may be particularly recommended in the areas susceptible to water eutrophication.

Keywords: domestic sewage treatment plants, activated sludge, submerged biofilters, hybrid treatment plants

INTRODUCTION

A considerable number of rural settlements in Poland, as well as numerous small urban centres do not yet have a regular sewage disposal systems, contrary to well established water supply system. The disproportion between the development of water supply and sewerage systems poses serious hazards to sanitary conditions and protection of the natural environment in these areas. Unfortunately, due to dispersed buildings, unfavourable land configuration, etc., construction of centralized sewerage systems is either unprofitable or impossible from the economic point of view. Therefore it is necessary to use local system of waste disposal and treatment.

The literature on the subject provides numerous descriptions of technologies used for small sewage volume treatment [Błażejewski 1998, Heidrich 1998, Stańko 2007, Osmulska-Mróz 1995, Siemieniec, Krzanowski 2001] under semi-natural conditions using diffusing drainage, sand filters or hydrophyte filters. Systems of small sewage volume treatment under artificial conditions on biofilter or using activated sludge technology have been increasingly popular. A choice of sewage treatment should be preceded by a multi-criteria assessment considering the rules of sustainable development [Błażejewski 2003a, Błażejewski, Mazurkiewicz 2007].

The aim of the paper is presentation and operational evaluation of the latest systems of small sewage volume treatment from households based on the biofilter and activated sludge technology.

CHARACTERISTICS OF TECHNOLOGICAL PROCESSES APPLIED IN SMALL SEWAGE TREATMENT PLANTS

Small sewage treatment plants are mostly biological aerobic treatment plants with activated sludge or biofilters, although these two systems combined into one are more and more frequently observed as hybrid systems. At present, prefabricated treatment plants with a daily throughput of between several to many thousand cubic meters have been available in Poland.

Biological sewage treatment occurs during life processes of aerobic and facultative microorganisms as the result of organic pollutant breakdown into simple compounds: carbon dioxide and water and as the result of new cell mass formation [Błażejewski 1998, 2003b, Heidrich 1998, Osmulska-Mróz 1995]. Small sewage treatment plants use microorganism culture either in the form of small floccules (activated sludge method) or bacterial film, attached to biofilter plenum. The proper course of sewage treatment process is conditioned by the availability of a suitable amount of organic matter, best in the form of short-chained organic acids, prolonged contact of sewage with microorganisms, as well as separation and drainage of the excessive bacteria biomass.

Among numerous solutions of small sewage treatment plants are technologies based on low rate activated sludge with prolonged aeration and aerobic stabilization of sludge. In case of biofilters, dominant are systems using stationary, mobile or revolving filter beds, which are usually naturally aerated [Łomotowski 1998].

Like in the case of semi-natural systems, before biological treatment processes sewage must undergo preliminary treatment in order to remove solid particles. This process occurs in pre-settlement tanks. In small sewage treatment plants biological part of the process is usually combined with secondary settlement tanks in which sedimentation of produced bacterial mass occurs.

A REVIEW OF THE LATEST SOLUTIONS AND OPERATIONAL EFFICIENCY OF HOUSEHOLD SEWAGE TREATMENT PLANTS

Activated sludge treatment plants

The method of sewage treatment using activated sludge has been known since the beginning of the twenty century. Activated sludge is composed of microorganisms which at suitable oxygen supply are capable of organic substance mineralization from sewage. At proper modification of the process by creating alternative aerobic, anoxious and anaerobic conditions it is possible to cause additional reduction of biogenic substances (nitrogen and phosphorus) apart from removing carbon compounds. In practice traditional household sewage treatment plant systems are miniatures of large systems. However, due to a different specificity of sewage produced by dispersed houses and different than it is in the areas with centralized sewerage system, small systems face operational problems: breaks in aeration because of power cuts, lack of stability in activated sludge biocenosis development due to considerably irregular sewage inflow, etc. [Makowska 1999]. For these reasons mini treatment plants based on activated sludge and operating in a batch sequencing system have been gaining popularity. They are commonly called Sequencing Batch Rectors (SBR). Unlike in the case of flow system, the whole treatment process occurs in a single tank. The basic condition of efficient SBR treatment plant operation is automatic control system ensuring realization of subsequent treatment cycles composed of succeeding phases of filling in with simultaneous mixing or aeration, aeration, sedimentation and decantation and periodical excessive sewage discharge [Makowska

1999, 2003, Mańczak 2003]. An example of an SBR mini treatment plant offered by GRAF enterprise is presented in Figure 1. These are one-container or two-container systems servicing between 2 and 16 inhabitants. The total reactor volume ranges between 4.7 and 12.0 cubic meters. The whole system is equipped with modern control system.

Sewage is aerated by means of an aerator pump, disc aerators (Klaro Quick and Klaro Easy systems) or through membrane duct aerator. Individual appliances of the treatment plant are placed in a single tank divided into two parts, of which the first is a pre-settlement tank and the second one an SBR reactor [Małe oczyszczalnie ścieków 2007]. If a septic tank or leak proof cesspit exist, there is a possibility to place a modernizing set in it, which will function as SBR bioreactor.

The existing treatment plant could be extended by an additional denitrification system. The producer guarantees COD value below 100mg $O_2 \cdot dm^{-3}$ and BOD_5 below 25mg$O_2 \cdot dm^{-3}$ in treated sewage, in mean daily poured sample in the outflow from the system (classic system) and COD ≤75mg$O_2 \cdot dm^{-3}$, COD ≤ 15mg $O_2 \cdot dm^{-3}$, N-NH_4 ≤ 10mg $O_2 \cdot dm^{-3}$ and N_{org} ≤ 25 mg $O_2 \cdot dm^{-3}$ (system with additional denitrification) [www.graf-online.de].

Moving bed biofilm reactors (MBBR)

Operational problems of mini sewage treatment plant based on activated sludge are connected with considerably irregular inflow of sewage and its diversified composition which may be eliminated through filling bioreactor chamber with plastic granulate. Such solution limits sewage washing out of the bioreactor at hydraulic overloading. An example of such appliance together with the evaluation of its operating performance was presented in the paper by Siemieniec and Krzanowski [2002]. The authors analyzed treatment plant serving the needs of Educational Institutions Complex at Moskorzewo town in the Świętokrzyskie Province. The process line in this treatment plant comprised grease separator localized in the kitchen drainage system, sewage pumping facility, Sebico 600D pre-settlement tank, bioreactor with moving bed in the form of PE crimped profiles and secondary settlement tank for secondary sludge separation and additional settlement tank on the sludge recirculation line Figure 2. In result of combined denitrification (in the pre-settlement tank and in the settlement tank on the recirculation line) and nitrification (in the moving bed bioreactor), an increased reduction of nitrogen compounds from sewage was observed. Conducted operation test revealed high efficiency of organic substance removal from sewage (89.3% for COD and 98.8% for BOD_5), total suspended solids – 96.3%, total nitrogen – 65% and total phosphorus - 87.5%. Sewage in the outflow from the described system met the requirements stated in appropriate legal acts.

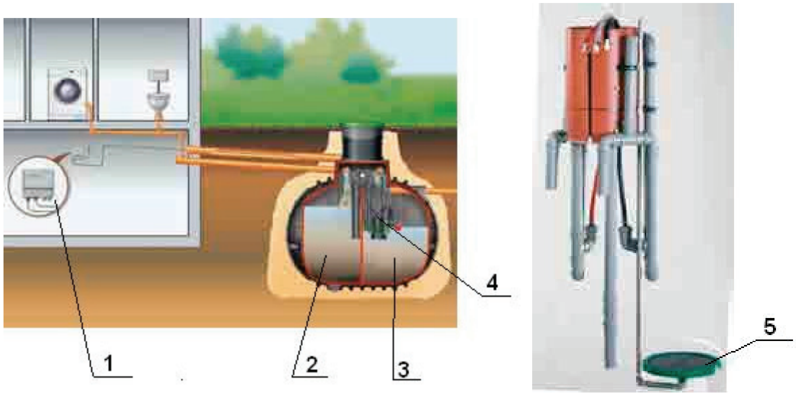

Figure 1. Mini treatment plant of SBR Aqua-Simplex type with aeration pump and modernizing set to place inside of multichambered tank [Małe oczyszczalnie ścieków 2007]: 1 – control system, 2 – sedimentation tank, 3 – SBR reactor, 4 – aerator pump, 5 – aerator disc

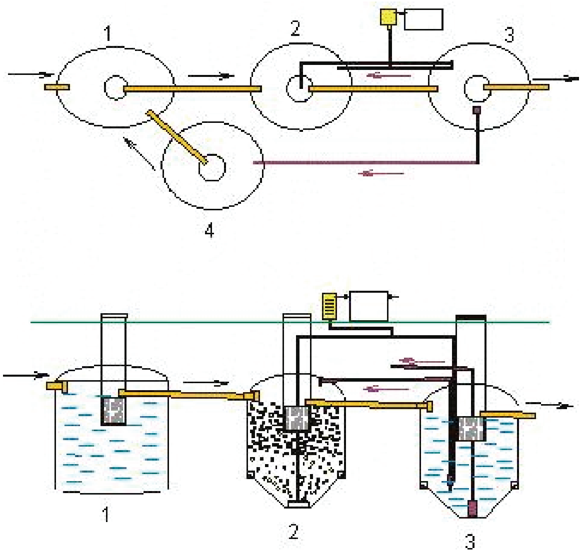

Figure 2. Scheme of moving bed sewage treatment plant at Moskorzewo town [Siemieniec, Krzanowski 2002]: 1 – sedimentation tank, 2 – moving bed biofilm reactor, 3, 4 – secondary tanks

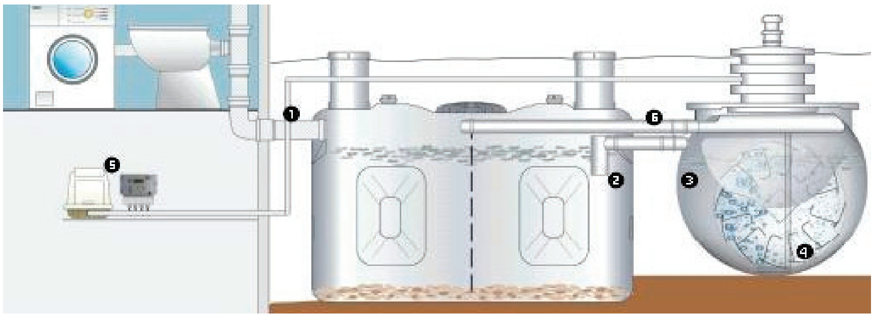

Figure 3. Stählermatic system with rotating disc filters [Kempa 2001]:
1 – inflow of raw sewages, 2 – outflow of sewage from sedimentation tank,
3 – bioreactor tank, 4 – rotating disc filters, 5 – control system, 6 – carry out of sewage

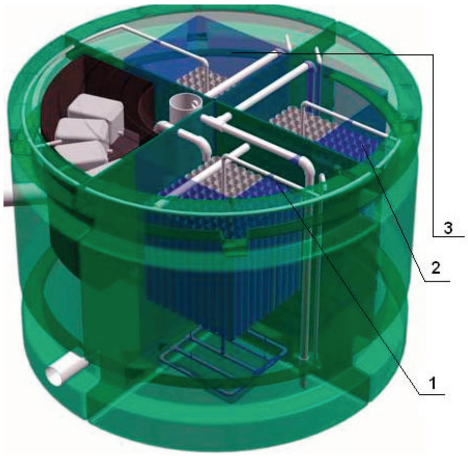

Figure 4. Scheme of sewage treatment plant of BioKube type [www.biokube.pl]:
1 - 3 – numbers of separate sections reactor

Biofilter and hybrid sewage treatment plants

Biofilter treatment plants were among the first types of biological sewage treatment plants. The first fixed sprinkling or water spreading biofilters, lined with crushed stone, coke or plastic packages evolved into rotating disc filters. When properly designed and constructed as models and simultaneously used as solutions oscillating between classical filters and activated sludge filters, they become competitive for the latter. Stählermatic system, which combines disc filter with activated sludge is little known and used in Poland but most reliable and often used abroad. The mode of this appliance operation is as follows: after mechanical pre-treatment in the pre-settlement tank, sewage is fed into a spherical container composed of biological chamber with integrated secondary settlement tank. Biological decomposition of pollutants takes place under conditions of constant oxygen supply from the air. The air is forced to the bottom of the biotank and simultaneously enforces rotation of the filter with numerous profiled plastic discs. The discs are driven by an aerator installed in a control box (see Figure 3). Excessive sludge accumulating on the bottom is removed from the biotank to the pre-settlement tank by a mammoth pump. A characteristic feature of this installation is a set of filter discs with special surface profile on which additional attachments in the form of scoops are installed, which while rotating gather a portion of sewage together with air ensuring very good self-aeration and self-oxygenation of sewage due to diffusion [Kempa 2001].

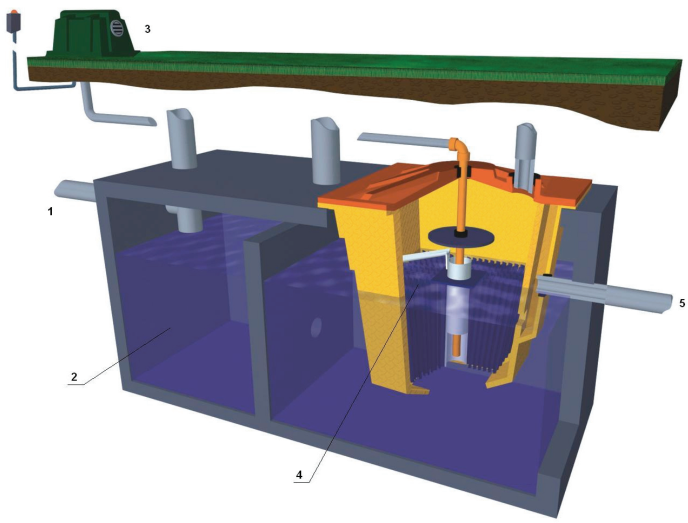

Figure 5. Scheme of sewage treatment plant of RetroFast type [www.biomicrobic.com]: 1 – inflow of raw sewages, 2 – sedimentation tank, 3- aeration blower, 4 – submerged bed of RetroFast type, 5 – outflow of treatment sewages

Other advantages of this installation comprise are among others: large space for creating and maintaining the biofilm, increased sludge age due to autotrophic organism accumulation in the biofilm, intensive aeration of sludge, improvement of the sludge volume index, lower costs of installation and operation.

Exemplary results of research on sewage treated in the treatment plant operating in the Stählermatic system at Niederzeuzhein [Kempa 2001] demonstrate high efficiency of the sewage treatment plant operation. Multiannual mean values of COD in the treated sewage were $35 mgO_2 \cdot dm^{-3}$, $BOD_5 < 5 mgO_2 \cdot dm^{-3}$, N_{org} – $10 mg \cdot dm^{-3}$ and P_{org} – $1 mg \cdot dm^{-3}$.

Another example of innovative biofilter appliance is a Danish BioKube sewage treatment plant of performance between 5 and 1000 PE. It is based on submerged biofilters. The discussed technology uses BIO-BLOCK liner in the form of piping made of polyethylene net placed in blocks. Sewage is pre-cleaned in the pre-settlement tank and then flows to section one and two (see figure 4) containing biofilters where the process of organic pollutants removal occurs first followed by sedimentation. In section three nitrification process and secondary sedimentation take place. Sludge produced in each of the three sections is returned to the pre-settlement tank. Sewage treatment plant of this type may be adjusted to phosphorus removal by an additionally provided chemical phosphorus removal kit [Gromiec 2006]. Results of operational tests for waste treatment plants from 5 PE reveal highly efficient performance. Mean value of BOD_5 in cleaned sewage was $2.9 mg\ O_2 \cdot dm^{-3}$, total suspended solids $5.4\ mg \cdot dm^{-3}$, $N\text{-}NH_4$ – $0.38\ mg \cdot dm^{-3}$ and total phosphorus $0.70\ mg \cdot dm^{-3}$. Advantages of this treatment plant include: simple construction, easy installation and extension, low energy consumption, as well as stability and reliability.

The last of described solutions is a biofilter of RetroFAST type promoted by American Smith & Loveless Inc. enterprise [www.biomicrobics.com]. Sewage treatment plants of this type are used mainly in places where it is impossible to build centralized sewer systems, i.e. for small communities. This is a mechanical-biological sewage treatment plant composed of pre-settlement tank, bioreactor with special filling and aeration blower. RetroFAST treatment plants are hybrid system using submerged biofilter and activated sludge (figure 5). Sewage in the bioreactor is aerated with compressed air supplied by blower as an of water-air hoist. Organic constituents contained in the inflowing sewage are food for aerobic bacteria which attach themselves to a honeycomb resembling medium inside the container. Organic substance mineralization process and ammonium nitrogen nitrification occur on the surface of the biofilter. Nitrified sewage is then carried away outside the biofilter into the anaerobic environment where denitrification process takes place. Excessive sludge generated in the purification process is deposited on the bottom of the tank and is pumped out periodically. Apart from unique lining of the biofilter a SaniTEE screen is placed in the outflow from the pre-treatment settlement tank. Its aim is to average sewage flow and retain solid and floating particles. Special construction of the screen makes possible its easy cleaning which does not require special skills.

Exemplary results of operational tests conducted at RetroFAST sewage treatment plant at Krzywaczka village (Małopolskie Province), cleaning wastewater from a family house inhabited by four persons are presented in Table 1.

Table 1. Physical and chemical characteristic of raw sewage and after successive stage of treatment in RetroFast sewage treatment plant in Krzywaczka [authors' research]

Indicator	Sedimentation tank	Anaerobic tank	Aerobic submerged bed	Outlet |well	Total reduction [%]
BOD_5 [mg · dm^{-3}]	145.76* 239.2-74.15	119.6**	45.325	24.55 60-2.4	83.2
COD [mg · dm^{-3}]	306.08 449.6-189.6	190.4	146.465	83.06 143.98-47.18	72.9
Total suspended [mg · dm^{-3}]	129.55 283.2-36	426.8	170.9	14.75 50-0.4	88.6
Phosphate [mg · dm^{-3}]	34.28 64-21	101.5	29.5	41.5 107-22.6	-21.0
Ammonium nitrogen [mg · dm^{-3}]	49.64 66.45-36.1	43.45	49.81	41.76 48.65-36.2	15.9
Nitrite nitrogen [mg · dm^{-3}]	0.016 0.068-0	0,0	0.149	0.071 0.35-0.014	-343.7

* - $\frac{average}{\max - \min}$, ** - only one measurement

CONCLUSIONS

Treatment plants for small volumes of sewage have been more and more often installed in Poland over the recent years. This type of treatment plant may be built for a single or several households or public institutions, such as schools, offices or hotels, etc. Each such solution is composed of a mechanical treatment (pre-settlement tank) and the main biological stage a bioreactor with activated sludge or biofilter. Because of considerable irregularities of the sewage inflow from single houses and different sewage composition, mini treatment plants, particularly these based on activated sludge often face operational problems, e.g. carrying away of the sludge, which considerably diminishes their technological efficiency. Therefore, innovative solutions for small sewage volume treatment are more and more frequently used, since such small treatment plants are more stabile and reliable. Attention should be also paid to solutions combining classical activated sludge method and biofilters. Beside their advantages involving considerable resistance to fluctuations in the volume and composition of inflowing sewage, they are characterized by low costs of construction and operation.

All solutions of domestic sewage treatment plants presented in this paper ensure highly efficient reduction of pollutants, as has been corroborated by numerous operational tests performed on the existing installations. Usually outflow from such systems is directed to the ground through sewage diffusion appliances, with no risk to groundwater. The other alternative involves accumulation of purified sewage in special tanks and using it for watering of trees or bushes, etc.

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