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OF TECHNOLOGY

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„ENVIRONMENTAL ENGINEERING – THROUGH A YOUNG EYE"

VOLUME 36

ENVIRONMENTAL ENGINEERING SYSTEMS

Edited by
Iwona Skoczko
Joanna Szczykowska
Monika Wysocka
Maciej Załuska

Białystok 2017

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THE UTILIZATION METHODS OF MUNICIPAL SEWAGE SLUDGE AND THEIR IMPACT ON THE ENVIRONMENT

Keywords: municipal sewage sludge, utilization methods, impact on the environment

Abstract:

The generation of sludge is inextricably linked with the sewage treatment. Sludges are natural product of wastewater treatment processes. The average amount of generated sludge is from 1 to 3% of the volume of treated waste. The relatively small amount of sludge affects the high cost of their disposal constituting even 50% of the total cost of the treatment. Until recently, we were able to identify six basic groups methods of sludge management: storage, agricultural and horticultural use, thermal transformation, industrial use, recovery of chemicals or fuels, land reclamation and forestry.

The first of these methods by the European Union directive and national regulations cannot be applied from 1 January 2016. It forced the development of others and search for new methods of sludge management. This article in overview way analyzed different groups of sludge management methods, shows benefits and disadvantages, and their impact on the environment.

Introduction

The primary piece of legislation regulating the management of waste (which also include municipal sewage sludge) is the Waste Act of December 14, 2012 year. It defines municipal sewage sludge as [24]: "coming from the sewage treatment plant sludge from the digesters and other installations for treatment of municipal sewage and other wastewater a composition similar to the composition of municipal wastewater". Sewage sludge is an unavoidable and natural product of wastewater treatment. They are formed during the various stages of wastewater treatment. The amount of generated sludge is about 1 to 3% by wastewater flowing volume, but for the cost of processing is about 50% of the total cost of the sewage treatment plant [2, 5, 18, 21].

Detailing the provisions of the Act [24] in the context of municipal sewage sludge is the Regulation of Minister of Environment of 6 February 2015 in case of municipal sewage sludge [25].

According to the Central Statistics Office contained in the National Waste Management Plan 2020 [23] the amount of sewage sludge produced in 2011-2015 increased, as shown in Fig. 1. Using the data obtained from previous years, calculated the likely quantities of municipal sewage sludge (assuming the immutability of growth). Analysis of the received data (Fig. 1) has been noted that in 2020 in Poland the production of sewage sludge could reach the level of 640 thousand tons, compared to 2015, an increase of over 11%.

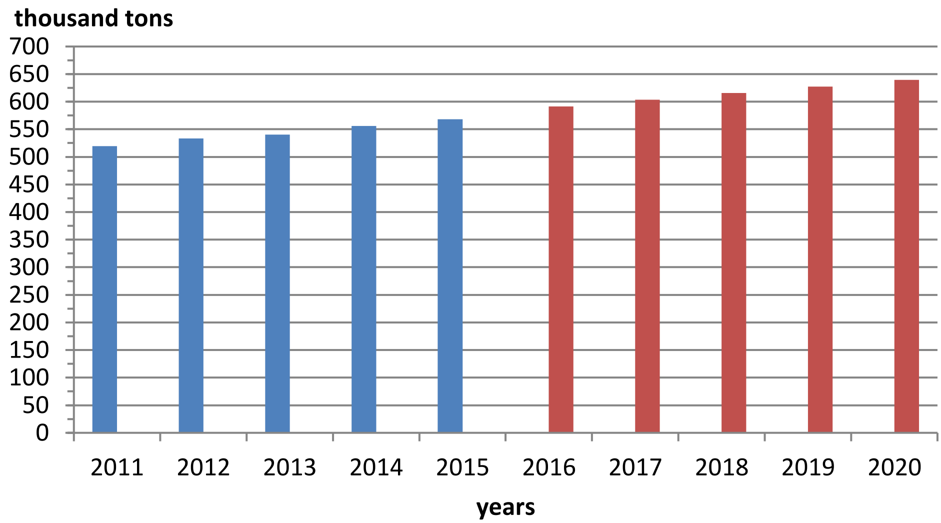

Fig. 1. The amount of sewage sludge generated in Poland in 2011-2015 with the perspective of 2020
Source: own study based on Central Statistics Office data

Sewage sludge can be divided due to their origin and type. Due to the origin we differentiate [3]:

- sludge from municipal wastewater treatment plants - they are characterized by a significant ability to decay due to the high content of organic matter, little ability to dewatering with its high content, as well as the presence of pathogenic bacteria and parasites,
- sludge from municipal and industrial wastewater treatment plants - show less ability to decay because of their composition, their ability to dewatering is larger, they contain more heavy metals than sludge from municipal wastewater treatment plants.

Due to the type we differentiate [1, 3, 19]:

- raw sludge - among which can be identified initial, secondary, from chemical precipitation and mixed sludge,
- mineralized (stabilized) sludge - depending on the method of disposal can be identified fermented sludge (after fermentation), stabilized oxygen sludge (after the process of aerobic stabilization), washed sludge (after the washing process), thickened sludge (after the process of compaction, which hydration is 90 to 95%), dehydrated sludge (after dehydration process, which the hydration is 50 to 70%) and dried sludge (after drying or dewatering process, the hydration is from 5 to 20%).

In accordance with Article 5 the Act on waste, each waste producer should [24]:

- prevent waste generation or reduce the amount of waste production and its negative impact on the environment in the manufacture of products, during and after their use,
- provide compatible with the principles of environmental recovery, if could not be prevent it generation,
- provide compliance with the principles of environmental disposal of waste, which generation could not have been prevented or which could not be recovered.

In the Act on Waste assumed that the disposal of waste consists of submitting them to the processes of biological, physical or chemical transformation in an endeavor them to the condition that does not pose a threat to life, health or the environment.

Annex 6 of the Act to the disposal include:

- depositing neutral waste on landfill,
- processing in soils (eg. biodegradation of liquid waste or sludge in soils),
- storage by the deep injection (eg. injection of waste that can be pumped),
- surface retention (eg. placement of waste into ponds or lagoons),
- depositing on dangerous waste landfill or non- dangerous waste landfills,

- placement (flooding) in the bottom of the sea (according to Art. 55, landfilling of waste is prohibited in Polish maritime areas),
- biological treatment by which produce waste material (eg. fermentation),
- physico-chemical treatment, which results is waste generation (eg. the evaporation, drying, precipitation),
- thermal processing of waste in installations or devices located on land,
- thermal processing of waste in installations or devices located on the sea,
- storage of waste containers in the ground (eg. in the mine).

Annex 5 the Act on Waste defines the activities involving the use of waste in whole or in part or leading to the recovery from waste substances, materials or energy, together with their use. Included here:

- use as a fuel or other means to generate energy,
- recycling or reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes),
- spreading on the surface of the earth, in order to fertilizer or improve soil or soil remediation.

In the Act on Waste enshrined also that storage can be directed only waste which otherwise disposal was impossible for technological reasons or unreasonable for ecological or economic.

Methods of disposal and management of sewage sludge contained in the Act can be grouped into 6 groups shown in Fig. 2.

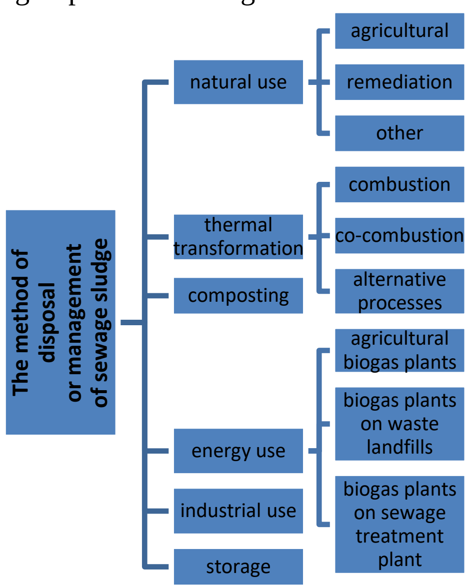

Fig. 2. Division the methods of disposal and management of sewage sludge
Source: own compilation

Percentage distribution of the amount of sewage sludge on different methods according to the Central Statistical Office [31] shown in Fig. 3.

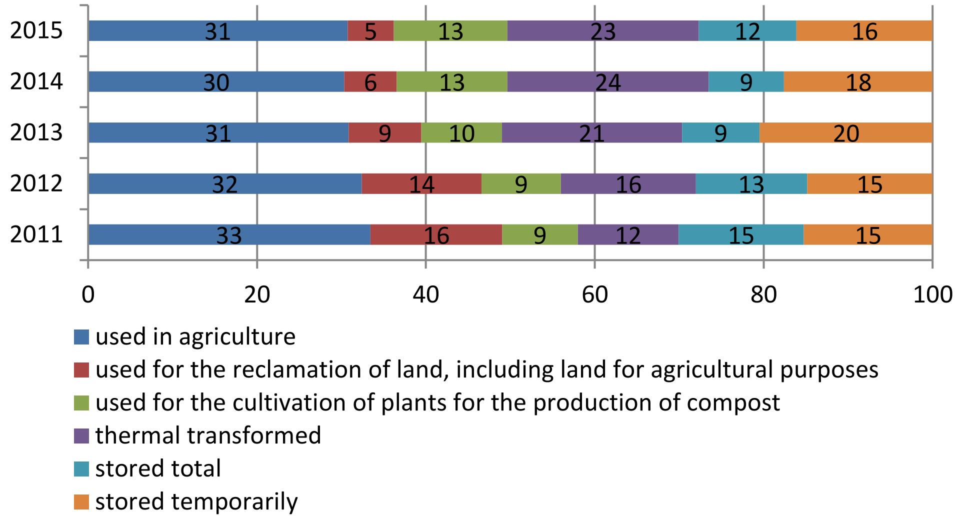

Fig. 3. Methods for development of municipal sewage sludge
Source: own study based on Central Statistics Office data

Analyzing these data it can be observed that year-on-year decreases the amount sludge used for land reclamation (from 16% in 2011 to 5% in 2015). Increases characterized by thermal transformed (12% in 2011 to 23% in 2015), and the use sludge for the cultivation of plants for the production of compost (from 9% in 2011 to 13% in 2015).

Natural use of sewage sludge

Restoring the soil components accumulated in sewage sludge is correctly not only from an economic point of view, but also necessary to preserve and restore the ecological balance. The mineral and organic composition of sludge from municipal sewage treatment plants is similar to the soil organic matter called humus. This allows the natural use of sewage sludge [1, 7].

According to the Act on waste municipal sewage sludge may be used if they are stabilized (i.e. having undergone the processes of aerobic or anaerobic biochemical stabilization)and prepared in accordance with the goals and methods of their use, in particular by subjecting them to treatment of biological, chemical, thermal or other process that reduces the vulnerability of municipal sludge to decay and eliminate the threat to the environment or human health [3].

The methods of natural sludge use can be divided into three basic groups: the agricultural use, non-agricultural use and others. Due to the presence of heavy metals, organic micro-pollutants and pathogens the agricultural use of sewage sludge practically possible a small degree. Reclamation is the most realistic use of sewage sludge [3].

Agricultural use of sewage sludge

Among the methods of the natural use of sewage sludge, due to the fertilizer properties the particular interest is aroused the agricultural use of the soil fertilization, plantation and forest nurseries crops trees and shrubs. Sewage sludge abound with organic matter and nutrients for plants, mainly nitrogen and phosphorus, which determine of their very high useful [3, 9].

The dose of sewage sludge used as fertilizer for the soil is limited by [4, 19]:

- nitrogen content in the sludge,
- heavy metals content in the sludge,
- of heavy metals content in soils,
- presence of pathogenic organisms,
- solid consistency.

The use of sludge as a fertilizer should not only provide the right conditions for plant growth, but also to maintain the ecological balance and proper sanitary condition of the soil. In the application of municipal sewage sludge in agriculture dose of sludge is determined for each batch of sludge separately. The dose depends on the type of soil, the method of its use, the quality of the sludge and the demand of plants for phosphorus and nitrogen. The permissible content of heavy metals which may be introduced with the sludge does not exceed 20 mg of cadmium per kg of dry solids, 1 000 mg of copper per kg of dry solids, 300 mg nickel per kg of dry solids, 750 mg of lead per kg dry matter solid, 2 500 mg of zinc per kg of dry solids, 16 mg of mercury per kg of dry solids and 500 mg of chromium per kg of dry solids [3, 19].

The advantages of agricultural sewage sludge management can include:

- return to the soil environment early uplifted from him biomass (return ingredients to the natural circulation) [3],
- the beneficial effects of sewage sludge fertilizer, especially on light soils (increase crop yields and improve some properties of the ground) [3],
- abundance organic matter in the sludge (which is subject the time humification) and nutrients for plants (especially nitrogen and phosphorus),
- the presence of nitrogen in the readily assimilable compounds form (from 30 to 50% of the total content) [3, 8],
- the presence of phosphorus in the form of polyphosphate (detergents), readily hydrolyzed to orthophosphates absorbed to plants [3, 8],
    - neutral or alkaline sludge pH, which indicates a high content of calcium and magnesium [3],

- improve the properties of water and air of the ground, increase sorption capacity of the ground, the intensification of biological life and the creation of crumbling structures in the substrate [3].

The disadvantages of the sewage sludge use in agriculture include:

- a small amount of potassium in the sludge ground [3],
- the possibility of excessive concentration of heavy metals and biological contamination [3],
- the possibility of environmental contamination foreign substances to the environment (eg. greases, oils, pharmaceuticals, plastics) [3],
- contaminated soil can contaminate crops, and consequently endanger human and animal health [3].

Remediation use of sludge

One of the simple ways to use sewage sludge can be soil remediation devastated by the industry, which involves restore the level of humus and soilless land reclamation [3, 14].

Sludge can be used on soilless land, such as [32]:

- natural land with degraded soil and vegetation cover,
- land naturally devoid of soil cover (eg. the excavation),
- embankments (including landfills) masses of geological origin,
- industrial waste landfill,
- municipal landfill.

The main objective of soil formation remediation of the formation of plant cover that protects the soil surface from the destructive effects of water, wind and sun, and protecting the local climate [32].

Remediation doses of sludge depend mainly on [32]:

- use of remediation land,
- the intended intensity of soil fertilization,
- the heavy metals content in the sludge,
- consistency of sludge and its application techniques,
- restrictions resulting from environmental protection on adjacent areas.

The advantages of the use of sludge for remediation are [3]:

- increased by approximately twenty times the content of organic material building humus in the digested sludge as compared to the humus ground,
- reduction of dust from landfills undergoing reclamation by sludge.

The disadvantages of the use of sewage sludge in the remediation include:

- restriction of use due to the protection of water,
- the use of liquid sludge increased health risks (formation of harmful aerosols).

Other methods of the natural use of sludge

Sewage sludge can be used to consolidate the surface of fly ash landfills and other dusty waste or embankments threatened by water erosion [32].Sewage sludge together with seeds is spilled on the ground (hydroseeding), which allows for:

- surface fixation of the bed particles in the porous layer (permeable membrane),
- seeds glued to the ground,
- providing nutrients to plants in the early stage of their life,
- supplementing the organic components necessary for the proper functioning of the micro-organisms.

Sewage sludge also provides water for sprouting of plants and buffering functions on fields both acidic and alkaline.

The advantages of the use sludge in hydroseeding are [3]:

- the ability to resign from expensive anti-erosion preparations (which are a component of the mixture applied to the surface) by introducing instead dehydrated sewage sludge,
- improving soil structure and adding to it the nutrients.

The disadvantages of the sewage sludge use in hydroseeding include:

- the use of liquid sewage sludge to hydroseeding is not recommended when the embankment are located in the zone of water intakes and at a distance of less than 20 meters from the buildings and the bathing,
- evenly spreading with seed hydroseeder,
- low costs of preparation of the ground or surface under hydroseeding,
- speed of execution of work - using hydroseeding can assume lawns or even sown area on the surface of many hectares.

Thermal transformation of sewage sludge

In the context of spending constraints related to the natural use of municipal sewage sludge, arising from the laws and the lack of potential areas for possible their application, thermal sludge disposal is becoming increasingly important. Methods of thermal sludge treatment include combustion, co-combustion and alternative methods [1, 3, 11, 28, 29].

The main parameters determining the usefulness of sludge for thermal neutralization are [1]:

- hydration (up to 50%),
- content of non-health substances (up to 60%),
- content of combustible substances (over 25%).

The combustion of sewage sludge

The combustion is the oxidation of organic compounds to CO_2 and H_2O. The process aims to reduce the volume of sludge produced. It is used where it cannot be used for agricultural use, due to the high concentrations of heavy metals. Combustion of sewage sludge without the use of additional fuel is difficult because of the high content of mineral in the dry matter, sometimes of up to 60% and the high moisture content of at least 50%. However, it is possible, provided the use of appropriate technologies and effective methods of dewatering [1, 3, 15, 29].

The combustion of sewage sludge can be realized [1]:

- in a fluidized bed,
- in kilns with mechanical grate firing,
- in a rotary kiln,
- in different varieties of shelf kilns.

The fluid bed kiln is essentially cylindrical, walled chamber. In the lower part there is a perforated floor and above the perforated fluidized bed. The sludge, which should be burnt, and the extra fuel is introduced into the fluidized bed. There evaporate the liquid components of the sludge, and the contained organic compounds start to burn in the form of fine particles are carried by a mixture of steam and the exhaust gas from the fluidized bed and above it, before leaving the space of the combustion chamber to burn the end of [1].

The best installation for combustion of municipal sludge is slatted incineration plant with reciprocating or cylindrical grate. Most European incineration plants of waste is just such a design for sewage sludge [1].

Rotary kilns are mainly used for combustion solid waste, but are also applicable to the incineration sewage sludge and sludge. The rotary kiln is made of encapsulated a ceramic material tube located with a slight decrease in the level. The sludge is supply from the higher located end of the kiln. As a result of the rotational movement of the drum and its inclination, the sludge is moved towards the opposite end of the drum. On this side of the kiln is located the chamber of combustion and exhaust fumes and ash [35].

Co-combustion of sewage sludge

Co-combustion can be divided into [29]:

- co-combustion sewage sludge with municipal solid waste - such a solution reduces the investment costs for the heat needed to evaporate the water from the sewage sludge and surplus heat to create steam, and also supports the burning of waste and sludge,
- co-combustion of sewage sludge and coal, the coal should be dried to an average of 90% dry matter, while the brown coal to a lower value. Burn-

ing sludge in the coal boiler plants is achieved good conditions for the elimination of organic compounds contained in the waste, and the use of their energy resources,
- co-combustion of sewage sludge in cement kilns - safe way to burn a variety of organic waste. They must be dried and have a calorific value up to 16 MJ / kg. In addition, the chlorine content should not exceed 5% by weight of sludge [1, 10].

Alternative of sewage sludge thermal treatment processes

Among the alternative processes are distinguished wet oxidation, pyrolysis and gasification (including combinations thereof), and vitrification [1, 29].

Wet oxidation is characterized by the possibility to use concentrated mechanically and not-dewatered sludge. During this process, in the reactor are conditions the high temperature and pressure, which allow the oxidation with oxygen use of the organic matter contained in the waste. The result is to obtain mineralized sludge, biodegradable effluent and post-reacting gas [33].

Pyrolysis of waste is carried out under anaerobic conditions at a temperature of 350 - 500 ° C. This results in three products: a solid phase, pyrolysis gas, a liquid phase - of a mixture of oils and tars. Some of the liquid and gas products is recycled to cover the heat demand of the process [1].

Gasification is the thermo chemical conversion of organic solid or liquid particles in a gas, of suitable caloric content. The composition of the resultant gas mainly depends on the substance which is subjected to the process and it can distinguish chemical compounds, such as CO_2, CO, H_2O, CH_4, H_2, otherwise - trace amounts of higher hydrocarbons and inert gases as well as different impurities. The process is characterized by the presence of gasifying agent, and in that there is in oxygen deficiency conditions [34].

Vitrification is a thermal transformation of the substance in the form of vitreous, which tends to alter the properties and form of the material subjected to modifications. It consists of a controlled dosage of energy to a substance that decomposes at high temperatures to produce gaseous phase is then subsequently ashing and melted. The product is vitrificat characterized by amorphous structure, low chemical reactivity, the preferred chemical properties, good mechanical resistance and the no toxicity and no pollen [35].

Composting of sewage sludge

Composting is a natural extending under aerobic conditions, the exothermic process of biological oxidation the organic fraction of sludge. This process may produce a product of air-dry, stable and emitting far less odor as compared with sludge which has been produced [26, 27].

Conditioning process makes two basic objectives [3]:

- disposal, it is the transformation of waste containing easily decomposed organic substances and pathogens in the stable material, inoffensive for the environment, safe in terms of sanitary and hygienic, easy to store, transport and use,
- production of high-grade organic fertilizer - compost - does not contain ingredients harmful to the environment, mainly heavy metals and are difficult to decompose organic substances, PAHs, chlorinated, such as PCBs, dioxins.

Composting sewage sludge allows [5]:

- elimination of health risks resulting from the accumulation of sewage sludge,
- reducing the weight and volume of sewage sludge,
- reduction of surface landfills,
- increase the productivity of soils.

From the technological point of view composting of sewage sludge can be performed in reactors or piles with or without the addition of material building the structure as shown in Figure 4.

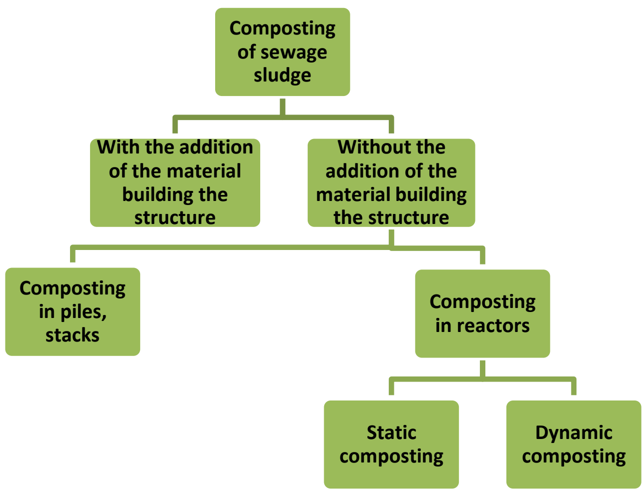

Fig. 4. The division of composting methods
Source: [1, 5]

Sewage sludge to be composted should have the following characteristics [5]:

- organic matter content (over 50%),
- water content (50 to 60%),
- the correct ratio of carbon to nitrogen.

The main advantages of the composting process are [5]:

- the ability to use as a very fertile material to enrich the soil with nutrients, which allows you to restore the organic fraction of the sludge to soil environment,
- compost produced from sewage sludge can be used not only in agriculture, but also to shape the landscape (reclamation),
- compost has a positive effect on soil fertility and improves its structure, reduce soil silting, oxygenates the soil and promotes the development of biological life in the soil,
- composting of reduces the emission of greenhouse gases, methane and carbon monoxide and reduce nitrogen pollution of groundwater.

The disadvantages of the composting process we include:

- the presence of high temperature (above 70°C) at an early stage of process, which can lead to emission of extremely troublesome and unpleasant odor to the environment,
- compost produced from sewage sludge can contain increased heavy metal content.

Energy use of sewage sludge

In the process of anaerobic digestion sewage sludge we obtain stabilized waste (sludge digestate) and biogas, which is a valuable fuel gas, and at the same time a source of renewable energy. In Poland, for many years there is a perception that the anaerobic stabilization is recommended only for large wastewater treatment, and for smaller economically justified to stabilize the sludge under aerobic conditions. Analysis of the profitability of the construction a plant for anaerobic stabilization sewage sludge indicate that this recommendation is wrong [6, 20].

Physico-chemical properties of waste generated in the methane fermentation process to a large extent depend on the quality of the substrate introduced into the bioreactor. Practically any organic material which does not contain inhibitors may be substrate used for the production of biogas. In agricultural biogas plants are used primarily: livestock manure, energy crops, residues and by-products of agri-food and forest biomass. As a substrate in biogas plants waste disposal beyond the waste, which due of its dangerous nature they require thermal processing are used as co- substrates used in agricultural biogas plants. In the case of biogas utilities, it is separated fermentation chambers sludge in wastewater treatment plants and the installation of anaerobic stabilization and installations located on landfill sites, as the substrate are: municipal sewage sludge, selectively collected biowaste, organic fraction the separation of mixed municipal waste, other waste from industry and trade [17, 20].

Considering the size of biogas production in the methane fermentation process is advantageous to use at the same time few types of waste in the process of co-fermentation. The results of a joint study of fermentation sewage sludge with other biodegradable waste in an increase in the efficiency of biogas production and a higher percentage of methane. In operational practice is best to use liquid / semi liquid waste of the agri-food industry, which does not require preparation before entering the bioreactor. Technology co-digestion of sewage sludge in agricultural biogas plants is used eg. in Denmark (biogas plant in Thorso), where the proportion of sewage sludge in the mixture undergoing fermentation is maintained at a level of 20%. This type of solutions are not practiced in Poland, despite the absence of technology contraindications [13, 20].

Methane fermentation process in wastewater treatment plants is carried out in separate digesters. They are reservoirs of cylindrical shape or close to oval, usually reinforced concrete structure. The process is typically carried out at a temperature of 35 - 38°C (mesophilic fermentation). Products of the fermentation process of unstable sewage sludge is digested sludge and biogas. Technical possibilities of using the energy contained in the biogas is [20]:

- electricity production in spark or turbine engines,
- heat production in the adapted gas boilers,
- production of electricity and heat in associated units (cogeneration),
- the use of gas as a fuel for traction engines / vehicles,
- use of gas in technological processes, eg. in the production of methanol.

Biogas from methane fermentation of sewage sludge can be used to generate power when the biogas is equipped with a production line allowing [20]:

- reception of biogas from digesters,
- mechanical purify and desulfurization of biogas,
- biogas storage tanks to stabilize the pressure,
- drying of biogas by dehydration condensation of water vapor,
- final drying of biogas from mechanical impurities for highly efficient flow filters,
- operating combustion of biogas (engine, kiln),
- emergency combustion of biogas (torch).

Industrial use of sewage sludge

Sewage sludge can be used in many industries. The most important examples of the use of sewage sludge are [1, 3, 12, 16, 30]:

- additive in the production of bricks and ceramics,
- the use of fats from sewage sludge,
- manufacture plastic masses from sewage sludge,

- supplementary feed for domestic animals and birds,
- additive to concrete or "green concrete".

According January Bień [1], sewage sludge can be used for the production of bricks. In Port Elizabeth in North Africa sludge from the local sewage treatment plant are used to manufacture the bricks in a brickyard. The volume of the sludge batch is from 5 to 30%.Additionally the studies of Rećko [12] has shown that granular sludge with waste carbon mules have advantageous properties, such as chemical and mineral composition, mechanical strength, calorific value, and that this can be exploited in the manufacture of ceramic construction.

In municipal waste is contained a certain amount of fatty substances. A major part thereof is in sediment with the form of fine emulsion, and the rest in the form of a film covering the surface treatment. According to data, per capita per day is from 0.5 to 1.0 g technical grease derived from fats contained in the wastewater. In 1 t of technical fat can be produced 1.5 t of soap [1, 3].

The activated sludge contains a significant amount of nitrogen, the major constituent protein, and small amounts of fiber. From the nitrogen and phosphorus contained in the substance can be obtained a substrate for the plastic masses production. From the resultant pulp you can produce various kinds of objects. Large wastewater treatment plants, having equipment for treatment using the activated sludge chamber can produce up to 100 tonnes of dry product per day, as a raw material for plastic masses [1, 3].

The detailed analysis of the activated sludge showed that it could be used as a feed for animals. The activated sludge contains for addition nutrients to also significant amount of protein. In sludge has been detected a high content of various amino acids, vitamins, minerals and trace elements. In addition, the sludge was detected vitamin necessary for proper metabolism of animals. It is particularly important that in the activated sludge were detected sought vitamin B12, which is essential for proper development of the organism [1, 3].

Sewage sludge also can be used to produce "green concrete". The term "green" is assigned to the concrete that meets one of the following five criteria [30]:

- CO_2 emissions associated with producing the concrete is reduced30%,
- concrete contains at least 20% of the waste products used as aggregate,
- the production of concrete are used own waste products from the concrete industry,
- the production of concrete are used new types of waste products, previously placed in landfills or disposed of in another way,
- the waste fuel from the natural CO_2 in terms of replacing at least 10% of the fossil fuel used in the production of cement.

Storage of sewage sludge

Since 1 January 2016 landfilling of untreated sewage sludge, which was previously one of the methods of sewage sludge will be virtually impossible due to the failure to comply with the requirements set out in Annex 4 to the Regulation of the Minister of Economy of 16 July 2015 on the admission of waste for storage landfills [22].

According to the Act on waste, for the storage can be directed only waste which disposal otherwise was impossible for technological reasons or unreasonable for ecological or economic. Also it sets out a number of prohibitions on waste disposal, including may not be stored waste in liquid state in this waste having a water content greater than 95% of the total weight excluding slurry. Sludges sent to landfill must be subjected to the processes of stabilization and drainage [19].

Summary

Depending on the properties of the produced sludge, local conditions and the factors formal and legal in Poland used many methods of sludge management. The choice of method of disposal of sludge depends on their quality, especially the presence of hazardous substances to the environment. The main problem is the release into the wastewater significant amounts of heavy metals that even after the process of their treatment remain in the sludge. Classification of sewage sludge for agricultural use brings with it requirements that must satisfy both the agricultural areas and used sewage sludge. The permissible amounts of chemicals, which may contain sewage sludge, are strictly defined standards. The condition for the use of sludge for these purposes is their stabilization and preparation by treatment with biological, chemical, thermal or other processes so as to reduce susceptibility to decay and eliminate the threat to the environment or human health. Similar, strict requirements are sludge applied to land reclamation or other natural purposes.

Legal aspects concerning the treatment of sewage sludge for thermal utilization are not specified separately, therefore, should be followed in this case the rules on waste combustion specified in the Act on Waste. Combustion of sewage sludge may occur in the combustion plants of hazardous waste, combustion of waste other than hazardous and municipal, as well as in municipal waste combustion plants. Waste combustion plants shall be designed, constructed, equipped and operated in such a way that to minimize the amount and harmfulness of waste and other emissions. It should also provide continuous measurements of emissions during the combustion process and permissible quantities of substances released into the environment should be clarified.

Composting of sewage sludge can be realized together with other waste (biodegradable fraction of municipal waste) and is performed most often outside the wastewater treatment plants in composting plants. This direction of sludge management is correct in the case of producing compost that meets the appropriate standards and the existence of suitable market for this product. The use of natural and agricultural sewage sludge is possible while complying with the relevant legal requirements in terms of quality (content of pathogenic organisms, toxic substances), the application method and the area of land which could be used.

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ANALYSIS OF THE EXTRACTION OF GROUNDWATER FROM DEEP IN THE PODLASIE

Keywords: deep aquifers, wells, deposits of chalk, water parameter

Abstract:

Białystok groundwater intake supplies about 300 thousand people. The main source of water at the intake is Supraśl River, right tributary of Narew River. Surface, infiltration and deep waters constitute the intake in Jurowce, operating on deep water wells connected to pump units. The entire area of intake is located on the surface of about 55 ha and currently exploits 37 deep water wells that draw water from quaternary aquifers. The water extracted in this way forces municipal water supply systems to impose large costs on the water treatment process for human consumption. The solution to this problem may be water extraction from deep aquifers, unexploited so far in Białystok. A good example of using such water is Grodno city in West Belarus, at a distance of 80 km from Bialystok, drawing water from these aquifers at 100 m^3 per day. Extracted water comes from a level separated by large cretaceous deposits, which effectively protect it from various external factors. For this reason, water extracted from such wells has very good quality parameters. Geological sections of Białystok and Grodno show large cretaceous deposits on a similar depth. Large cretaceous deposits are very close to Białystok, which enables to state an assumption that Białystok water supply systems can use them.

The article presents the assessment of extraction possibilities of deep aquifers for Białystok. For this purpose, the analysis of geological sections of the entire region was conducted, as well as hydrogeological conditions at the intake. The possi-

bility of using deep aquifer beds in Białystok was subjected to comparison to extracted water in Grodno, which exploits water from deep aquifers.

Groundwater

In accordance with definition in the Act of 18.07.2001 “Water Law”, *the groundwater term* is understood as water found beneath the surface of earth in free spaces of rocks of the earth’s crust, which depending on the depth create near-surface water and deeper functional water-bearing levels. The main sources of groundwater are:

- infiltration – absorption of atmospheric falls to the bedrock,
- condensation of water vapor in the air appearing in caves,
- some geological processes associated with formation of rocks and geological structure [1].

It is possible to divide groundwater into:

- standard groundwater, which use and protection are subject to provisions of the “Water Law”,
- brines, healing and thermal waters, which in accordance with the Act of “Geological and Mining Law” are ore and are subject to provisions of this law [1,2].

Environmental conditions

According to information of the Polish Hydrogeological Survey, the area of Białystok, capital of Podlasie, lies within Białystok plateau range, it is a wavy and wavily – hummocky, varied with embankments of end moraines and kames, old-glacial plateau, intersected with river valleys. Terrain is very varied. Altitude is there even up to 50 meters above sea level, and wavily – hummocky moraine hills sometimes reach 200 meters above sea level. Running parallel Supraśl valley is indented relative to plateau to the depth from 20 to 50 meters. Hillsides of the valley are steep, and the width of its bottom varies from 800 meters up to even 1500 meters [1]. The area is ranked among Mazurian uplands. It is formed by Precambrian crystalline rocks, on which lies varied Lower Jurassic and strongly reduced deposits of Middle and Upper Jurassic. Cretaceous deposits are covering the Jurassic area, falling to the west according to gradient of the older ground. Mesozoic formations are covered with pieces of Eocene sandy deposits with coal dust, Oligocene glauconitic sands, as well as loam and sludge with fillers of Miocene lignite coal. On cretaceous or Palaeogene and Miocene sediments underlain Pleistocene

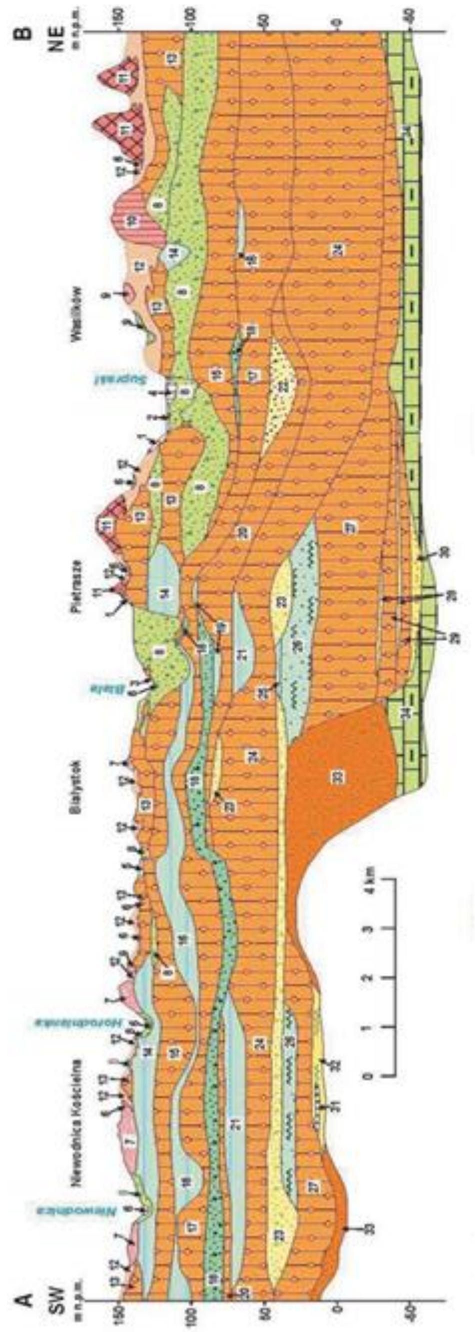

Fig. 1. Geological cross-section of Bialystok
Source: [3]

1 – Anthrosol, 2- Peat from Holocene, 3- Silt from Holocene, 4 - Sand from holocene, 5 – Sand and gravel from Diluvium, 6- humus and silt from Holocene, 7- Sand and gravel from Wolstonian Stage, 8- Sand and gravel from Wolstonian Stage, 9- Sand and gravel from upper Wolstonian Stage, 10- Sand, gravel and clay from Wolstonian Stage, 11- Sand and gravel from Wolstonian Stage, 12- Sand, gravel and glacial erratic from Wolstonian Stage, 13- Glacial till from Wolstonian Stage, 14- Silt and loam from Wolstonian Stage, 15- Glacial till from Wolstonian Stage, 16- Silt and loam from Wolstonian Stage, 17- Glacial till from Riss Glaciation, 18- Sand and gravel from Riss Glaciation, 19- Silt and loam from Riss Glaciation, 20- Glacial till from San Glaciation 2, 21- Silt and loam from San Glaciation 2, 22 - Sand and from San Glaciation 2, 23- Sand and gravel from San Glaciation, 24- Glacial till from San Glaciation 1, 25- Silt from San Glaciation , 26- Sand and gravel from Midel I, 27- Glacial till from Nida Glaciation, 28- Sand and gravel from Narew Glaciation, 30- Glacial till from Narew Glaciation, 31- Lignite from Miocene, 32- Silt and lignite from Miocene, 33- Sand and lignite from Paleogene, 34- Marl and chalk from Cretaceous

Fig. 1. Geological cross-section of Bialystok area
Source: [3]

formations associated with several transgressions and regressions of the Scandinavian ice sheet. Thickness of Pleistocene formations is about 120 to about 200 m. Glaciation: the oldest, South-Polish and Middle-Polish formed boulder clays, sands and water-glacial gravels. Interglacial settlements constitute river sands and gravels, river-lake sands and sludge, water-logging loam and sludge, gravels, glacier sands and sludge, lake sludge and peats. Retreating ice sheet left end moraines, sandar, eskers and kames. Increased organic accumulation in river valleys and depressions without natural water outflow is characteristic for Holocene [Graph A]. Geological section of Podlasie shows large cretaceous deposits. Therefore, there is likelihood of aquifers under cretaceous layers. A good example of using such water is Grodno city in West Belarus, at a distance of 80 km from Bialystok, drawing water from these aquifers at 100 m3 per day. The map of Belarus presents a range of waters at a depth of 400 m below the ground surface [Figure 2]. Extracted water comes from a level separated by large cretaceous deposits, which effectively protect it from various external factors. These waters are of very good parameters, thus the treatment costs are very small. However, currently the entire area of Białystok intake exploits water from quaternary aquifers. The water extracted in this way forces municipal water supply systems to impose large costs on the water treatment process for human consumption. The solution to this problem may be water extraction from deep aquifers, unexploited so far in Białystok [3.4]. On presented geological section of Białystok area [Figure 1] we can see cretaceous deposits at a depth of about 200 m, there are no sections reaching deeper. Based on geological sections of neighboring cities, mainly Grodno, using deep deposits it is possible to state that such aquifers are located in the capital of Podlasie [5].

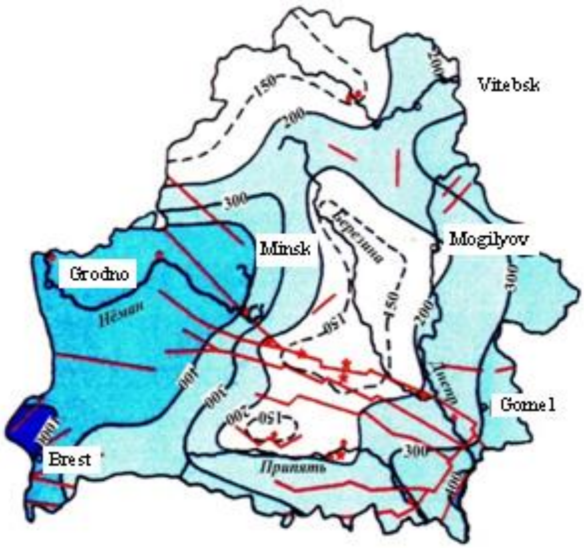

Fig. 2. Maps of deep water depths of Belarus
Source: [5]

Groundwater resources

The greatest impact on existing hydrogeological conditions in the area of Białystok has quaternary aquifers (Pleistocene level), cretaceous level and Oligocene level [6].

The cretaceous level was tested with only one exploratory hole. Three zones of the depth were examined. The most beneficial depth turned out to be a depth of 300 m to 335 m where individual productivity was 1.81 m^3/h m [7].

The Oligocene level is quite varied water-bearing level. Prevalence of drinking water has been found in several research commodities, but only one was extracted. Water flow rate was 1 m^3/h m. Water extraction to supply the city is not significant, taking into account the large spread of layers and small water flow rate [7].

The Pleistocene level was divided in three functional layers:

- near-surface aquifer,
- first deep functional aquifer,
- second deep functional aquifer [7].

Near-surface aquifer is associated with sandy fluvioglacial and glacial sediments of the upper Pleistocene. This layer forms the functional water-bearing level called supraclay level. It is most often open level, supplied directly by infiltrations of atmospheric falls and snowmelt water. The depth of aquifer rarely exceeds 5 m, and thickness is located within the limits of a few to 36 m. Water-bearing level is characterized by high efficiency up to 80 m^3/h. This layer occurs to the east of Białystok and in surroundings of Zaścianki and Grabówka. The rest part of the area, on which such layer occurs, does not affect the exploitation of water, because there is a small thickness and lack of sandy formations, which adversely supports accumulation of larger amounts of water. This water-bearing level is exploited only by individual wells [7,8].

The first deep functional aquifer constitutes the functional water-bearing level, which supplies Białystok in water. This layer is found in fluvioglacial formations of the Middle centre-Polish glaciation, as well as in gravels and river sands interstadial [7,8].

The main aquifer is formed here by sands in some places with gravels and gravel form. Layer extends to practically in the entire area, the thickness varies from 14 m to 20 m, filtration rate ranges from 6 to 32 m/d, while the maximum efficiency of wells is 90 m^3/h. Aquifers located in Supraśl valley cause that it is characterized by very good hydrogeological parameters. Sands forming water-bearing complex in some places have 100 m of thickness. Filtration level is from 17.5 to 60.5 m/d. The efficiency of well may reach up to 70-265 m^3/h [7,8].

The second deep functional aquifer is also called the footwall level. There are found mainly sands and water-glacial gravels of South-Polish glaciation lying on river-lake interglacial sands and sludge of Lesser Poland. This layer does not have continuous spread in the field. The layer is recharged by upper and side aquifer. In terms of hydrogeological account, this layer has secondary functional importance [7,8].

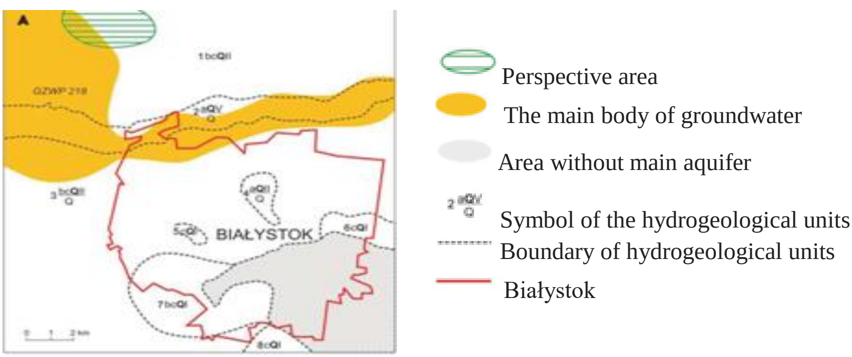

Fig. 3. Map of hydrogeological conditions in the Bialystok region
Source: [3]

Figure 4 is describes the percentage of groundwater abundance in terms water-bearing levels system.

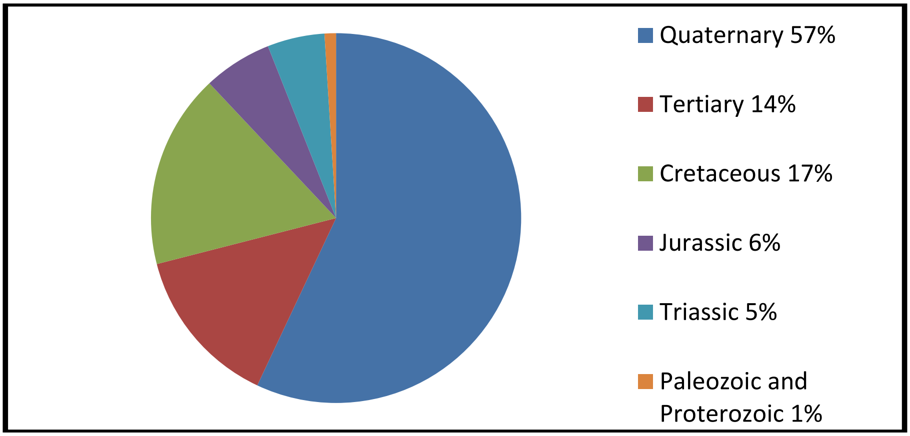

Fig. 4. Groundwater resources in aquifers
Source: [9]

Dominating contribution in disposable resources has quaternary level of 57%. It is conditioned to great availability of waters from this level, because there are the shallowest. Water-bearing levels in cretaceous formations have the meaning role. They are 17 %. However, older formations of Paleozoic and Proterozoic have a minor role [9].

Analysis of Figure 1 "Geological section of Białystok region", Figure 3 "Maps of the depth of deep waters" and Figure 4 "Groundwater abundance in water-bearing levels system" enables to examine the possibility of using deep aquifer beds in Białystok.

In addition, attention should be paid to geological map of Poland without Quaternary and Cenozoic (Figure 5). The blue belt crossing the entire country is ranked among the Jurassic and Lower Cretaceous about 100-200 mln years. This structure is called the Middle-Polish embankment, and on both sides of this embankment are younger upper-cretaceous rocks (on the map green color). Therefore, the entire area of Podlasie lies on the large cretaceous deposits, which enables to consider the possibility of using cretaceous deposits in Białystok.

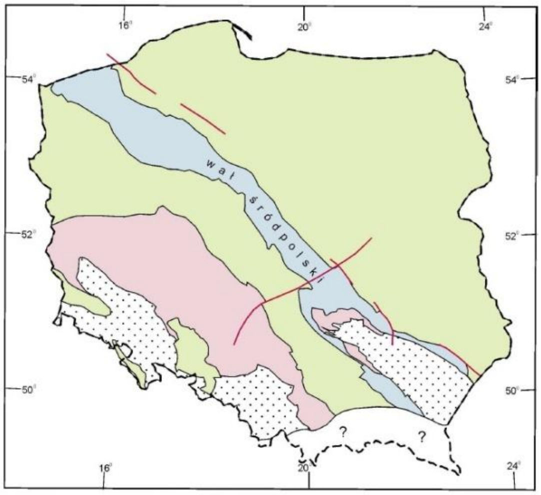

Fig. 5. Geological map of Poland without Cenozoic
Source: [10]

Analysis of deep bed resources of aquifers

Mainly the groundwater resources are divided into four categories:

- static: this level is determined as retention level, determining the content of free water in porous rock formations,
- dynamic: popularly called renewable, most often formed as a result of infiltration of different atmospheric falls,
- exploitation: determine the possible to extract the amount of water depending on prevailing technical, economic and hydrogeological conditions,
- disposable: waters extracted from useful water-bearing levels in hydrogeological conditions [3,4,9].

Evaluation of groundwater reserves provided in the Atlas, although does not specify the disposable resources, has significant importance in view of detailed analysis of the groundwater renewability, in which large contributions had research team from the Institute of Meteorology and Water Management (IMiGW). The research conducted by this team were based on the analysis of 30-years observation, among others in 2000 rain stations, 900 wells and over 200 gauging sections [3,4,9].

Analysis of obtained results enabled to estimate the main indicators characterizing the groundwater renewability: indicator of potential recharge of the phreatic nappes (understood as the total infiltration of fall to aeration zone, decomposing on the effective infiltration and evapotranspiration), which mainly were in a range of

600-400 $m^3/d\cdot km^2$; underground outflow to rivers and renewable resources module of functional levels: deep, i.e. >150 m up to 10 $m^3/d\cdot km^2$ and 50-150 m in a range of 10-50 $m^3/d\cdot km^2$, and shallow, i.e. up to 50 m in a range of 50-200 $m^3/d\cdot km^2$.

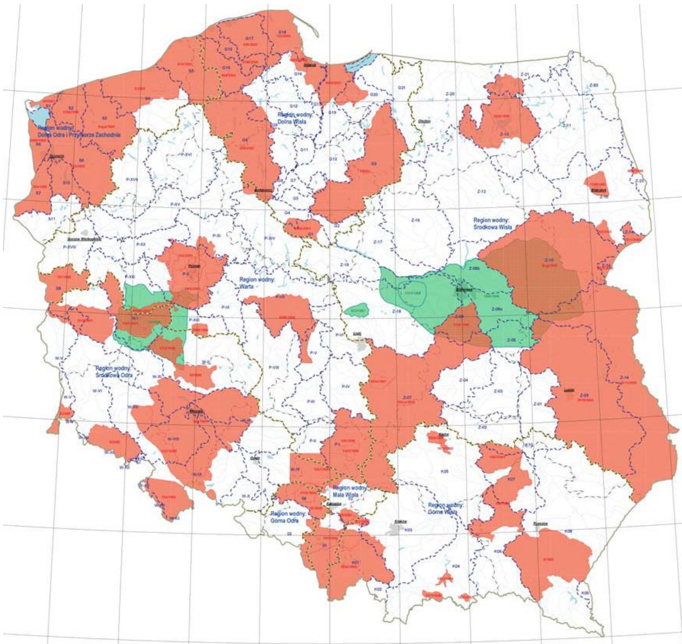

Fig. 6. The extent of areas of disposable groundwater resources
Source: [11]

Disposable resources of groundwater are set for balance area (Figure 6). Red color constitutes the water-bearing system within drainage basin area. While green color indicates deep system, and perspective resources were set in areas outside their range.

Total disposable resources for the entire Pleistocene level are 4029 m3/h, which gives the module of disposable resources on a level of 208.85 $m^3/d\ km^2$. The first deep aquifer has 73.5% of disposable resources, and second 20.4%. Other 6.1% constitute disposable resources of near-surface layer. The vast majority of groundwater intake of Białystok area exploits water from the first deep aquifer. Total water consumption from municipal intakes and individual company intakes in 2003 in Białystok was described in Table 1 [11].

Table 1. Information about ponor waters for Białystok

Surface		102,0 km^2
Population		294 864
Water consumption	municipal	1388,7 m^3/h
	industrial	986,9 m^3/h
Water supply	Capture of surface waters	0,1%
	Intake of groundwater	99, 9%
Reserves of groundwater		96 700 m^3/d
Emergency water supply	minimal	92,1 m^3/h
	necessary	184,3 m^3/h
	optimal	368,6 m^3/h
Problem of the city		1. Recent dry years have resulted in the lowering of the groundwater level of the first useful aquifer. This results in reduced efficiency of infiltration, therefore it is necessary to increase the absorption of surface water from ponds fed with Supraśl River 2. The low state of the Supraśl River during the drought causes a more concentrated load transport, which aggravates water quality. For this reason, surface views on groundwater intakes should be changed

Source: [11]

Extraction possibilities from deep aquifers at Jurowce intake

Grodno confirms the presence of deep aquifers, at a distant of 80 km from Białystok. Grodno uses water exclusively from underground sources in order to secure the water supply. Centralized system of water supply includes three groundwater intakes ("Gozhka" "Donuts" "Chehovschizna"), which support 113 artesian wells. All exploited complexes are protected, because above the water-bearing lever is impervious cretaceous layer, which has 50 – 88 m. Wells in the intake are drilled to the depth on which is aquifer about 250-320 meters. It is presented by geological section of Grodno (Figure 7). This layer is separated from the environment with large cretaceous layer, which constitutes the barrier against interference of pollutants in deep water. Above are clay and sandy layers, which also have aquifers, but they are of much lower quality than those found at a depth of over 300 meters. An example geological section for the city of Białystok shows very similar situation (Figure 8). At a depth of about 200 m below the surface, there are found cretaceous layers, which can hide deep aquifers [5].

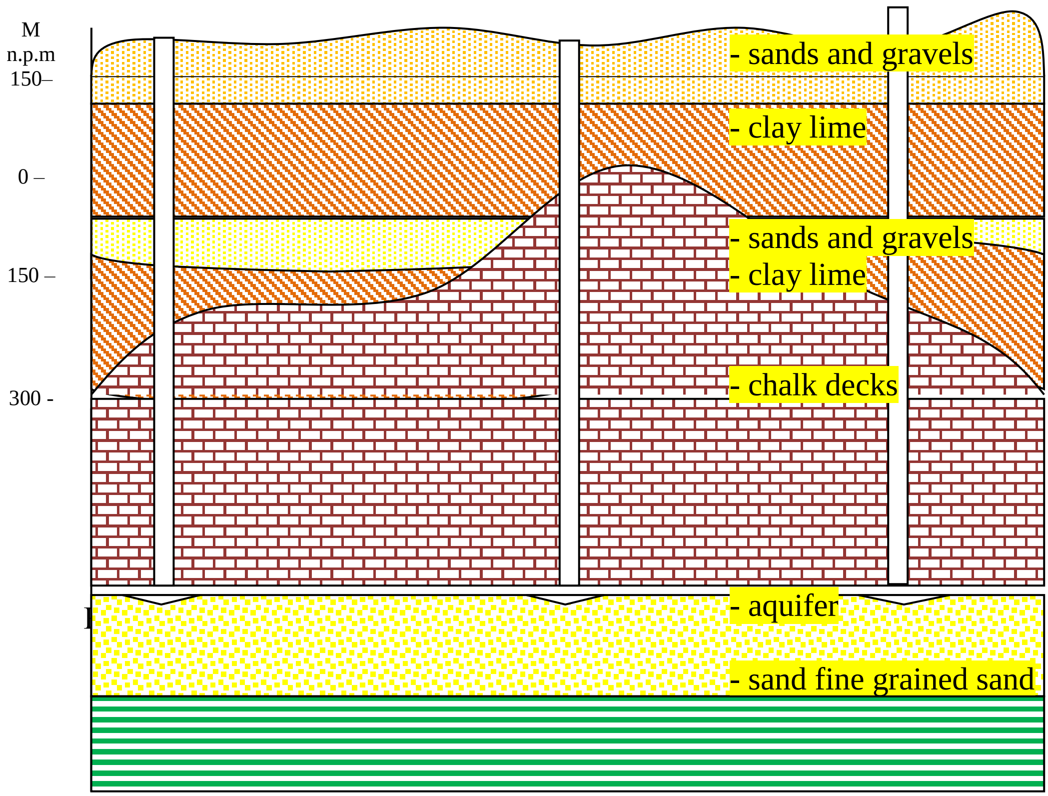

Fig. 7. Geological section of Grodno
Source: Own elaboration based on [5]

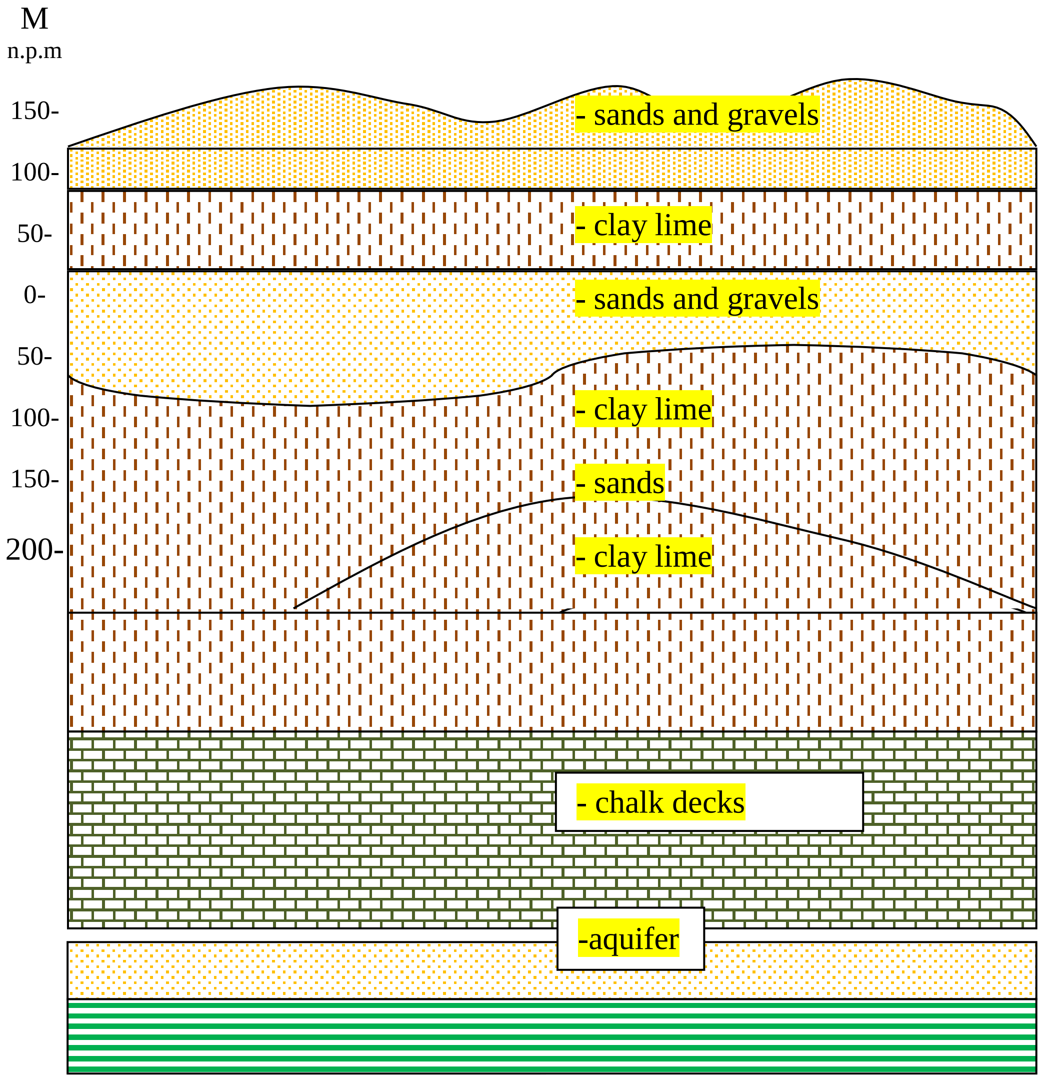

Fig. 8. Geological section of Białystok
Source: Own elaboration based on [3, 4]

Water quality dependent on aquifer

Water extracted in Białystok in all aquifers belongs to simple waters, two-ionic HCO3-Ca. Hard and medium-hard waters of low dry matter content. Stated raised norms of iron and manganese. Previous studies of water samples did not reported exceeded recommendations of heavy metals. Waters in Białystok are exposed to anthropogenic pollutants by the lack of insulation of aquifers. Water quality of the first deep functional layer is quite varied and depends on its area. In the area of plateau, water is characterized by a low mineralization, medium-hard and reaction of 7.2 pH up to 7.8 pH. Color and turbidity may be slightly increased. Sometimes we can observe increased content of ammoniacal nitrogen. Nitrates and nitrites are usually in trace amounts. Chlorides and sulphates are also listed in quantities not-threatening to human health [6].

Table 2. Comparison of water quality parameters

Parameter	Symbol	Unit	Quality of water in Jurowce	Quality standards	Quality of water in Biała Podlaska	Quality of water in "Chehovschizna" Grodno
Turbitidy	-	NTU (mg /L)	<0,20	1	0,19-0,87	<0,58
Color of water	-	mg Pt/L	<5	15	<5	-
Potential of hydrogen	pH	pH	7,4	6,5 - 9,5	7,4-8	7,48
General iron	$Fe^{2+/3+}$	mg/L	2,6	20	**0,040-0,166**	**0,5**
Manganese	Mn^{2+}	mg/L	<1	5	<1	**0,016**
Chlorides	Cl^-	mg/L	7,0	250	-	2,88
Ammonium ion	NH_4^+	mg/L	<0,1	0,5	<0,161-0,19	-
Nitrite	NO_2^-	mg/L	<0,03	0,5	0,0161-0,041	**0,020**
Nitrate	NO_3^-	mg/L	4,4	50	**0,044- 1,65**	3,15
Permanganate	MnO_4^-	mg/L	2,5	5,0	-	-

Source: [6]

Compared with the results of water from Grodno and Biała Podlaska, which extract water from deep aquifers, water in Białystok is lower quality in terms ofnitrate and iron content. These values are smaller due to extraction of water from the aquifer from a deep level, which is very well isolated. Thanks to such reliable nature conservation, e.g. excreta from livestock and pollution from waste management industry are almost impossible to get to aquifers. Extracted drinking water is not polluted with organic substances, pesticides, heavy metals, which can be found in other cities and countries obtaining the drinking water from shallower sources of surface waters (rivers and reservoirs). Artesian water extracted from depths is very good quality, it has very good microbiological and chemical parameters, deprived of nitrites, nitrates, ammonium nitrogen and other pollutants. Chemical composition of drinking water from water-bearing levels in Grodno is presented as follows: bicarbonate of calcium and magnesium from the mineralization of 0.3 - 0.5 g/dm^3, medium-hard, and in some cases of high iron content from 0.5 up to 2.0 mg/l. Iron is removed on stations of removing iron. Stations are intended to remove water from natural iron in simplified aeration method. De-ironing relies on spraying water in the fountain, iron ions combine with the oxygen in the air and precipitate in a form of iron hydroxide, then releases through sand filters [6, 5].

Summary

Białystok water intake is able to produce 100 000 m^3 of water in a day. Technological solutions used in the intake cause that costs of water treatment are high. Extraction of surface, infiltration and deep water is the cause. Deep water wells are extracted from quaternary aquifer, which can be exposed to pollutants and external factors. Surface and infiltration water is even more polluted, thus its treatment cost is high. The solution to this problem may be water extraction from deep aquifers, unexploited so far in Białystok. Geological sections show large cretaceous deposits, which are a natural insulator for these layers. Water extracted from such wells has very good quality parameters, which to a large extent would streamline water treatment for human consumption. Example of such cities as Grodno (Belarus), Biała Podlaska (Poland), or Brześć (Belarus) shows that it is possible to use deep aquifers and supply the entire cities thanks to them. Analysis conducted in the article of water quality extracted in Grodno confirms its very good parameters.

Extraction of water from deep aquifers would streamline the entire water treatment procedure; it would also reduce the operating cost of the entire intake. It should be noted that in the first place it is necessary to start from drilling the exploratory hole, which will confirm the existence of deep aquifers at the intake [13,14,15].

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PHARMACEUTICALS IN A SURFACE WATER

Keywords: pharmaceuticals, environment, surface water

Abstract:

In the paper pollution of surface water by selected pharmaceuticals as well as selected degradation methods of these pollutants are described. Characteristics of selected pharmaceuticals are presented. Wastewater outflows from municipal treatment plants are main sources of pharmaceuticals pollutant in surface water. According to the literature data in surface water in Poland selected pharmaceutics have been detected. The highest concentrations of the medicines were identified in Odra River, in the Kłodnica River and in the Warta River. These pollutants in water environment are often cumulated in sediments. Based on the literature data it can be stated that both biological and physicochemical processes are effective in pharmaceuticals removal. The most effective ones are: advanced oxidation processes, reverse osmosis, nanofiltration and sorption on activated carbon. Effective removal of pharmaceutics is a current problem because the surface water is very popular source of tap water in our country.

Introduction

In recent years the increasing interest of analytics are the residual substances of chemical compounds, also called as emerging contaminants. This group includes the number of chemical compounds - the active compounds of pharmaceutics, compounds of cosmetics' additives used in personal care products, surfactants and other additives, preservatives and bromine and chlorine organics reducing or limiting fire risk of plastics [1-3]. Pharmaceutics contain bioactive chemical compounds affecting natural physiological processes in organisms and because of this they are applied e.g. in the medicine and veterinary medicine. There are over 4000 active compounds and the amount of commercial products reaches 10 000. Taking into account that the bioactive compounds undergo metabolic transformations the contaminating group still increases [4-6]. The municipal wastewater are regarded to be a main source of pharmaceutics and their metabolites. The source of pharmaceutics in the environment applied in the veterinary are chicken farms, where the growth stimulators, antiparasitic agents as well as inhibitors of the growth of non disadvantageous microflora (protozoan) are applied. Then, these compounds cumulate in the manure and they runoff to the surface water. The fates of pharmaceuticals in the environment are presented in Fig. 1.

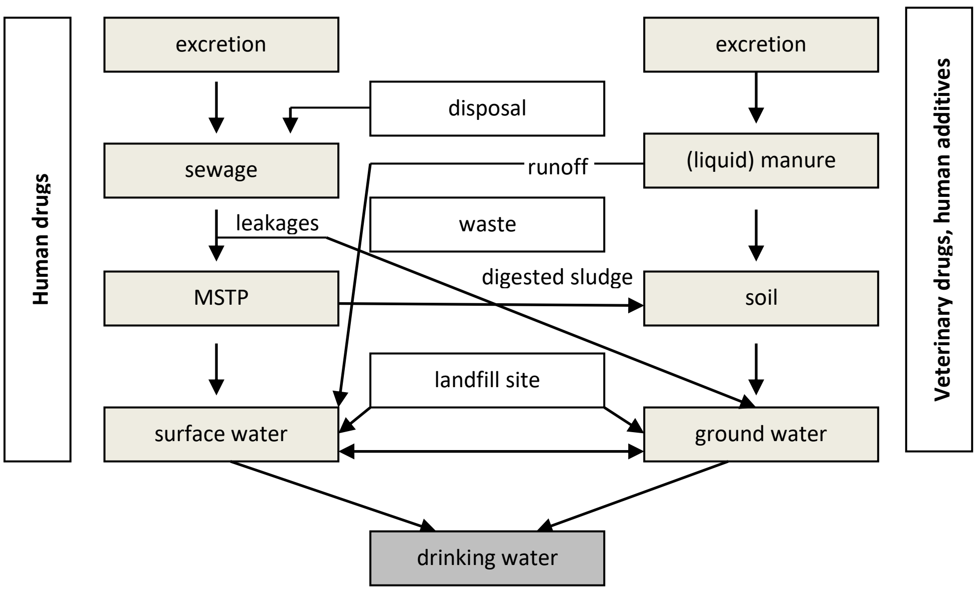

Fig. 1 Fate of the pharmaceuticals in the environment
Source: [7]

Characteristics of selected pharmaceutics

There can be distinguished two main groups of pharmaceutics including steroids and non-steroids. Steroid substances are estrogens, progestrogens, androgens and phytoestrogens. The non-steroidal pharmaceutics are antibiotics, pain killers, β-blockers, fat regulators, antiepileptics and antidepressants [8-10]. Characteristics of selected non-steroidal pharmaceutics are presented in the Tab. 1 and Fig. 2.

Tab. 1. Characteristics of non-steroidal anti-inflammatory drugs – pain killers

Compound	**IUPAC nomenclature**	**Molecular formula**	**Molecular weight**	**Density**	**Melting temperature**	**Boiling point**
			g/mol	g/cm^3	ºC	ºC
Salicylic acid	2-hydroxybenzoic acid	$C_7H_6O_3$	138.121	1.44	158.6	211.0
Ketoprofen	RS-2-(3 benzoilo-phenylo) propanoic acid	$C_{16}H_{14}O_3$	254.28	33.0[1]	94.0	no data
Diclophenac	o-N-(2,6 dichloro-plenylo) aminophenyloacetic acid	$C_{14}H_{11}Cl_2NO_2$	296.15	1.43	157.0	412.0
Ibuprofen	(RS)-2-[4-(2-methyloprophylo)phenylo]propanoic acid	$C_{13}H_{18}O_2$	206.28	21.0[1]	75-78	no data

Source: [10, 11]

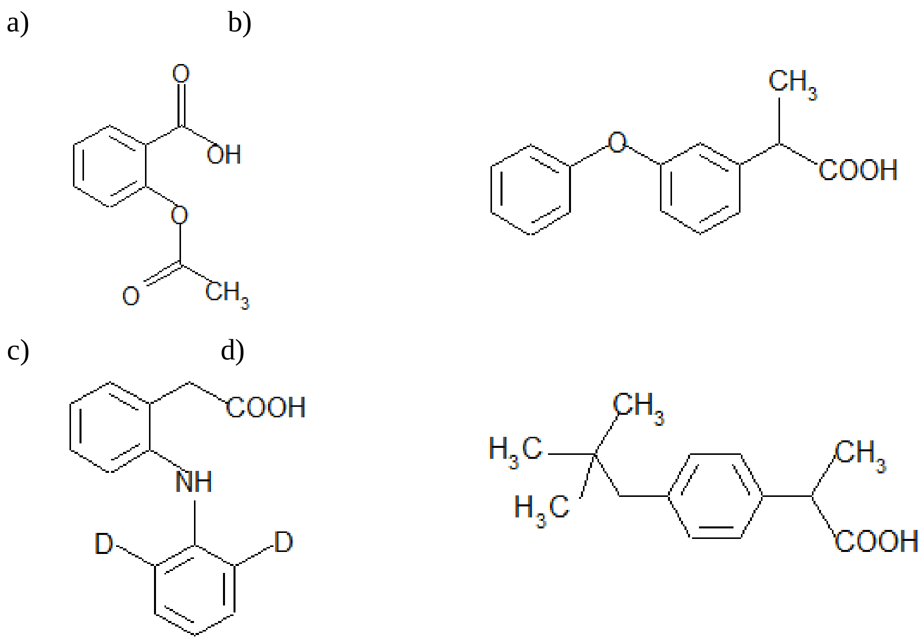

Fig. 2. The Structure of selected pharmaceutics : a) salicylic acid, b) ketoprofen c) diclofenac d) ibuprofen
Source: [11]

The mentioned pharmaceutics vary in toxicity and intensity of their activity. Antibiotics are specimens naturally produced by fungi and bacteria. At present, about 150 antibiotics are used, which have ability to inhibit metabolic processes of various pathogenic microorganisms. The activity of antibiotics is mainly to block the biosynthesis of wall cell and to change the genetic material or blocking of protein synthesis [11 -13]. The medicines regulating lipid management are pharmaceutics applied in order to reduce concentration of triglycerides and cholesterol; they also regulate fat fates. Characteristics of selected antibiotic and lipid regulating drugs are presented in the Tab. 2 and Fig. 3.

Tab. 2. Characteristics of selected antibiotic and lipid regulating drugs

Compound	**Solubility in water**	**Molecular formula**	**Molecular weight**	**Melting tempera-ture**	**Biological half life**
	mg/L		g/mol	ºC	h
Erythromycin-antibiotic	1.44	$C_{37}H_{67}NO_{13}$	733.93	191	0.8-3.0
	IUPAC nomenclature: 3R,4S,5S,6R,7R,9R,11R,12R,13S,14R)-6-{[(2S,3R,4S,6R)-4-(dimethylamino)-3-hydroxy-6-methyloxan-2-yl]oxy}-14-ethyl-7,12,13-trihydroxy-4-{[(2R,4R,5S,6S)- 5-hydroxy-4-methoxy-4,6-dimethyloxan-2-yl]oxy}- 3,5,7,9,11,13-hexamethyl-1-oxacyclotetradecane-2,10-dione				
Bezafibrat-lipid regulating drugs	Insoluble	$C_{19}H_{20}ClNO_4$	361.819	186.0	1-2
	IUPAC nomenclature: 2-(4-{2-[(4-chlorobenzoyl)amino]ethyl}phenoxy)-2-methylpropanoic acid				

Source: [10, 11]

a) b)

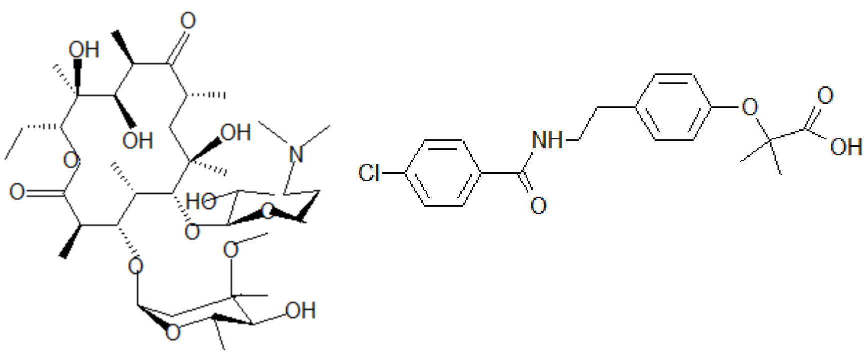

Fig.3 The Structure of selected antibiotics and lipid regulating drug, respectively : a) erythromycin b) bezafibrat
Source: [11]

Chemical properties of selected β-blockers are presented in the Tab. 3.

Tab. 3. Characteristics of selected β-blockers

<table>
<tr><th rowspan="2">Compound</th><th>Solubility in water</th><th rowspan="2">Molecular formula</th><th>Mass weight</th><th>Melting temperature</th><th>Biological half life</th></tr>
<tr><td>mg/L</td><td>g/mol</td><td>ºC</td><td>h</td></tr>
<tr><td rowspan="2">Propranolol</td><td>61.7 mg/L (at 25 °C)</td><td>$C_{16}H_{21}NO_2$</td><td>259.34</td><td>96</td><td>4-5</td></tr>
<tr><td colspan="5">IUPAC nomenclature: (RS)-1-(1-methylethylamino)-3-(1-naphthyloxy)propan-2-ol</td></tr>
<tr><td rowspan="2">Atenolol</td><td>13300 mg/L (at 25 °C)</td><td>$C_{14}H_{22}N_2O_3$</td><td>266,34</td><td>146 - 148</td><td></td></tr>
<tr><td colspan="5">IUPAC nomenclature: 2-[4-[2-hydroxy-3-(propan-2-ylamino)propoxy]phenyl]acetamide</td></tr>
</table>

Source: [10, 11]

In the Fig. 4 the structures of β-blockers (propranolol, metoprolol) are presented.

a) b)

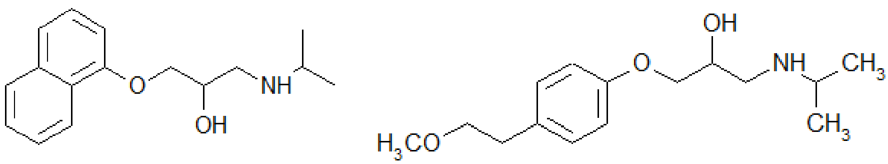

Fig. 4. The structure of β-blockers: a) propranolol, b) metoprolol
Source: [11]

The hormones are applied in order to regulate the internal organs. There can be distinguished natural hormones (progesterone, testosterone, estradiol) and artificial ones, e.g. (ethinyloestradiol) (Fig. 5). β-blockers are pharmaceutics inhibiting sympathetic nervous system. Antidepressants are applied in neurological disorders, they have effect on the mental health and selectively to central nervous system. Pharmaceutics do not undergo the complete decomposition in the organism, thus they are released both in metabolized form and non-metabolized form [10, 11].

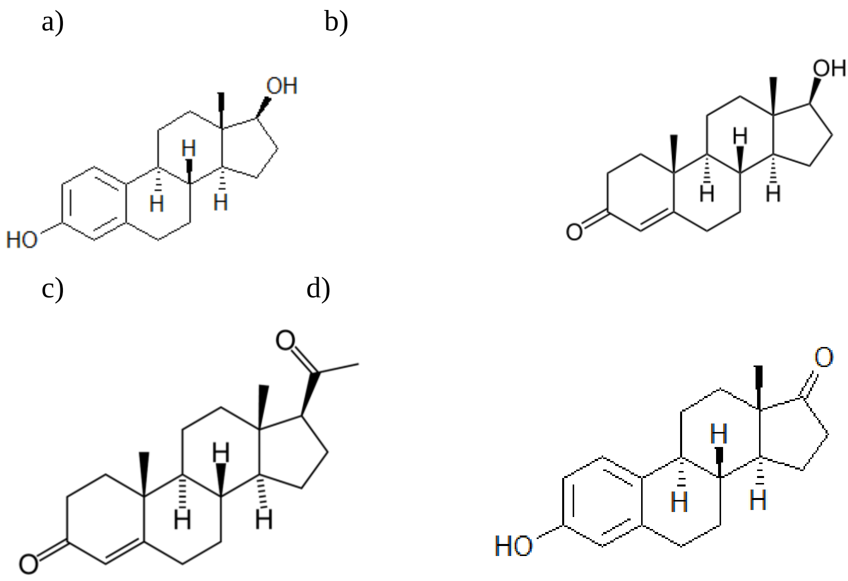

Fig.5. The Structure of selected hormones: a) estradiol b) testosterone c) progestrone d) estrone
Source: [11]

Concentration of pharmaceutics in surface water

The literature sources regarding the presence of pharmaceutics in the environment and their removal are wide [8, 13, 14]. According to these data, in Polish surface water pain killers, β-blockers and antidepressants were detected. The concentration of diclophenac, ibuprofen and paracetamol ranged: 0.5, 0.1 and 0.058 μg/L, respectively [8]. The newest investigations regarding the determination of medicines in surface water in Poland have taken into account the selected non-steroidal pain relievers, β-blockers and corticosteroids. The highest concentration of investigated medicines were determined in Odra River in Wrocław and Kłodnica (in the area of Gliwice). For example, the concentration of aspirin ranged 0.7μg/L, metamizole 0.9 μg/L, whereas in the Kłodnica River the concentration of naproxen exceeded 0.8 μg/L, respectively. In the Warta River (in the neighbourhood of Częstochowa) the following non-steroidal medicines available without prescription were identified: diclopehanac, naproxen and paracetamol [13].

Usually determined hormones include: estrone ($C18H22O2$), 17β-estradion ($C18H24O2$), and 17α-ethinyloestradiol ($C20H24O2$). Dudziak and Luks-Betlej determined the concentration of the afore mentioned estrogens in three location points on Odra, Vistula Rivers and Gliwicki Chanel. In water samples taken from Odra River and Gliwicki Chanel only estrone was detected in the concentration of

1.3 ng/L and 1.1 ng/L, respectively, whereas concentration of estradiol in Vistula River reached 1.3 ng/L [15, 16].

Few times higher concentrations were determined in surface waters in Germany, the Netherlands and Italy. The concentrations of estrone reached 4.1 ng/L, whereas, estradiol and ethinyloestradiol did not exceed 5.5 ng/L and 5.1 ng/L, respectively. The determined low amounts of studied estrogens in waters are probably the result of the sedimentation and accumulation in sediments, as well as the bioaccumulation in fat cells of water organisms. The foreign data indicate that estrone was found in the range of 1.5-33 ng/kg in sediments. The concentrations of the remaining estrogens varied from 0.7 ng/kg to 16 ng/kg [15, 16].

In other European countries the concentration of pain relievers such as: ibuprofen and paracetamol in surface water reached 1μg/L (United Kingdom). The high concentration of antidepressants was found in surface waters in Germany (1.07 μg/L). Among antibiotics sulfametoxazol was determined and it was found in the concentrations from 0.026 to 0.06 μg/L [8].

In table 4 the range of the pharmaceutics concentrations in environmental samples in UK and in other countries of Europe compared to effluent from WWTP are presented [3, 10].

Tab. 4. Pharmaceutics concentration in surface water and in effluent from wastewater treatment plants in the UK and in other European countries

Pharmaceutics	Compound	The range of the pharmaceutics concentration, ng/L		
		Surface water	Maximum in surface water	Effluent from wastewater treatment plant
Non-steroidal drugs	Diclofenac	<0.5-154	568 (18,740 *)	58-599
	Ibuprofen	1-2,370	5,044 (31,323 *)	143-4,239
	Naproxen	1-59	146 (19,609 *)	170-370
	Ketoprofen	1-4	14 (2,710 *)	16-23
B-blockers	Propranolol	<0.5-107	215	93-388
	Atenolol	<1.0-487	560	2,123-2,870
	Metoprolol	<0.5-10	12	41-69
Lipid regulators	Bezafibrate	10-60	90	177-418
	Simvastatin	<0.6		3-5
Antibiotics	Erytromycin	<0.5-159	1,022	109-1,385
	Amoxicillin	<2.5-245	622	31
	Metronidazole	<1.5-12	24	265-373
	Sulfamethozole	<0.5-2	8	10-19

*- pharmaceutics concentration in surface water in other countries of Europe

Source:[3, 10]

Pharmaceutics in surface water are accumulated in sediments and in water organisms. In table 5 the range of the pharmaceutics concentration in sediments are presented [4]. Pharmaceuticals can be also accumulated in living organisms. No detailed data are available, but e.g. diclofenac (carboxylic acid with pKa value similar to other carboxylic acid ibuprofen) bioconcentration factors are 10÷2700 in the liver of fish, and 5÷1000 in the kidney. The values of factors were dependent on exposure concentrations [17].

In surface water pharmaceutics are not completely biodegradable and their transformation is related to the phenomenon of cometabolism and synergy effect. It was stated that in natural water environment abiotic transformations of pharmaceuticals play more important role than biological processes, however the fates of these compounds in surface water are not well known [17]. Abiotic transformation of these compounds in the surface water may be affected by UV radiation, free radicals or temperature. The products of transformation of pharmaceutics identified during UV exposure and during biodegradation are different [3].

Tab. 5. Pharmaceutics concentration in sediments

Pharmaceutics	**Number of analyzed compounds**	**Concentration, µgk/g**	**Pharmaceutics**	**Number of analyzed compounds**	**Concentration µg/kg**
Antbiotics	19	1.2-30.8	Antidepressants	8	0.4-26.1
	14	0.9-1,560	Anti-inflammatory	4	2.0-38.0
Non-steroidal	16	4.85-5,096	Estrogens	7	0.04-22.8

Source:[4]

The efficiency of photodegradation depends on properties of individual compounds, the strength of the solar irradiation and on constituents present in water which act as photosintethisers generating hydroxyl radicals and singlet oxygen (e.g. humic acid, nitrates) [17].

Concentration of pharmaceutics in drinking water

Presence of pharmaceuticals in surface water poses a threat of drinking water pollution. No monitoring programes for routinely testing of these compounds in drinking water are involved worldwide. This is because of high costs [7]. Some data on the concentration range of antibiotics are however available. According to the data presented by Ye and Weinbeg [19] concentration of selected antibiotics in drinking water has been less than 75 ng/L. Also results obtained by other authors indicate that concentrations of antibiotics, anitiepileptics and β-blockers in drinking water do not exceed 100 ng/L [7]. During water treatment removal of pharmaceuticals is expected during disinfection. The pollutants which are efficiently removed during drinking water disinfection by chlorine are e.g. estrone and 17β-estradiol, whereas ketoprofen and naproxen are resistant to oxidation by chlorine ad chlorine dioxide. Ketoprofen and naproxen are however effectively oxidised by ozone [18]. UV irradiation at typical disinfection applications is ineffective in pharmaceuticals removal [18]. Other processes of water treatment such as advanced oxidation processes are effective in pharmaceuticals removal similarly to ozone. Micro- and ultrafiltration processes (membrane processes) are not sufficient in pharmaceuticals removal because the size of pores in membranes are too large to retain these pollutants. Reverse osmosis and nanofiltration are however very effective in removal of pharmaceutics from water [18]. Removal of pharmaceuticals occur also during treatment of water by granular activated carbon [17].

Summary

The residues of pharmaceutics in surface water are important not only for water organisms but they also may be risky for humans, mainly in tap water. The literature data state that the standard processes of water purification do not guarantee the sufficient removal of these compounds. Such processes as advanced oxidation and selected membrane methods (nanofiltration, reverse osmosis) are effective in the removal of these compounds from the water. It is pointed out on the possibility of decomposition of pharmaceutics in the photodegradation process under the environmental conditions [3,14]. Due to the fact that surface waters are often the source of drinking waters, the problem of limitation of the load of these micropollutants in treated wastewater and their obligatory control is actual [4]. At present, the pharmaceutics are omitted in the legislations. There are no permissible concentrations of these compounds neither in drinking water nor in the treated wastewater. Furthmore, they are not included in legislations aiming classification of water and their monitoring [20-21].

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REMOVAL OF ORGANIC MICRO-POLLUTANTS, INCLUDE PAHS FROM EFFLUENTS FROM WASTEWATER TREATMENT PLANT USING MEMBRANE PROCESSES - OVERVIEW

Keywords: PAHs, membrane techniques, organic micropollutants

Abstract:

In this paper will be described the different membrane techniques and possibility of their use in treatment of effluents from wastewater treatment plan of organic micropollutants, including PAHs. Due to the mutagenic and carcinogenic micropollutants and their ability to bio-accumulate in fat tissue of animals and the ability to absorb on the surface of the plant, should seek to best techniques to remove them from the environment. One of the main source of pollution surface water are hitting not polishing sewage from plant to receiver, therefore important is good purifying. Membrane processes are currently many applications both in industry and in protecting the environment. Membrane processes are the best available method, and as demonstrated by research and literature can be successful used alone and in integrated systems.

Introduction

Organic micro-pollutants can be divided on natural and anthropogenic, but because of the chemical structure on inorganic and organic. One of the main sources of pollution of surface water is treatment of effluents from wastewater treatment plant discharged into surface waters. Micro-pollutants can be further divided into primary pollutants that are present in pure water and the secondary formed during purification. The group of micro-pollutants primary include polycyclic aromatic hydrocarbons (PAHs), pesticides, surfactants, ethers, alcohols, glycols, aliphatic and aromatic amines and phenols. This group also often contains toxic components, wherein adverse properties are revealed only after contact with other chemical compounds present in the water. The second group includes, among others organic compounds of chlorine and bromine. Polycyclic Aromatic Hydrocarbons (PAHs) belong to the so-called. persistent orgaic pollutants. PAHs are a health hazard due to toxic effect on DNA. Considering the content of PAHs in surface waters, it should be mentioned that this treated sewage wastewater discharged from the plant are one of their main sources. Moreover, they are hardly biodegradable and easily accumulation. Research conducted, eg. in the municipal treatment plant in eastern China, showed a total concentration of PAHs in treatment of effluents from wastewater treatment plan at the level of 2240 ng / l [2]. In studies conducted in Poland with the use of treatment of effluents from wastewater treatment plant, the total concentration of 16 PAHs was 1,390 ng / l [3]. This shows that PAHs are not removed sufficiently in the technological existing plant. The legal provisions for treated wastewater have not determined limits for PAH, although the recommended monitoring of surface waters [4,5,6].

Characteristics of membrane processes

Currently membranes processes occupy an important place in the industry and have a wide spectrum of applications. The aim of the process of membrane separation is to facilitate the flow of one component of the mixture and stopping the other components of the mixture. This allows a membrane that is permeable barrier for one type of particles of the mixture [7]. European Society of Membrane determines the membrane as a barrier separating the two solutions. The membrane is a barrier and causes selective movement of the components at different rates. It can be molecularly homogeneous that is completely uniform in structure or may be physically or chemically heterogeneous, contain holes or pores, have a layered structure.

The process of membrane separation has many following advantages:

1. Energy efficiency
2. Environment friendly

3. Clean technology (waste-free)
4. Ease the process
5. Greater flexibility in system design.

However, in addition to the advantages in the above technique, there are also disadvantages:

1. Polarization concentration-, which involves formation of the surface layer of the polarizing membrane. It is a thin layer of solution in which the concentration is higher than the concentration of the substance retained in the solution subjected to filtration. Concentration polarization can not be completely eliminated.
2. Fouling
3. Selectivity
4. The membrane life

The right choice of the membrane is conditioned by the rules for its subsequent use, for example, a decrease in water hardness or removing specific gases or chemicals. During the process, distributed components do not undergo biological, chemical and thermal transformations. There are several criteria on which can be divided the membrane. Usually the division based on the structure of the membrane or driving force of process. The driving force of process may be a difference pressure (δp), concentration (δc), temperature (δt) or potential difference occurring on both sides of the membrane. Table 1 summarizes the characteristics of membrane processes [9,10].

Tab. 1. Characteristics of selected membrane techniques

Process	**Driving force of the process**	**Types of membranes**	**Separation mechanism**	**Application**
Mikrofiltration MF	Δp to 5 atm.	Asymmetric porous φ to 10 nm	the effect of sieve	separation of microorganisms
Ultrafiltration UF	Δp 0,5-10 atm.	Asymmetric porous φ to hundreds nm	mainly the effect of sieve	Separation macromolecular compounds
Reverse osmosis RO	Δp 50-100 atm	Asymmetric microporous φ < 1 nm	diffusion	Separation small molecular compounds; desalination
Nanofiltration NF	Δp 10-30 atm	Asymmetric microporous ionic φ <2 nm	diffusion, hydratation, electrostatic interaction	Separation small molecular compounds; desalination

Process	Driving force of the process	Types of membranes	Separation mechanism	Application
Dialysis Hemodialysis D, H	Δc_i	Asymmetric porous	Diffusion	Separation small molecular compounds from macromolekular solutions
Pervaporation	Δc_i	dense, polar, nonpolar	Diffusion	Separation liquid solutions

Source: [10]

Structure of membranes

The membrane is the phase that may have a symmetric or asymmetric structure. The asymmetric membrane is active separating layer of finely porous covering layer microporous substrate or the microporous layer applied to the porous substrate (so-called. composite membranes). In general, regardless of the above classification may also be subdivided into three main structures of the membranes. They are porous membranes, dense and liquid.

In porous membranes driving force of separation is the result of sieve, or the efficiency of the separation depends on the size of the membrane pores. In dense membranes separation of the components is determined by the difference in solubility and diffusion rates. This membranes are used in processes of pervaporation (PV) and the separation of vapors and gases (VP, GS) and low molecular weight compounds. The last group include polymer gels with built-in functional groups. That group work as conveyors interacting with the selected component and forming a complex with it. Then the complex diffuses to the opposite surface of the membrane, where is released to the receiver solution. The membrane may be in the form of a flat film, or a so-called capillary. hollow fiber.

Depending on the construction of the membrane can be retained particles range in size from tenths of microns to a tenths of nm. Microfiltration (MF), ultrafiltration (UF) and dialysis (D) is used to separate the large particles having a size of 50 - 0,5μm and sizes typical for colloidal particles (500 to 1 μm), mainly from the solvent and low molecular compounds. In the processes of reverse osmosis (RO) and nanofiltration (NF) are used w specific types of membranes which are used to separate the components do not differ too much in size. An example of such mixtures may be mixtures of gases and vapors, or low molecular compounds and a solvent (which is usually water). Another membrane process is called. Pervaporation, which is used for separating such. azeotropic mixtures. The table 2 characteristics of separation processes due to the type of removed particles [10, 11].

Tab. 2. Characteristics of separation processes due to the type of removed particles

Separation technique	Microfiltration	Ulrafiltration	Reverse osmosis	Nanofiltration
Separate substances	Emulsions, colloids, bacteria, proteins, viruses, sugars, dyes, H2O	proteins, viruses, sugars, dyes, H2O	sugars, H2O	sugars, dyes, H2O
The size of separated substances	0,1(μm)	0,01(μm)	0,001(μm)	0,0001(μm)

Source: [8]

Removal of organic micro-pollutants

In the process of cleaning the water treatment are used mainly membrane technique due to the pressure difference.

For such processes include:

- microfiltration (MF),
- ultrafiltration (UF),
- nanofiltration (NF),
- reverse osmosis (RO).

Processes ultrafiltration(UF) are used to treat solutions of macromolecules from low molecular compounds, cleaning emulsions and solutions colloidal or pretreatment before referring them for further purification. Nanofiltration (NF) is a process involving both the effect of pressure and diffusion processes or reverse osmosis. It is used to water desalination and removal of organic compounds to an acceptable level. Then it is not necessary to use the expensive reverse osmosis. Reverse osmosis (RO), as the name suggests is a process related to the natural phenomenon of osmosis. Osmosis takes place by natural solution having a higher solute concentration for a solution with lower, which equalizes the concentrations of both solutions. The external pressure-balancing osmotic flow is called the osmotic pressure, and its value is characteristic for the solution.

A reverse osmosis process takes place in a forced diffusion of any component of the chemical solution with a lower concentration into a solution with a higher concentration by a semi-permeable membrane under the influence of an applied hydrostatic pressure exceeding the osmotic pressure. This is the process used for the separation of low molecular compounds such as inorganic salts or low molecular weight organic solvent. The driving force of the process as already mentioned above, the applied pressure, which should be higher than in the case of ultra-and microfiltration. Typically in the range of 1 to 10 MPa. The concentration of particles in a solvent affects the value of pressure to be applied to a reverse osmosis process could proceed properly [10,11,12,13].

Membrane filtration processes are more and more applications in industry and environmental protection, among others, they are used for the treatment of industrial and municipal wastewater and water treatment. Guidelines Research Centre of the European Commission (JRC) published in December 2015 recognize the membrane techniques and semi-permeable membranes for the best of the available methods (BAT - Best Available Technology). The application of membrane processes in technology cleaning the wastewater is possible after diagnosis of mechanisms and factors that determine the efficiency of removal of micro-pollutants [14]. Among the high-pressure membrane processes the reverse osmosis (RO) and nanofiltration (NF) are the most effective techniques for the removal of organic micro-pollutants as demonstrated by research and literature reports. Nanofiltration is a technique of membrane properties intermediate between ultrafiltration and reverse osmosis. The membranes used in this technique are characterized by a high degree of retention of organic compounds having a molecular weight greater than 300 Da.

US Environmental Protection Agency indicates 16 compounds of PAHs, which should be monitored in the environment. These are: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, dibenz (a, h) anthracene and benzo (g, h, i) perylene, and indeno (1,2,3-c, d) pyrene. Due to their adverse effects on living organisms are recognized as one of the most toxic compounds. Because of the high values of partition octanol/water coefficient(Kow) and easily adsordable and migrate between different parts of environment , removal PAH from agueous solution in a large degree , is a problem. Reports in the literature show that there are many methods used to remove for example biodegradation - aerobic and anaerobic processes, chemical and physical methods and combined of above methods. They are often inadequate and do not provide satisfactory results, especially for industrial wastewater treatment. Often during the above processes, waste products are made, whose properties are not fully understood. Taking above facts into consideration it should be look for the most effective techniques of physical and chemical removal of PAHs in order to protect the environment. Based on the available literature, it can be concluded that the most important in the removal of PAH from aqueous solution is nanofiltration (NF) and reverse osmose (RO) and the less- ultrafiltration (UF) and microfiltration (MF). These techniques are used as the unit processes as well as in combination with traditional methods.

Dudziak et al. showed high efficiency in the removal of PAH by means of reverse osmosis, nanofiltration and ultrafiltration and retention factors ranged 70-94%

[15]. The study conducted using two nanofiltration membranes : NF-SF10 and NF-DS5DK. Filtered water contained mixtures of PAH and phthalate standards, whose total concentrations ranged from 55 to 2300 ng/dm3 (PAH) and phthalates 120-1400 μg /dm3. These concentrations were chosen to correspond to little, medium and strongly contaminated water in the examined micro-pollution groups. The presence of xenobiotics in filtered waters was controlled by chromatography. Both nanofiltration membranes effectively removed both PAHs and phthalates from the tested waters. Test compounds were removed at a level close to 90% (PAHs) and nearly 100% for phthalates [16] In other studies, where ultrafiltration was used after filtering PAH degradation rate of an average of 85%, and for each hydrocarbons ranged from 27 - 100%. In the first stage of the research, wastewater was filtrated on the sand bed, after the initial filtration process the wastewater flew to the ultrafiltration module and then was separated on the membrane (type ZW-10). A gas chromatography-mass spectrometry (GC-MS) was used in order to qualify and quantify the PAHs. Conducted studies confirm the high removal efficiency of PAHs in the ultrafiltration process [17]. In studies that examined the effectiveness of nanofiltration Dudziak and others showed greater efficacy nanofiltration than reverse osmosis in removing PAHs from aqueous solutions. The experiments were carried out on Osmonics Inc. membranes. UF-type HP09 SEPA CF and UF-type DSGM SEPA CF and membranes produced in Silesian University of Technology: UF-type PVC1O and UF-type PSF 17. Tested membranes removed efficiently PAHs, THMs and phthalates - the retention coefticients were in the range of 50.0-99.9%. These studies show no relationship between the molar mass xenobiotic and value retention factor.[18]. The study, which evaluated industrial wastewater from the coking plant, process of nanofiltration preceded by coagulation. An integrated system combining coagulation and RO or NF was used in the study. Pre-purified coking wastewater has been characterized. Concentration of ammonium nitrogen,chemical oxygen demand (COD), total organic carbon (TOC), total nitrogen (TN), total carbon (TC), turbidity, temperature and pH and sixteen PAHs. In the research 2 types of membrane were used. One nanofiltration commercial polymer flat membrane (DK) and one reverse osmosis polymer membrane(AG). The pH of the wastewater after coagulation was equal to 5.01. The initial concentration of PAHs in coke wastewater effluents was 94.73 μg/l, whereas in wastewater after coagulation this value decreased to 58.91 μg / L. The total concentrate of Σ16PAH after nanofiltration was 18.69 μg / l, and after reverse osmosis 5.94 μg /l. The mean retention coefficient for RO was 89.9%. The treatment of coking wastewater in the coagulation process allowed to remove 38% 16PAHs, NF-68%. The average retention factor for RO for 16PAH was 90%. Studies have confirmed the possibility of using a membrane process for the treatment of high-PAH effluent.[19]. As mentioned above, the high retention factors PAH provides the use of reverse osmosis. In reaserch Dudziak et al. were tested RO membrane SS10.Test gave coefficient removal of PAH out of

the water at 68% - 88%. In a study conducted by Smol et al in municipal landfill leachate osmotic ADF polyamide membrane was used. In the first stage of testing leachates were filtrated on the sand bed (pre-filtration). After the pre-filtration they were directed to the membrane module for the main filtration Research confirmed the high efficiency of reverse osmosis in the removal of PAHs. Total removal of PAHs in the RO filtration (including filtration on sand bed) was at 81-86% and for individual hydrocarbons was in the range 19-100%.[20] It was noted that the degree of PAH removal of leachate from landfills in the RO affects the molecular weight and the effectiveness of separation increases with the molecular weight of the compounds. For the same type of membrane waste water treatment was carried out. The largest retention factor was 86% for PAH with lowest number of rings. Removal efficiency benzo (g, h, i)perylene was similar to that of benzene(a) pyrene and was 40%. The dependence of the retention coefficient increases with molecular weight, and therefore the number of benzene rings was not confirmed in the aqueous medium [21].

Research shows that membrane techniques check in also in the degradation of pharmaceutically active compounds, surfactants (PhACs), disinfection by-products (UPD) and oxidation, most important of which are trihalomethanes (THMs) and acids haloacetic (HHA), active compounds estrogenic (EDCs) and plant protection agents and pharmaceutically active compounds (PPCPs). Disinfection by-products (UPD) and oxidation are undesirable substances. The most important are trihalomethanes (THMs) and haloacetic acids (HHA). For removal of it is used reverse osmosis and nanofiltration. In this study the efficiency of THM removal by nanofiltration (NF) membranes using NF200 and DS5 increased with increasing pressure [14]. In the case of the pitch and PhACs complete degradation of this depends on the physicochemical properties of individual molecules (size, polarity, dipole moment), the membrane used and the processing conditions (eg. PH). Endocrine active compounds (EDC) are chemical compounds that can interact directly or indirectly on the endocrine system causing a particular effect in the tissues and target organs. EDCs behave similarly to natural and synthetic estrogens, and the body can: mimic endogenous estrogen (produced by the body) [14, 18,22,23]. Phytoestrogens and mykoestogens can be removed in the RO and NF efficiency at 70-93%, and plant protection agents characterized by a low molecular mass, are efficiently removed during the process or process-integrated NF or MF with adsorption on activated carbon. NF process removes the pesticides of more than 190 Da to below detection [22, 23].

Surface-active compounds SPC) is a specific component of anthropogenic pollution. These include detergents, bleaches inhibitors, stabilizers, optical brighteners. Conventional methods such as coagulation, foaming ,sorption, ion exchange, oxidation is very limited because of the heterogeneous structure chemical SPC, which is why the pressure membrane techniques are an alternative method of removing the SPC [14]

Major impact on the efficiency of removal of organic micro-pollutants in the membrane processes are unfavorable phenomena, which are concentration-polarization, blocking membranes (fouling) and precipitation stone membrane (scaling). Fouling is a phenomenon of deposition of substances on the surface of the membrane pores and is a phenomenon characteristic of all of the pressure membrane technology, but especially those involving the use of porous membranes. Fouling can be reversible or irreversible. Reversible, when it is possible to restore the original performance of the membrane as a result of the total removal of the sludge. Sometimes, however, despite the action of mechanical cleaning, and even the chemical it is not possible to restore the initial performance of the membrane, then we are talking about fouling irreversible [23, 24,25]. The efficiency of removal of micro-pollutants from wastewater (retention factor) is affected by the molecular weight of the compound and the limit resolution of the membrane (cut-off), although parameters such as the geometry of the molecule compound, the pore distribution of the membrane, and the hydrophobicity or hydrophilicity should not overlooked in the planning process [14, 25].

Membrane bioreactors

When discussing membrane processes should also mention the integrated systems combining biological methods of the membrane, as exemplified by bioreactors with membranes MF / UF (MBR).There is a division between two basic design of bioreactors. Construction of the submerged membrane module of the bioreactor and the structure where the two elements are separate. The role of the membrane module is to separate the activated sludge retention of macromolecules and enable a longer residence time of the sludge in the reactor, then this form is ideal for the development of specific bacteria capable of removing even hard biodegradable micropollutants like pesticides, hormones and pharmaceuticals. MBR has many advantages such as very high efficiency of phase separation and the possibility of removing organic micro-pollutants (eg. Pharmaceuticals), smaller reactor volume and less excess sludge produced [26]. The effectiveness of the removal process is influenced by the type of material it is made of a membrane. Research has shown that the use of bioreactors allows to receive treated wastewater with very high quality, so that the surface water gets smaller load of pollutants. For PPCP degree of remove is almost 100% [14].

Summary

Results of research described in this paper indicate that membrane techniques are good processes which can achieve high efficiency of removal of organic micro-pollutants. Studies cited here were conducted under different conditions, using various aqueous solutions. The results are promising but unfortunately difficult to compare. It should also be remembered that, in fact, PAHs do not occur singly but in mixtures. A real wastewater contains in addition to mixtures of PAH, other compounds of various impacts.

Important is the recognition of the proprties of molecules of pollutants in order to select the appropriate process and appropriate membranes. Particularly important are the processes of NF and RO, which is obtained by using the degree of removal of PAH from 85.9% to more than 99% regardless of the molecular weight of the compound. Although membrane processes is the best available technology (BAT-Best Available Technology) energy-efficient, environmentally friendly and waste-free during this planning process, we should not forget about the phenomena that hinder their proper conduct such as fouling and scaling

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SAFE MOUNTING OF THE WINDOWS IN THE CURTAIN WALL

Keywords: windows, replacement of windows, the location of windows in the wall, the wall-window connection

Abstract:

The paper presents the most important information about safe mounting of the windows in residential buildings in accordance with obligatory regulations. There is also described the innovative system of installation of the windows in a layer of thermal insulation, that ensures the minimization of heat loss by linear heat bridges. The paper points out the most important studies, of which casing-reveal connections should be subjected to, so that they can obtain Technical Approval.

Introduction

Mounting of the window in the wall seems to be a simply, not very complicated and fast action. But we should remember that the way of window's mounting has a major impact of the energy balance of the whole building, because not only the properties of window affect the value of that balance, but also the wall-window's joint has a big meaning. A couple of factors influence the valid window's placement. First of all, place of mounting of the window in the wall (depending on its construction), needs to be chosen correctly, later insulating and packing materials need to be checked for suitableness, and at last, they need to be used in an appropriate way.

The article presents the technical conditions of the window's mounting with reference to the new guidelines [11]. In addition, there will be described the thermal-insulating system of window's mounting in the thermal insulation layer of the wall in three variants, which is having a great popularity on the building's market and can fulfil the very strict expectations of the window's energy standard. The authors will also indicate the most important research that the casing-reveal connections should carry out, to receive a Technical Approbation and the builder's sign.

The necessary requirements, which must be met before installing the windows

According to the building art, the mounting of the windows should be the next task after finishing the wet works, or before the wet works are done - when the thermal – moisture conditions inside the house are provided. Nonetheless, before the building team can take care of the mounting of the windows, there is a couple of conditions which must be fulfilled.

First and foremost, when the building is new, works should be started with checking dimensions of the window's aperture and comparing them with dimensions in technical documentation of the building [5]. It happens very often that this action prevents spending money for exchanging the windows or changing the dimensions of the window's aperture. It also permits to save the time if workers find imperfections at this point. Next, there should be done the verification of some features, like: the kind of reveal, the verticality and flatness of the walls, state of implementation of reveals, especially their evenness and smoothness[5].

When analyzing the replacement of old windows to new ones in existing buildings, several stages of preparatory work may also be mentioned. First of all, it is necessary to analyze the type of external wall in which the exchanged window is located. It is important to determine whether it is a three-layer wall with insulation in the middle, full or double-layered with insulation layer from the outside. Then you have to check with what reveal we have to deal with, whether it is a variant with the break jamb or without it. The next step is to make the forging in the wall to determine the appropriate dimensioning of the new window. If necessary, needed forging in the masonry should be made, to properly dimension the window's opening. Then the window's hole should be cleaned from the old mortar, plaster, dust and particulates. Once any additional work has been established with the investor (such as replacement of an internal or external window's sill), mounting of the window to the wall can be started [11].

The dismantling of the old windows

Removing old windows from the reveal should occur, when the investor is already in possession of a new window joinery (so that the hole after the dismantled components can be immediately filled up). Work should be organized in a way that the replacement of a single window lasts up to two hours. The method of dismantling the old window depends primarily on how it was previously mounted in the wall. The old methods of the casing-reveal montage consisted mainly of using nails or screws to connect with the wooden pins in the bricks. Then the masking batten, which was plastered on both sides, was fixed. Considering this, getting the entire casing out of the reveal would require the plaster to be forged along the entire circuit of the window from the outside. This solution seems to be extremely labour-intensive, that is why it is easier to get out the old window frame with fragments of the reveal. [4]

The first stage of dismantling the old window is to take off the window sash and pull the outer window sill, when it is still attached to the casing. To properly remove the sash, they have to be gently lifted on the hinges in the open position. However, if there were reworks intended to lower the window's header, then the hinges must be cut, starting from the bottom one [4]. Tilt-and-turn window's sash, which have the so-called position's change lever, are disassembled right after the hinge mechanism and the tilting stop is isolated [4]:

- after opening the window (in casement position) the upper arm of the hinge should be differentiated by putting forward the detent up;
- after closing, position the lever mechanism to the tilt position, then open it again, taking care not to cause it to fall down and in that position set the mechanism up to the previous position (hopper), which will cause the latch, placed at the bottom, to be disconnected;
- the sash can now be removed by lifting it upwards.

After disassembling the window's sash and the masking battens, there should be found spots on the casing, where there are not any combining elements. Then one of its sides should be cut twice at intervals of about 10 centimetres. In the case of buildings insulated with a lightweight wet method, in order not to destroy the façade, only the bottom of the casing is cut. There is also made a cut to the connection of frame-insulation with a knife, so that during the dismantling the plaster will not be destroyed. The cut out piece of the reveal should be removed.

The mounting of the window in the bearing wall

This part of windows installation in the wall should begin with a thorough check in the construction project and in the technical documentation of the object, of how the window should be located in the hole. If we do not know the course of isotherms, windows can be positioned as follows [10]:

- in a three-layer wall with thermal insulation inside - in the zone of the insulation layer (fig. 1a);
- in a double-layer wall with thermal insulation outside the wall - in front of the wall (fig. 1b) or in the face of the wall (fig. 1c);
- in a full wall (monolayer) without thermal insulation - half the thickness of the partition wall (fig. 1d).

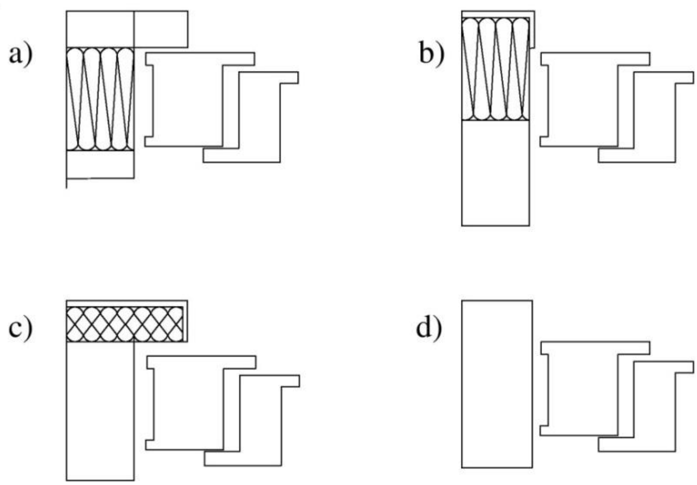

Fig. 1. The site of the reveal's windows: a) three-layer wall with thermal insulation in the central part; b) double-layer wall with thermal insulation in front of the wall's face; c) double-layer wall with thermal insulation in the wall's face; d) monolayer wall without thermal insulation
Source: [5]

It should be noted that in the case of passive or energy-saving buildings with double-layer external walls with insulation from the outside, the window should be partially or fully extended in front of the face of the wall (fig. 1b) [5].

The next one step is the adequate arrangement of the windows in the window's aperture. The bearing and distance blocks are used for that (fig. 2). They are disposed depending on the window's type, its class, amount of sash, dimensions and kind of opening (hopper, till and turn or sliding). These element are mainly used for temperature's and its own weight's non deforming purposes. The bearing blocks are used only in monolayer walls, that is in a case, when the window can't be installed in thermal insulation layer. They are always placed as close as possible to the centre of the base of the windows and mullions, to avoid flexion of the lower profile of the frame. It is important to not remove them after the mounting of the window. The bearing blocks are used to regulate the short-term position of the window during its installation [6]. When they are no longer needed, they should be removed.

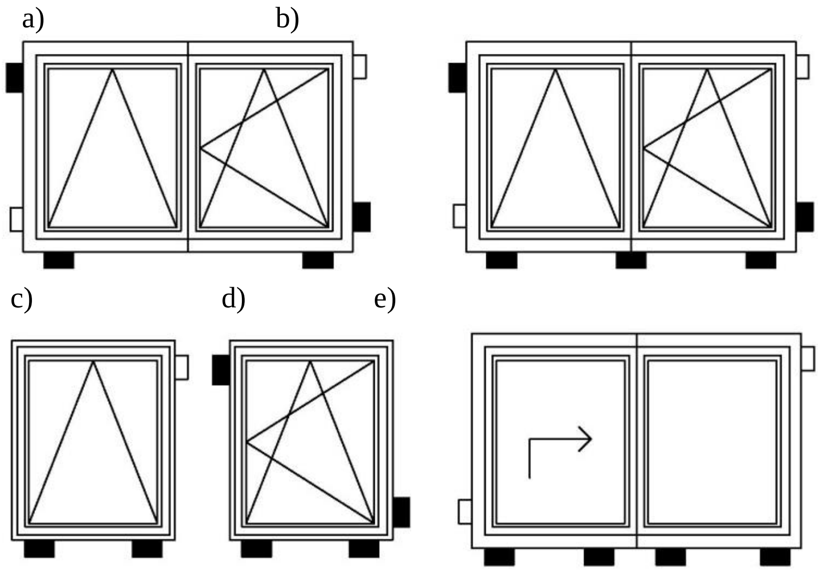

Fig. 2. The arrangement of the distance and support blocks a) double sash window (U+RU); b) double sash window(RU+RU); c) hopper window (U); d) till and turn window (RU); e) sliding window-door; the black ones – bearing block, the white ones – distance blocks.
Source: authors's resources

We should also mention about the ways of mounting of the windows - direct and indirect. The first one occurs when the fastening element extends through the window frame and is anchored in the reveal. If the window is mounted on an aluminum profile, the procedure is carried out by the inner part of the casing. The indirect way of window's mounting consist of using the anchor bolts, which are connected to the wall thanks to dowels (expansion bolts). Anchor bolts, made of the sheet metal, are 1,5 mm thick, and are installed to the frame profile using screws, they are also installed to the reveal using mechanical fasteners [5].

The packing of the connection wall-window

The wall insulation and packing system should be triple-layered [5]. The exterior layer is a packing part of this system. It is made of vapourpermeable materials. The central layer is its thermal and acoustic installation and is made of natural materials and polyurethane foam. The interior layer is (like the first layer) a packing part of system, but is made of vapourproof materials. These information are shown in tab.1.

Tab. 1. The packing and insulation materials used to fulfil the chinks between the casing and the reveal

The place of mounting	The insulation/seal materials
The exterior layer (packing)	vapour-permeable membrane, impregnated resile vapour-permeable band, elastic vapour-permeable membrane, elastic lasting putty, vapour-permeable band, universal vapour-permeable or vapour-proof band
The central layer (thermal insulation)	man-made mineral fibres, polyurethane mono- or poli-component foam, corkboard
The interior layer (packing)	vapour-proof membrane, impregnated resile vapour-proof band, elastic vapour-proof membrane, elastic lasting putty, vapour-proof band, universal vapour-permeable or vapour-proof band

Source: own elaboration

To pack the wall-window's connection we can use: vapour-permeable and vapour-proof membranes, impregnated resile vapour-permeable and vapour-proof bands, elastic lasting putties, universal vapour-permeable or vapour-proof bands, vapour-permeable or vapour-proof bands [1]. The insulation materials used in as a thermal insulation are: man-made mineral fibres, polyurethane mono- or poli-component foam, corkboard. [1]

The window's mounting in the insulation layer

As stated in the European Directive (Directive 2010/31/EU) on the energy specification of buildings, in 2 years' time, so at the beginning of January 2019, all investors will have to adhere to very strict conditions for the construction of passive or almost passive (zero-energy) buildings. Such assumptions make it possible to create new technologies both in the field of production and mounting of the windows, which eliminate linear and point thermal bridges.

Innovative solutions for the warm mounting of windows are widely popular not only in Poland, but also in Western Europe. An increasing number of constructed energy-saving and passive buildings using the Illbruck MOWO system, have prompted the authors to discuss its key assumptions. The basic principle is that the mounting of windows is done in the surface of thermal insulation. In addition, it is based on the glue weld, which is responsible for load handling. There are three variants of this system [2]:

- for the 35mm bay,
- for the case of the 90mm bay,
- for the case of the bay from 120 to 200mm.

The first system can be used when builders have problems with installing the window (mainly with fixing and sealing), when it is only partially extended in the thermal insulation. Then the elements of the analysed system should be used, which is the appropriate installation plate and the expansion tape. The installation plate should be glued in a way that it enables to create the frame needed to embed a window into it. However, it is stipulated that the edge of the window's profile does not protrude beyond the installation plate. The sealing is realized by means of a specialized expansion tape. It is worth mentioning that the formed frame becomes an extension of the reveal. [2]

In the second variant of this system, a system installation profile, insulation profile and expansion tape should be used. As a bearing-frame, a profile with a triangular section and slightly shortened edges is used. The connection with the thermal insulation layer of the building is enhanced by the use of insulating wedges. [2]

And finally the third one, where an "L" shaped frame should be made to create lever conditions (this can be used even in multi-layered constructions). Installation angles, expansion tapes and insulation blocks, which provide proper connections to the wall's elements and high insulation montage, are used here. [2]

This system provides a reduction in linear thermal bridges and allows the investor to assemble and insulate the windows, before the outer layer of thermal insulation is laid. In addition, the system manufacturer declares an air infiltration rate of a<0,1 [m^3/(mhdaPa$^{2/3}$)]. Another advantage is the very high acoustic insulation, which no other manufacturer declares. [2]

Research of the performance of connection made between casing-reveal

In The Technical Conditions, [10] there are described the most important criteria which let us set down the leakproofness of the joints between wall-window, as well as allowing air flow between casing-reveal. The Institute of Building Technology, cooperating with producers of the window's mounting systems, determined criteria and methods of research of primary features the mounting's windows system, based on the heat-insulating joint's tests. Recently, in ITB has issued an approval of this kind of joints. [3]

The research of joint due to its air permeability is carried out in accordance with standard PN-EN 12114 *Thermal properties of buildings. Air permeability of building components and building components. Laboratory test method.* [8] and is about measuring the air flow through the wall-window connection. The evaluation of air permeability is based on the specified air infiltration coefficient in the zone, which is under test (thermal insulation profile) for a pressure difference of 1 hPa. A reliable result is the one that does not exceed 0.3 [m^3 / ($mhdaPa^{2/3}$)]. [10]

Research of the connection due to its leakproofness is carried out on the basis of the assumptions contained in the standard PN-EN 1027 *Windows and doors. Watertightness. Study method* [7]. The estimation of water permeability through the tested connection consists of continuous spraying of the isolated sample with a specified amount of water, which is dependent on the cross-sectional size of the sample with simultaneous action on it with increasing pressure at the same time. The quantity of sprayed water, the pressure applied to the sample and any leakage through the sample is measured. As a result, we get the class of watertightness of the wall-casing connection in accordance with standard PN-EN 12207. *Windows and doors. Air permeability. Classification* [9].

It is also important to mention about the connection study due to its strength, among others, the wind effect. This research consists of applying a pressure in the two directions of winding and sucking with an estimated value of +/- 2hPa and 200 fatigue cycles, which are negative and positive pressure of +/- 1hPa, to the surface of the sample of the connection. Endurance studies are always performed in the last order (if several different studies are planned) as they usually result in over-exploitation or destruction of the sample, which becomes not suitable for further testing. [3]

The mistakes of the mounting of the windows

According to [4], mistakes occurring in mounting of the windows are usually: wrong mounting of the windows, faulty insulating and finishing of conflations. If we want to talk about correct installation of the window in the wall, we must remember about using retention pins of matching type and the appropriate layout of arrangement of the anchor bolts. The finishing of conflation of casing-reveal should be made fast and efficiently to reduce the influence of solar radiation, that affects packing material.

Additionally, very often there can be noticed a lot of inadequacies, like:

- errors in dimensioning,
- lack of correct expansion joints;
- bad condition of the mounting base;
- lack of bearing blocks and windowstill battens;
- inappropriate amount of retention pins and anchor bolts;

- incomplete packing of the joints.

Conclusions

Installation of the window should be the culmination of the construction works, which are leading to the closing of the shell stage of the building and take place after finishing the wet works. This principle applies to all types of windows, both made of wood and PVC or aluminum. However, the most important thing is to provide adequate thermal – moisture conditions in the rooms, so as not to have to deal with moistness in the new profiles.

The location of the window in the outer wall must always be done in accordance with the art and the technical documentation of the building. The recommendations say that in the case where the isothermal powder compartment is not known, a window in the monolayer wall is fixed to the half of the wall thickness, whereas in the double-layer wall - in the face or front face of the wall and in three-layer wall - in its central part, which is the thermal insulation layer.

The innovative systems of mounting of the windows in thermal insulation layer of the curtain wall can eliminate (or minimally deplete) the linear thermal bridges in the point of contact casing-reveal and reduce a permeability of sounds from outside to inside the rooms.

Thanks to the specification of the innovative systems of mounting of the windows, manufacturers have the opportunity to apply for the Technical Approval of their wall-window connection sets at the Institute of Building Technology. Such a document allows the marking of products with a building sign which has not been used on the market so far.

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EXPERIENCE OF DEVELOPMENT OF WATER SUPPLY AND WASTEWATER DISPOSAL PLANS FOR LARGE RUSSIAN CITIES

Keywords: electronic model, water supply, wastewater disposal, model calibration

Abstract:

This paper deals with the construction of an enlarged model of water supply and wastewater disposal systems by the example of large Russian cities having the population of over 500 thousand people. The work tackles the principles of the construction of the model, describing the process of model calibration and the basic approaches to the analysis of the operation of water supply and wastewater disposal systems.

Introduction

Based on the requirements of Russian legislation, municipal local authorities should develop the centralized water supply and wastewater disposal systems in accordance with the water supply and wastewater disposal plans (Federal Law №416, 2011). "MosvokanalNIIproject" institute successfully implemented projects of water supply and wastewater disposal plans for the following cities: Ufa, Irkutsk, Penza, Orenburg and Tyumen.

If the population of a city exceeds 150 thousand, the water supply and wastewater disposal plans for this city should include the electronic (hydraulic) models of these systems (the Resolution of the Government of the Russian Federation N782 of 05.09.3013 “Concerning the Water Supply and Wastewater Disposal Plans”).

In order to develop adequate and full-value electronic model it is necessary to collect a considerable amount of data, including topology and configuration of all existing pipelines, geodetic elevation of the pipe, the flow characteristics of the consumers, the characteristics of pump units and a lot of other data. The complete acquisition of these data may require 4 years or even more. If the relevant «Vodokanal» (a Water Supply and Wastewater Disposal Administration in Russia) has no detailed electronic model within the framework of the development of water supply and wastewater disposal plans, it is usually decided to build its enlarged version. In this case the development of the model is aimed at the evaluation of the main pipelines and the basic pumping stations operation. Subsequently, based on the analysis and testing of the model as well as on the basis of the urban area development plan, the models are built taking on the ground of future development of the systems.

This article describes the experience of “MosvokanalNIIproject” in the development of water and waste disposal plans for large Russian cities based on the scheme for the implementation of electronic models.

The characterization of the city in question

The city in question occupies the area of about 30 thousand hectares, while its population amounts to 520 thousand people. The water supply volume amounts to 218 thousand m^3 per day, 13 percent of which are consumed for the own needs of the enterprise, while 30 percent are water losses.

The specific water consumption rate of local population is 194 l per day per capita.

The city is characterized by a considerable altitude difference. The highest point is located 254 m above the Baltic Sea level while the lowest point is 134 m above the sea level and on an average the city is located 174 m above the sea level.

In this connection, the water supply system of the city is subdivided into 7 areas, which being operated in accordance with a combined “parallel” and “sequential” scheme. The pumping stations of the city are subdivided into the following three categories:

1.Raw water pumping stations (1st stage pumping stations);
2.Drinking water pumping stations (2nd stage pumping stations);
3.Booster pumping stations (3rd stage pumping stations).

The total length of the city water supply network is about 819 km.

Among the main problems of the urban network are the exceeding of the free head maximum permissible values in the vicinity of the pumping stations and insufficient pressure heads in the remote districts of the city. This situation makes it impossible to connect some new districts to the network in the future.

Forming the calculation scheme of the electronic model of a water supply network

"ZuLu" software developed by "Politherm" Ltd was chosen for the implementation of the water supply and wastewater disposal model (PolitermLtdwebsite, 2015).

The construction of a water supply and wastewater disposal electronic model and subsequent relevant hydraulic calculations were aimed at the assessment of the operation of urban main pipelines. At first the realization of the set tusk required the forming of the calculation scheme for the current situation in the water supply network. The main pipelines were taken as a basis of the calculation scheme. In this case the pipelines having the diameters equal to the diameter nominal 300 or exceeding it were termed as a system of mains.

When forming the calculation scheme, it was assumed that the consumption of water in the city takes place from the key water intake points located at the points of the intersection of the main pipelines as well as at the points wherefrom the local industrial enterprises take the water required for their needs.

Based on mentioned above, the calculation scheme for the current situation in the water supply network was developed. It comprised 457 key water intake points, 330.8 km of main pipelines and 7 water pumping stations.

In order to determine the existing condition of the water supply network, the hydraulic calculation was made for the hour of maximum water consumption. The maximum daily water consumption was identified on the basis of the available statistics for the capacity values of the water pumping stations. The hour of maximum water consumption was identified through the detection of the maximum hourly pumping capacity of the second-stage pumping stations for a given day. The inflows/outflows for the reservoirs located in water supply zones were accepted according to the averaged data on water level measurements in reservoirs for the hour of maximum water consumption.

The flow rate distribution by the water supply areas was calculated on the basis of the maximum hourly water consumption, the volumes of the water pumped by the water pumping stations per hour and the territorial balance.

The key water intake points were correlated to the relevant water supply areas.

Concentrated water intake for the needs of industrial enterprises was correlated to the relevant key water intake points of the network, which were identified on the basis of routing and the location of enterprises.

In order to calculate the flow rates in the key water intake points, the total amount of water consumed by biggest consumers was deducted from the total volume of water supplied to the water supply area. The result thus obtained was divided by the total length of pipelines in the calculation scheme thus giving the specific flow rate per 1 meter of the tube.

Since "Zulu Hidro" software has no any function for the calculation of the half-sum of the lengths of pipelined connected to the key water intake points, this problem was solved using the possibilities offered by MS Excel. The developed algorithm using the data bases of the network sections (initial point, final point and pipe length) calculates the half-sum of the lengths of the pipes adjacent to the key water intake point.

Based on the distribution and volume of water taken by concentrated consumers in the key water intake points, the half-sum of adjacent lengths and the specific flow rate per unit length, the flow rates in the key water intake points were obtained. They were included in the "Consumer" database in the "Zulu Hidro" software. Subsequently the flow rates in the key water intake points were corrected taking into account the factual data on water flow rates.

The calibration of the electronic model of water supply networks and the analysis of simulation results

The calibration of the electronic model of a water supply network in the city in question was aimed at maintaining the actual free heads in the key points of a calculation model. With this end in view, the following statistical data and full-scale measurements were used (they were made during the hour of maximum water consumption):

1. Free-head data before the pumping units in a central heat distribution station;
2. Free-head measurements made for fire hydrants at the hour of maximum water consumption.

In case of different results of free-head measurements in the key points of the network, the preference was given to the measurements made for fire hydrants.

The calibration of the hydraulic model was carried out through changing the following hydraulic characteristics of the pipelines in the calculation scheme:

1. Roughness;
2. Pipe fouling.

The average absolute difference between the model (without taking into account any considerable differences) and the actual operation of the network amounted to 16 percent, thus witnessing a sufficiently good level of model calibration.

Considerable differences between the calculation results and the actual head measurements may be explained by the impact of sub-mains operation, which were not taken into account in the water supply calculation scheme.

The analysis of water supply network operation was based on the constructed electronic model of the system. As a result of calculations, some reference points where the free head was not within the permissible range (26 – 60 meters) were identified.

The calculation also resulted in the detection of the distribution of the velocities of water movement in the network and the approval of the existing zoning of the system.

Water supply system behavior was also stress-tested on the basis of breakdown and fire situations.

The analysis of the water supply network operation has made it possible to determine the measures required for the improvement of water supply and distribution networks. These measures include the following:

1. Installation of pressure control valves and rehabilitation of main pipelines;
2. Re-layingofexistingwatermainsand construction of new ones aimed at providing new urban districts with water;
3. Construction of additional pumping stations to provide the planned new districts with water;
4. Construction of additional clear water reservoirs.

Some electronic models of the future development of the network have also been constructed (10-year intervals). They are based on the electronic model of the existing situation and comprise the measures identified as a result of the network operation analysis. The calculated load in these models was increased as some new future areas have been included in the scheme and the water consumption rate of industrial enterprises has been increased.

Forming the electronic models for a wastewater disposal system

The electronic model of the existing situation of the wastewater disposal network was based on the same principles used for the construction of the electronic model of the water supply network. The main sewers of the city were used as the basis for the calculation scheme. The model was based on the flow characteristics of wastewater pumping stations including the complete load of local population connected at the moment to the wastewater disposal networks of the city as well as the load exerted by industrial enterprises. The electronic model of the wastewater disposal system of the city in question takes into account 705 key points, 170 km of gravity-flow sewers, 70 km of pressure sewers and the existing wastewater pumping stations.

In order to determine the existing condition of the sewerage network, the calculation was made for the hour of maximum wastewater inflow. With this end in view, based on the available statistical data, the day of maximum average daily flow rate of wastewater was identified. The nominal hour was identified through determining the maximum sum of hourly deliveries made by the wastewater pumping stations for a given day.

The calculation points, formed as a result of this model building, were correlated to relevant wastewater pumping stations.

The distribution of flow rates by the calculation points of the network was made taking into account the results of studies and on the basis of available operating data.

The analysis of the existing condition of the sewerage system revealed the absence of second pressure-flow sewers of wastewater pumping stations and the availability of some sections of gravity-flow system having the exceeding filling value.

Based on the results of the analysis they made the following list of measures required for the improved operation of the sewerage system.

These measures comprise the following:

1. The rehabilitation of the existing gravity-flow sewers and the construction of new ones required for servicing the population of the existing and planned districts.
2. The construction of additional wastewater pumping stations.
3. The construction of second pressure-flow sewers for the existing wastewater pumping stations in order to improve the reliability of the system.

In a similar way to the water supply system, the electronic models for the future development of the sewerage system were constructed, the time interval was 10 years. These models comprise all measures detected as a result of the analysis.

Conclusions

Summing up the results, we may conclude that regardless the type of the system in question (should it be a water supply system or a wastewater disposal system) the construction of models comprises the following stages:

1. The construction of calculation scheme,
2. The determination of the flow-rate characteristic of the model,
3. Making the preliminary calculations for the system,
4. The calibration of the model,
5. The analysis of modeling results and the proposal of measures aimed at improving the operation of the existing system,

6. The analysis of the future development of the city and the proposal of measures for the connection of planned districts in the future,
7. Building the model of the future development of the system.

The volume of initial data required for the construction of the model, directly depends on the goals of modeling and has an impact on the accuracy of this modeling. The following initial data is sufficient for the construction of an enlarged water supply model of the city in question:

1. The topographic data on the main pipelines and facilities of the network.

By this we mean the lay-out of the main pipelines, their diameters, lengths and the geodetic marks for pipeline beginning and end. This point also comprises the indication of the locations of main pumping stations, reservoirs, switching chambers, etc.

2. The data concerning the equipment of the main facilities of the network.

This data must comprise the number and the characteristics of the main equipment of the facilities. For example, for reservoirs these should be its specifications, while pumping stations require the indication of the number of pumping units and their models and brands.

3. The statistical data on the operation of the system and other types of initial data.

This data includes the following:

- hourly data on flowrates for all main facilities of the system;
- free heads for pumping stations;
- water levels in reservoirs and free heads in the network observed in the city.

A very important condition: the statistical information concerning the operation of the network must be given for the selected calculation hour for the subsequent formation of the electronic model.

The other types of initial data include any available statistical information concerning the operation of pressure control valves, the measurements of flow rates and pressure heads in the system, some information about closed or partially closed valves, failed pipelines, etc.

The aforementioned principles and the required initial data are sufficient for the construction of an electronic model of the system in question and for the making of hydraulic calculations of acceptable accuracy.

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CONSTRUCTION, PROPERTIES, APPLICATIONS AND PERSPECTIVES OF THE DEVELOPMENT OF SANDWICH PANELS USED IN CIVIL ENGINEERING

Keywords: sandwich panel, SIP, composite

Abstract:

The paper presents issues related to sandwich panels used in construction of buildings. It discusses their construction and characteristics. It presents perspectives and directions for the development of sandwich panels.

Introduction

One of the source of inspiration for engineering applications is an observation of surrounding natural environment. For many complex structures, nature is often an incentive for finding the right solution. Sandwich structures in technique that are used as constructional elements, can be also found in nature - in the construction of bird feather, in cereal stem, in load-bearing systems of many living organisms - bones.

The greatest advantage of discussed constructions is their high stiffness and strength at relatively low weight. In addition, as a rule, sandwich constructions have good thermal insulating, acoustic, vibroisolating parameters and others related to the construction and physical parameters of the filling layer.

This review is intended to present the construction, properties and the way of applications of sandwich panels used in construction. The advisability of application is being considered, the subject matter of sustainable development and the benefits of using three-layer resulting from the thermo insulating properties of partitions is being raised. The prospects and development directions for layered construction systems are verified.

Construction

Sandwich structures are an integral part consisting of three layers. Two thin outer layers called faces are connected to the third thicker layer between them, called the core or filler. As a result of the bonding of the individual layers together, hard structure which carries considerable loads is being obtained.

The way of core formation and the method of its connection to faces are important for the strength and stability of the face, especially the local stability. Three-layer structures are defines as quasi-optimal constructions in which every element (layer) naturally contributes to achieving the best properties of the entire structure in given conditions. This is related to the ability to choice of material with the appropriate parameters for a given sandwich. In this way, a mutually complementary system is obtained using its strengths (parameters) in a maximum manner.

Faces

Layers of faces mainly fulfil load-bearing function. The face must have the ability to transfer tensions that affect it. In addition, faces fulfill other secondary roles, i.e. they protect the core, provide of waterproof, damproof, dustproof protection and other. Depending on them, the type of material from which the face is to be made is assorted. They can be steel, aluminum faces, wood-based panels (plywood, OSB panels, MFP), concrete slabs (Einea et al., 1991; Haffke, 2016), cement boards (e.g. MgO magnesium plates (LS TECH-HOMES SA, 2012)) and others. Of course, application of other faces on both sides of the panel are not excluded.

Core

The basic function of the core is to ensure spacing between faces, their stabilization and transfer of tensions from shear forces. Secondary roles, obtained through the use of appropriate structure or material, may include thermal and acoustic insulation, space for conduits. The core is mostly made of lightweight plastic or other lightweight structures of various materials. It can be in the form of a block with complete filling, e.g. PUR polyurethane foam, PIR polyisocyanurate foam, EPS expanded polystyrene (EPS), extruded polystyrene XPS, mineral wool, wood wool, metal foam. It can also be in the form of a complex construction, e.g. ribs rigidly connected to load-bearing layers (web core), truss core, corrugated cored, honeycomb core, spatial trusses (lattice core) or other structures. Examples are shown in Figure 1 below.

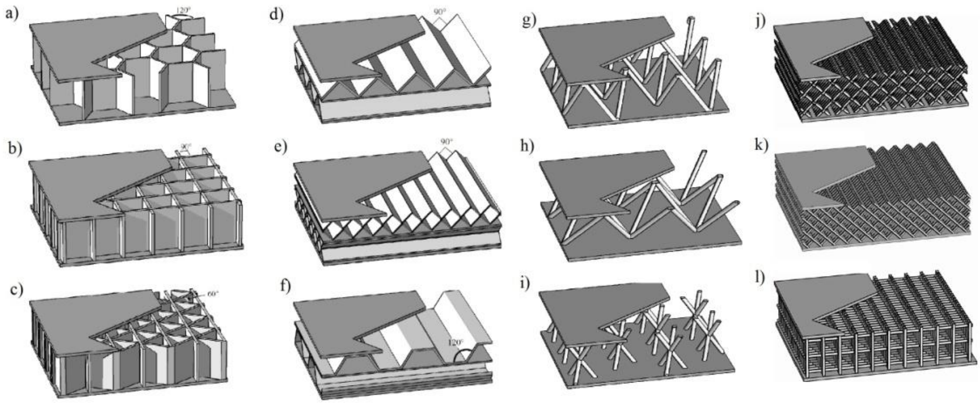

Fig. 1. Examples of structural cores; a) hexagonal honeycomb, b) square honeycomb, c) triangular honeycomb, d) triangular corrugation, e) diamond topology, f) steeper web truss corrugation with a flat top, g) tetrahedral lattice, h) pyramidal lattice, i) three-dimensional Kagome lattice, j) diamond textile, k) diamond collinear lattice, l) square collinear lattice
Source: [45]

In order to optimize the sandwich construction and its core, models are developed in which the density of the core material is varied according to its position relative to the neutral axis. In this way, multi-layered constructions, or with the core called gradient - figure 2. are created. On the static analysis of such systems it can be read, among others in the work (Marcinowski and Wasylkowski, 2006). Gradient cores are characterized by a smooth change in properties on the thickness of the element, which depends on the density of the material. This treatment reduces the disadvantages of three-layer construction by the presence of strong concentrations of tensions at the contact of materials with significant differences in material parameters, which can initiate cracks and delamination of layers. A collection of almost 300 works on gradient materials and their application in layered construction was collected by Birman and Byrd (2014).

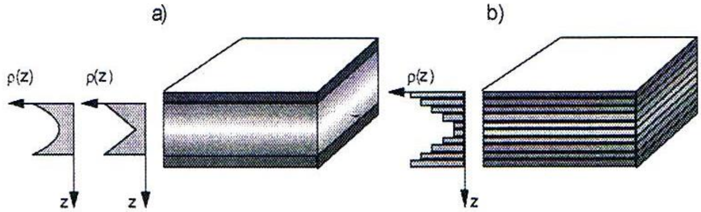

Fig. 2. Examples of gradient and multilayer core Constructions, a) three-layer construction with gradient core, b) multi-layered construction with differentation of layer density
Source: [50]

Differentiation of core density or type of material at length is also possible. Research conducted on such structures is presented, among others. in works (Lyckegoard et al., 2005; Jakobsen et al., 2007). In the first of these papers, the results of studies on panels show that in the support zone a different core material (Figure 3) is used, which increases the load capacity for delaminating the layers of the structure at the support, further strengthening the cutting zone and crushing. In contrast, in the second case, the application of element closing the edge of panel with improved strength parameters is discussed. The function of the so-called peel stopper shown in figure 4 is a protection against faces and the core delaminating at the edge of the panel.

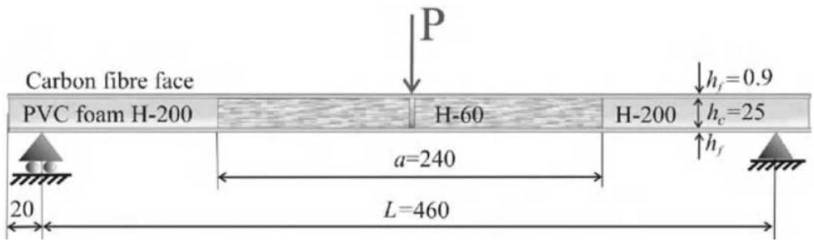

Fig. 3. Balk with a variable material in length
Source: [49]

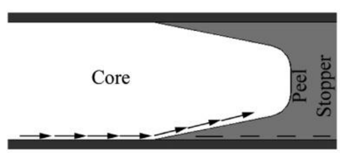

Fig. 4. The panel edge ended with a material of higher density
Source: [46]

Fixing layers

The method of fixing individual layers depends on the materials that are used. As a rule, by using metal sheet faces and wood – based panels and full core made of insulating material, bonding is done by using glue or own adhesion of bulking material (PIR / PUR foam). Less often, in the case of metal-filled structures, insulation layers and fill is connected by welding and soldering.

Panels with polyurethane and polyisocyanurate foam core are mainly produced on continuous production lines, where foam is distributed on one, sometimes on two faces. The foam growth and connection of faces lasts several seconds and then a three-layer panel is ready to use. Polystyrene cores are attached to faces by polyurethane adhesives, as are mineral wool cores. For trapezoidal surfaces of faces, the core is milled.

Connections

The type of applied connections depends on the material used on faces. It is possible to distinguish connections on slip tongues, lumber spline, or locks (figure 5, 6). Slip tongues and lumber spline are usually used for panels with wood-based panels faces, OSB, MFP, MDF and other particle board panels. The same applies to cement panels or brittle composite materials such as MgO magnesium panel. An additional foreign connecting element may be in the form of a wooden, steel or composite profile (eg polyester-glass composites made by pultrusion) or similarly like bonded panels, have a layered structure. Faces with additional connecting elements are fixed by means of steel pins, such as screw, staple, nail.

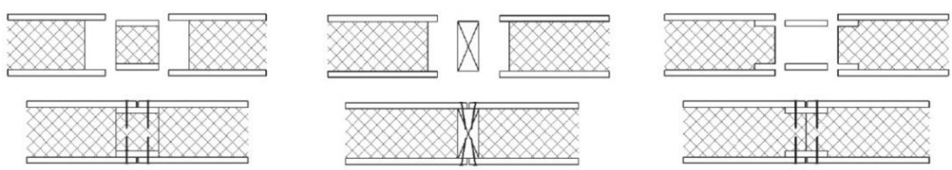

Fig. 5. Details of connection of layered wall panels with breakable faces, by using different joining methods; from the left: the block spline, lumber spline, slip tongues
Source: own elaboration

About locks it is said at the junction of a rather complex shape that is obtained by proper profiling of the sheets at the edge of panels (Figure 6). The role of the lock is to achieve the best possible contact between panels, allowing for mutual transmission of forces, and to ensure contact tightness and continuity of thermal insulation. Connectors between panels are sealed by using suitable impregnated gaskets, silicone sealants, in situ injection molded polyurethane foam and others. The plates themselves, while using as shells, are attached to the support structure by means of pin connectors – by self-drilling screws or rivets. It is possible sometimes to meet contact and corner strips and calotens - elements increasing the clamping surface of the connector.

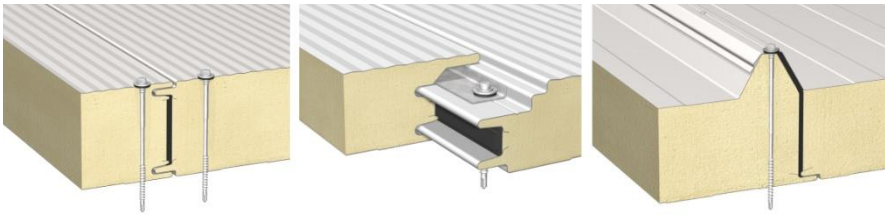

Fig. 6. Methods of joining two panels at the junction with the lock; from the left: visible lock of wall panel; hidden lock of wall panel; roof panel lock
Source: [36]

Characteristics

Sandwich panels are characterized by a number of properties in favor of their use:

- low own weight;
- high stiffness;
- high durability;
- high resistance to fatigue loads
- longer life span compared with ribs structures due to lack of stress-tension zones;
- aesthetics - the ability to use facade face exposed to the external environment, with a wide range of shapes (profiling) and color (the type of covering and its color);
- easy to adjust geometry even with complex shapes;
- short assembly time;
- elimination of wet works enabling the implementation in periods of negative temperatures;
- good thermal insulation, vibroinsulation and other parameters related to the construction and physical characteristics of the filling layer;
- versatility of the system allowing the use of different materials, adapted to the current needs;
- large absorption capacity for dynamic energy;
- the possibility of obtaining a non-flammable, waterproof, non-corrosive construction;

- possibility of installation in filler layer;
- lower cost of partitioning compared to traditional methods;
- energy efficiency in production, application and dismantling;
- reduction of CO2 emission in the process of realization of objects.
- Problems, defects associated with the layered construction:
- susceptibility of construction to buckling due to applied thin-walled faces and imperfections;
- complex mathematical model describing the phenomenon of loss of general and local stability (buckling and wrinkling), resulting in the need to simplify and analyze their impact on the accuracy of the solution;
- necessity to adhere to high quality performance regimes due to the need to limit imperfections;
- embarrassing and difficult technology of implementation when using structural filler (eg honeycomb cores);
- low resistance to point loads;
- construction sensitivity to changes and temperature gradients, due to the possibility of delamination and wrinkling of the faces;
- occurrence of creep phenomenon with prolonged loads of construction with soft plastic core.

Application

Due to their advantages, three-layer structures are very practical. It is used in many fields, including construction of machines, aircrafts, space shuttle, boats, cars, trains (French TGV, Italian Pendolino), tanks.

In the civil engineering sector, sandwich panels are commonly used in the industry buildings. Panels with steal faces to cover the roofs and curtain walling of industrial halls, production buildings and warehouses are often found here. Sandwich panels are very good at realization of refrigeration buildings. Other buildings in which layered panels are used are public buildings such as office buildings, health care buildings, sports and entertainment halls, stations, ports, airports, swimming pools, shopping and service facilities, cinemas, garage and business facilities, petrol stations, building facilities, kiosks, livestock buildings and others.

Layered constructions have also received high recognition in the military construction. High mobility, buoyancy and ease of assembly associated with low mass, and at the same time high resistance to static and dynamic load from explosion (Palla, 2008) and missiles, influenced their use. At the explosive load, more preferred structural systems of the core, eg honeycomb shaped, are noted (Karagiozova et al., 2009; Dharmasen, 2008).

In industrial, service civil engineering and other as mentioned above, sandwich panels used as vertical baffles are primarily self-supporting structures with steel faces, carrying loads only from their own weight and from pressures induced by wind. Such structures are curtain walling, fixed to the main structure of the building. A slightly more responsible task fulfil sandwich panels used as roof construction elements where they are more exerted, but still they are not the main load-bearing structure.

Using of sandwich panels as load-bearing structures for building construction is quite well known and used in the United States, Canada and Japan. This technology is defined as the Structural Insulated Panel (SIP). Buildings with SIP technology have achieved recognition for their very good reaction to difficult environmental influences (McIntosh, 2008), such as the earthquakes in Japan or Northridge California, Andrew hurricanes, Iniki in the southeastern United States, or record-breaking snowfall in the Cascade and Rocky Mountains.

In Poland, SIP technology is used in a negligible level, and these are rather individual cases of single-family houses. The difficulty in developing, using layered structures as load-bearing elements of buildings in Poland is the lack of technical and legal conditions determining and regulating the way of designing, executing, approving or issuing declarations of performance. Existing European guidelines for the technical approval of layered structures ETAG 016 (EOTA, 2003a, 2003b, 2005, 2004) concern only self-supporting structures. Ruling European standards do not allow to determine the panel strength in any other way than through experimental studies (Gourmandie, 2014). In addition, SIP-type constructions probably will not have a special demand in Poland for a long time due to the unfavorable mentality and beliefs of Polish in view of new, lightweight technology of houses construction.

Perspectives and directions of development

Vinson (2005) predicts the continuing development of sandwich structures, their continuing application in devices constructions and space vehicles, aircrafts and boats. He says that the greatest using will be in bridge construction. In addition, due to the growing demand for alternative energy sources, the development of wind power plants can also be a driving force for the development of sandwich structures, where sandwich structures are used for turbine blades construction.

The dilemmas of freedom of design and the product flexibility as well as the degree of prefabricates sophistication and its repeatability will inevitably arise in shaping of construction elements. Nevertheless, their application will require meeting certain standards concerning the performance quality and safety. Decisive role can also play a fast and cheap process of production and distribution of sandwich panels.

The technical development of the sandwich panels will be aimed at improving their properties, extending the scope of application and gaining new features.

Improvement of the properties consists mainly in striving to maximize the load capacity and rigidity of the structure, together with minimizing its mass. Improvement in thermal insulation, acoustic properties, heat energy accumulation, light transmission and other properties expected in the case in question must be improved. According to Pozorski (2014), methods of reliable design of sandwich panels should be much better developed. However, the current solutions are not optimal in terms of bearing capacity. Improving the geometry of roofing panels by properly profiling of faces can increase the permissible loads by several dozen percent (Pozorski, 2014). A great field for the improvement of mechanical parameters is also the work on improvement of the core, namely the differentiation of its density and mechanical properties depending on the position in terms of length and thickness. Another method of improving the load capacity of thermally stressed structures by about 35% can be achieved through appropriate shaping of supports molds (Pozorski, 2014; Studziński et al., 2013). It is based on the use of flexible supports and supports with slots. This method is currently rarely used in the optimization of layered construction. To a large extent, moreover, it is expected to improve the method of fixing the plates to the support structure and their interconnection. Unfortunately, studies in Poland related to this subject are quite modest.

An exemplary extension of the scope of application and new features of sandwich panels is their using as bracing elements, stabilizing other structural components and utilizing them as the main components of the load-bearing building structure. In Poland, manufacturers of layered load-bearing panels for the construction of walls (SIP), complement the wall with bar elements, performing the load-bearing function of the building. In such a system, in static calculations, sandwich panel acts as a support where it could play a major structural role. The reason for this is the lack of standardization and guidelines for the use of this type of construction in Poland. As a consequence, the amount of used material is unnecessarily increased and the building's thermal properties getting worse.

In addition to the common features of the sandwich panels, such as cover function, structural (load-bearing) function, thermal or acoustic insulation, sandwich panels may have other less known or innovative features. Sandwich panels can be used to illuminate the room, in case of using transparent materials, absorption functions of sunlight, consistent with the current tendency to search for environmental solutions.

Summary

Selected aspects related to sandwich panels are discussed in this work. The work was mainly focus on properties and possible applications of layered construction systems in civil engineering. It has been noted that very high potential of sandwich panels is used to a small extent, namely in the narrow range of possible applications, mainly as faces of building. This is largely due to deficiencies in standardization and guidelines for the use of layered construction systems as load-bearing systems. These, in turn, result from a limited knowledge of the issue, lack of certainty in their application and the obtained parameters. Experimental results often differ from those predicted by theoretical methods, due to the high impact of imperfections on the load carrying capacity of the structure, especially in case of application of thin faces.

Application of sandwich panels as load-bearing construction elements is not very popular in Europe. In the aspect of sustainable development, where there is a constantly striving for energy savings in the realization of objects and their usage, layered constructions show considerable advantage over current traditional solutions. Consequently, their subject matter should be more and more broadly discussed, and the knowledge necessary for the practical using and implementation of the products is constantly widened. It is also planned an increased using of layered constructions in the industry of renewable energy sources for the construction of turbine blades and for the construction of bridge structures.

Versatility and versatility of applications is achieved through favorable parameters, largely determined by the properties of applied materials. Formulating continuously new materials gives a chance of significantly improvement of panels properties and adapt them to specific requirements.

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PURIFICATION OF DOMESTIC WASTEWATER IN CLOSED WATER SYSTEMS IN AGRIBUSINESS BIOFILTERS FLOATING LOADING

Keywords: suspended sediment, water filtration, dirt-holding capacity

Abstract:

The method of purification of domestic wastewater on the installation of lighting-contact two-stage filters to enable them discharge into the water fishery purposes.

Introduction

According to [19] the application, there are two types of water:

- drinking water reservoirs and cultural and community purpose;
- industrial fishing pond.

For each of these reservoirs into account the maximum permissible concentration (MPC) of pollutants, the maximum concentration of the substances in which not deteriorate the organoleptic properties of water and industrial organisms (fish, crabs, clams) and are not allowed toxic substances (Table. 1). The State Sanitary Surveillance from the perspectives of its use carries out referring reservoir to a particular type of water.

Supervision of the conditions of discharge of treated wastewater into water bodies exercising sanitary and epidemiological stations and pool inspections.

As required by regulation [19, 20] for treated household wastewater regulations are established MPC pollutants (mg/dm^3):

- biochemical oxygen demand (BOD_{povn}) - not more than 15;
- chemical oxygen demand (COD) - not more than 80;
- suspended solids - not more than 15.

Tab. 1. The requirements for water quality of water bodies in predetermined alignment water

Types of water	**Categories water**	**Maximum permissible concentration (MPC), mg/dm^3**		
		BOD_{povn}	**The increase in suspended solids, $C_{s.s}$**	**Dissolved oxygen, O_2**
Sanitary: - water supply; - cultural and community	 I II	 3 6	 0,25 0,75	 4 4
Fishery: - restoration and conservation of fish species; - other fisheries management objectives	I II	3 3	0,25 0,75	6 6 (in summer) 4 (in winter)

Source: [19, 20]

Insufficient degree of biological wastewater treatment limits the possible use of technical water for industry and irrigation of crops.

Today, the traditional treatment for domestic wastewater is two-stage treatment includes mechanical and biological treatment plants. Increased demands on the environment and create conditions for the use of treated wastewater in agriculture and industry require the need for new technological scheme of deep purification of biologically treated wastewater.

Biochemical purification methods based on the use of microorganisms that oxidizing organic substances present in wastewater in the form of fine suspensions or colloids in solution.

Biochemical methods can almost completely remove organic impurities remaining in the wastewater after machining and significantly reduce the content of harmful microorganisms.

In agricultural systems, construction of sewer, which is biochemical purification, divided into two groups:

I - structures operating in natural or close to these conditions (irrigation fields, fields of filtration, biological ponds) where wastewater treated slowly through the supply of oxygen in soil and water;

II - buildings where wastewater treatment occurs in artificial conditions (biofilters, aerotanks) much more intense due to artificially maintain vital functions necessary microorganisms.

According to conventional technology treatment of domestic sewage, the technological scheme includes construction mechanical treatment and biological treatment and physical and chemical refining (Fig. 1).

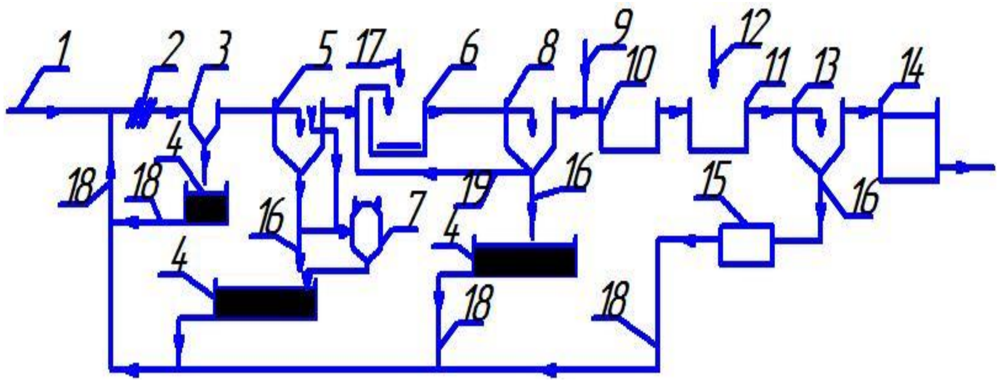

Fig. 1. The general technological scheme of treatment of domestic wastewater
Source: own
1-initial supply of waste water; 2-lattice; 3-removal of sand; 4-sludge pad; 5-primary settling tank; 6-biofilter or aerotanks; 7-digesters; 8-secondary clarifier; 9-supply of chlorine;
10-contact tank; 11-capacity for coagulation; 12-supply reagents; 13-tank; 14-sand filter;
15-thickener sludge; 16-discharge of sludge; 17-air supply; 18-removal pooled water;
19-removal of excess activated sludge in the aeration tanks.

Removal of coarse impurities from the treated water is in lattices 4 removal of sand 3 and 5. Due to the sump by gravity, precipitate particles that are heavier than water. The sludge is periodically pumped into 7 for fermentation or produce the sludge pad 4.

Biological water treatment occurs in biological facilities (biofilters or aeration), where special bacteria-destructors consume organic matter from water and air 17 cleaned it. Biomass aquatic organisms, increasing during water treatment, separated in 8 secondary clarifier and sludge dumped on the ground 4.

After biological treatment water treated with sodium hypochlorite 9 in contact tanks 10 within 20-30 minutes. To ensure reliable purification of water using its processing capacity in the coagulant 12, 11, 13 settling and filtering through sand 14. The resulting precipitate thickened in centrifuges, filters or vacuum filters 15 and dumped in landfills.

The disadvantage of the technological scheme of treatment of domestic wastewater is low efficiency of cleaning waste liquid in buildings, the complexity of the works, their large size and cost.

Material and methods

To improve technology treatment of domestic sewage in local agricultural systems, sewage proposed to replace processes in settling water ponds on its upward through the floating filter. Filtering boot and replace heavy load in biofilters for more effective download from nylon fibers.

The problem is solved by the introduction of technological scheme of waste liquid contact and lighting filters (CPF) 1-st and 2-nd degree with floating the filter load and biofilter (BF) of fiber loading, which provides increased speed of movement of water in plants, increase efficiency of processes remove impurities from the water and reduce the cost of these facilities.

For the purification of wastewater from agricultural enterprises, possible flowsheet in the application of two-stage CF filtered water (Fig. 2). Dissolved oxygen carried out by spraying it into the aerator 2 and through the air supply pipeline 4 through the air system 5. Oxidation of organic substances carried out by aerobic microorganisms that accumulate in the active sludge in the filter space 9 under CPP. Filtering Floating load 10 held by the CPP removal of sludge and wastewater helps clarify when it upward filtration. Purified water is collected upper drainage distribution systems 11 and removed from the CPF CPF-1, 2, and of CPF-2 through line 15 for further use.

Quick filters carry purified water, served through line 14 and withdrawn through the pipeline 25.

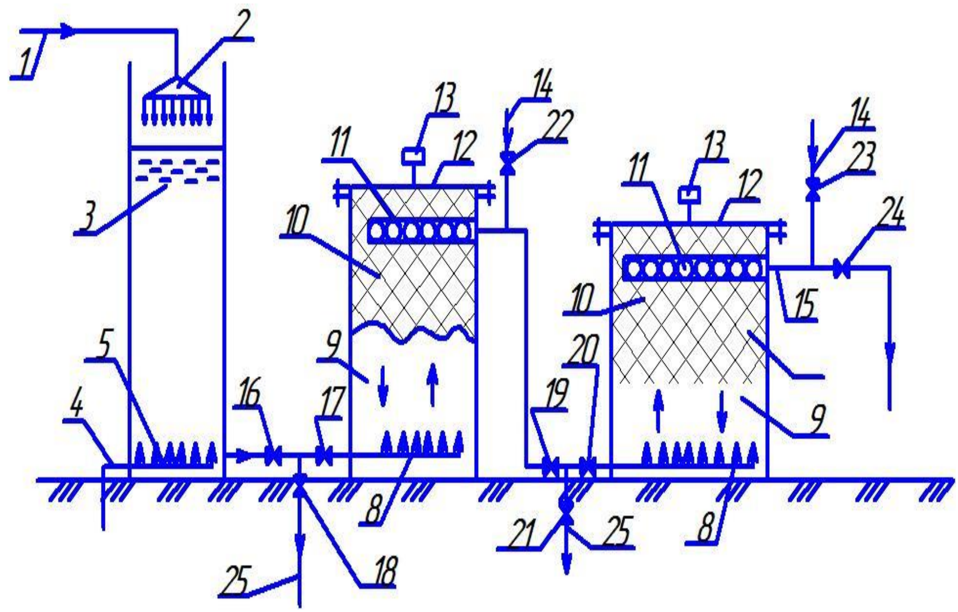

Fig. 2. Technological scheme biological wastewater treatment to two-stage filter

Source: own elaborated

1 - feed source water; 2 - aerator; 3 - clear the air; 4 - duct; 5 - air system; 6 - CPF 1st degree; 7 - CPF 2nd degree; 8 - lower distribution system; 9 - space under the filter; 10 – Filter with floating loading; 11 - upper drainage and distribution system; 12 - coverage; 13 - air valves; 14 - water supply to the washing CPF; 15 - removal of purified water; 16-24 - valves; 25 - wash water drainage.

Results and discussion

Table 2 shows the results of studies of specific changes dirt-holding capacity CPF and efficiency of T_f detention and speed water filtration.

An important characteristic is the specific filters dirt-holding capacity, is the amount of activated sludge, which falls on the cross-sectional area of 1m^2 CPF depends on the water filtration rate, filter cycle duration and the content of suspended solids in the raw water. It determined by the formula:

$$G_j = 0,024V_{f.j}\int_0^{T_{f.j}} C_{o.i}E_i dt \ [\frac{kg}{m^2}] \quad (1)$$

where:

$V_{f.j}$, $T_{f.j}$ – the water filtration rate, m/h, respectively, and the filter cycle duration, days, for a given cycle of measurements of the water filtration process;

$C_{o.i}$ – content of pollutants in the initial water, mg/dm^3, at a given time during the filter cycle;

E_i – water purification efficiency, determined by the formula:

$$E_i = \frac{C_{o.i} - C_{f.i}}{C_{o.i}} \tag{2}$$

where:

$C_{o.i}$, $C_{f.}$ – the hovering substances (HS) content, respectively, to the initial water and the filtrate, mg/dm^3.

Tab. 2. Results of studies depending G = f (TF Vf) and E = f (Tf, Vf) in apprehending CL in CF with two-stage filters

Tf, day	**Vf = 1 m/h**		**Vf = 3 m/h**		**Vf = 6 m/h**	
	G, kg/m^2	*E*, %	*G*, kg/m^2	*E*, %	*G*, kg/m^2	*E*, %
1	1,76	91,9	5,28	84,9	10,75	79,0
2	3,62	92,1	6,03	85,1	21,21	79,5
3	5,72	92,2	6,76	85,2	31,39	79,8
4	7,75	92,3	6,16	85,5	41,77	80,0
5	9,67	92,4	5,97	85,8	52,10	81,6
6	11,61	92,6	5,58	86,0	61,66	81,7
7	13,63	93,0	5,41	85,9	71,65	82,0
8	15,54	93,6	5,17	86,0	82,22	81,9
9	17,42	93,6	5,31	86,0	93,0	81,0
10	19,51	93,7	5,59	86,0	-	-
11	21,52	93,7	5,74	85,5	-	-
12	23,48	93,9	5,57	84,8	-	-
13	25,76	93,9	6,07	84,2	-	-
14	27,90	94,0	-	-	-	-
15	30,00	94,0	-	-	-	-
16	31,86	94,0	-	-	-	-
17	34,0	94,0	-	-	-	-
18	36,08	94,0	-	-	-	-
19	38,27	93,8	-	-	-	-
20	40,43	93,7	-	-	-	-
21	42,46	93,5	-	-	-	-
22	44,41	93,0	-	-	-	-

Source: own elaborated

The data in Table. 2 shows that over loop filtering water efficiency first increases to a point and then begins to decrease.

The main factor in the change of water efficiency is the value of specific dirt-holding capacity G at a given speed filtering water, there is a relationship:

$$E_{i.j} = f(G_{i.j};\ V_f) \tag{3}$$

Table. 3 shows the results of studies dependence E = f (T_F; Vf) and G = f (Tf; Vf) in wastewater from impurities that cause BOD_5.

Tab. 3. Results calculated values E and G during loop filtering for BSK_5 in CF with two-stage filters

Tf, day	**Vf = 1 m/h**		**Vf = 3 m/h**		**Vf = 6 m/h**	
	E, %	*G*, kg/m^2	*E*, %	*G*, kg/m^2	*E*, %	*G*, kg/m^2
1	87	1,66	79	4,57	75	9,64
2	88,1	3,36	79,7	9,69	75	19,01
3	88,9	5,22	79,9	15,44	75,5	28,25
4	90,2	7,06	81	20,90	76	37,92
5	90,3	8,83	82,6	26,25	77,2	47,07
6	91,5	10,67	83	31,30	78	55,90
7	92,5	12,57	83,3	36,24	78	64,91
8	92,6	14,39	83,6	41,02	77,9	74,37
9	92,8	16,19	83,6	45,86	77,2	84,10
10	92,9	18,16	83,1	50,93	-	-
11	92,9	20,09	82,5	56,18	-	-
12	93	21,95	81,7	61,33	-	-
13	92,9	23,97	81	66,63	-	-
14	93	25,95	-	-	-	-
15	93	27,85	-	-	-	-
16	93	29,65	-	-	-	-
17	92,6	31,61	-	-	-	-
18	93	33,53	-	-	-	-
19	92,5	35,65	-	-	-	-
20	92,1	37,67	-	-	-	-
21	91,6	39,48	-	-	-	-
22	91,1	41,27	-	-	-	-

Source: own elaborated

Fig. 4 shows graphs of dependencies efficiency wastewater treatment of organic matter, causing BSK_5 at different speeds rising to two-stage filtration filter with floating load.

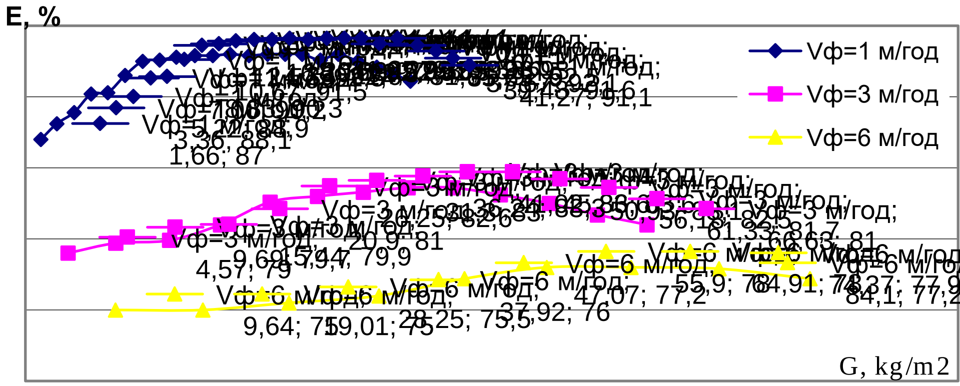

Fig. 4. Graph of E = f (G; Vf) BSK5 for water filtration at a rate of 1-Vf.1=1 m/h; 2-Vf.2=3 km/h; 3-Vf.3=6 m/h

Source: own elaborated

The estimated efficiency of sewage treatment to ensure regulatory quality indices of purified water CN depends on quality of initial water Co.

Need wastewater treatment efficiency increases with source water pollution Co (by BOD_{povn}). At the same figures as Co to 100 mg/dm^3 value EII almost 1,5 times smaller.

The duration of the filtration cycle BF within which the normative indicators of the quality of purified water provided for the corresponding speed of its filtration determined by the formula:

$$T_f = 100(G_{max} - G_{min})/C_o E_m V_f, \ [h] \qquad (6)$$

where:

$\mathbf{G_{max}}$, $\mathbf{G_{min}}$ – respectively, the maximum and minimum specific rate of occupancy of BF, kg/m^2 to ensure the normative quality indices of purified water C_n at a given filtration rate V_f and estimated initial water quality C for BOD and HS;

$\mathbf{E_m}$ – the average efficiency of water purification during the filter cycle, in fractions of a unit.

Conclusions

The use of closed water systems for agricultural enterprises provides an opportunity to conserve physical energy and water while minimizing the intake of fresh water from natural water sources and protecting the environment from pollution by sewage.

Wastewater from agricultural enterprises are not toxic and have a lot of organic matter, and therefore after treatment the treated water biological methods should be used for technical purposes and irrigation, and the precipitate formed - as fertilizer for feed crops.

Technological scheme of closed water systems depend on the type of natural water sources and extent of contamination after use in agricultural enterprises. They include facilities for natural purification and waste water supply, drainage and reuse water.

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