FACULTY OF CIVIL
AND ENVIRONMENTAL ENGINEERING
BIAŁYSTOK UNIVERSITY OF
TECHNOLOGY

POLISH ASSOCIATION
OF SANITARY ENGINEERS
AND TECHNICIANS

SERIES OF MONOGRAPHS

„ENVIRONMENTAL ENGINEERING – THROUGH A YOUNG EYE”

VOLUME 18

WATER MANAGEMENT AND PROTECTION

Edited by
Iwona Skoczko
Janina Piekutin
Łukasz Malinowski

Białystok 2015

FACULTY OF CIVIL
AND ENVIRONMENTAL ENGINEERING
BIAŁYSTOK UNIVERSITY OF
TECHNOLOGY

POLISH ASSOCIATION
OF SANITARY ENGINEERS
AND TECHNICIANS

SERIES OF MONOGRAPHS

VOLUME 18

WATER MANAGEMENT AND PROTECTION

SERIES OF MONOGRAPHS

VOLUME 18

Patronat
Rektora Politechniki Białostockiej
prof. dr hab. inż. Lecha Dzienisa

Wydział Budownictwa
i Inżynierii Środowiska
Politechniki Białostockiej

Honorowy Patronat
Prezydenta
Miasta Białegostoku

We would like to thank to our patronage for help
in organization of this event
and this publication.

Sponsors:

Patronage:

ENVIRONMENTAL ENGINEERING – THROUGH A YOUNG EYE

VOLUME 18

WATER MANAGEMENT AND PROTECTION

Edited by
Iwona Skoczko
Janina Piekutin
Łukasz Malinowski

Oficyna Wydawnicza Politechniki Białostockiej
Białystok 2015

Volume editor:

Iwona Skoczko
Janina Piekutin
Łukasz Malinowski

Editorial team:

Iwona Skoczko – Editor-in-chef
Janina Piekutin – Editor-in-chef
Łukasz Malinowski – Monograph composition

Reviewers of monograph:

dr hab. inż. Iwona Skoczko
dr n. tech. Joanna Szczykowska

All works published in the monograph are reviewed

ISBN – 978-83-62582-73-0

Oficyna Wydawnicza Politechniki Białostockiej

Oficyna Wydawnicza Politechniki Białostockiej
Ul. Wiejska 45C, 15-351 Białystok
Tel.: 85 746 91 37 fax: 85 746 90 12
e-mail: oficyna.wydawcznicza@pb.edu.pl
www.pb.edu.pl

TABLE OF CONTENTS

B. Eng. Artem Komarov[1], Assoc. Prof. Olena Zoria, PhD candidate
Kiev National University of Construction and Architecture
31 Povitroflotsky Pr., 03680, Kiev, Ukraine
e-mail: [1]komarow13@gmail.com

Research of separation process of sewage sludge with nickel release

Key words: *wastewater treatment, research, methods, sediment, nickel content, nickel release, extraction, technological processes of electroless nickel plating*

Abstract: In this article viewed methods of nickel ions removal from wastewater treatment at the Ukrainian industrial plants and presented research. Described effects of nickel exposure on the human organism; the main sources of environmental pollution by nickel; the conventional methods of nickel ions removal from wastewater treatment, their conception, advantages and disadvantages. Described tested in the research process methods of nickel release from wastewater at factories producing sanitary equipment. Considered dependence of percentage of nickel release from the sediment on the amount of ammonia water. Recommendations are given on the use of certain methods depending on features of production processes and, in particular, with electroless nickel plating equipment for rail transport.

1. Introduction

Nickel (Ni) is a toxic metal. Although Ni is omnipresent and is vital for the function of many organisms, concentrations in some areas from both anthropogenic release and naturally varying levels may be toxic to living organisms. According to literature data, in the case of nickel accumulation in the body affects the gastrointestinal tract, kidneys, lungs and may be the reason of gastrointestinal disorders, renal stress, chronic sinusitis/bronchitis and also reduced lung function (decreased pulmonary residual capacity, increased respiratory frequency). Both chronic and acute poisoning by nickel and its compounds may cause death. Threshold limit value of nickel in wastewater is 0,10 mg/dm^3.

At the same time nickel has a significant value in industrial wastewater, and its release and reuse in production may provide significant economic benefits. Besides, reusing treated wastewater drastically decrease costs for water consumption and wastewater. In connection with this, the most rational solution to this environmental and economic problem is creation of closed cycle water consumption on galvanic factories without release of wastewater into the pond.

Nickel and nickel compounds have many industrial and commercial uses, and the progress of industrialization has led to increased emission of pollutants into ecosystems. The main sources of environmental pollution by nickel are: the mining industry, non-ferrous metallurgy, machine construction, metalworking, chemical, equipment enterprises and other, which use various nickel compounds in technological processes; thermal power plants, which operate on mazut (fuel oil) and coal; road transport etc.

Existing physical and chemical purification methods do not always provide the required degree of release of heavy metal ions, and also require significant investments, therefore conducted active search for new effective and cheap ways to clean working environments. Efficiency of nickel ions release depends on its concentration in the water, the pH value, general mineralization of water, and also on the presence and concentration of ions of calcium, iron etc.

2. Methods of nickel ions removal from wastewater treatment:

The conventional methods of nickel ions removal from wastewater treatment:

- Reagent method. The essence of the method reduces to formation of hydroxides or heavy metal salts which are then removed by sedimentation, filtration or in the other ways of liquid-solid separation. As the reagents most commonly used alkali (sodium and potassium hydroxide), calcium oxide and hydroxide, carbonates of calcium, magnesium and sodium. Significant shortcomings of reagent purification method are: additional pollution of effluents by adding in it cations and anions of reagents; receiving difficult to dewater and not utilizable sediment.
- Ion exchange. Characterized by a high degree of purification and allows to extract and utilize impurities of nickel.
- Biological methods. Based on the properties of microorganisms to accumulate or absorb heavy metal ions.
- Adsorption. The advantages of this method are: no secondary pollution, the possibility of recovery (recuperating) of the collected substances and high, up to 95%, degree of purification, and disadvantages are significant cost of sorbents and the necessity of regeneration unit.
- Electrochemical treatment. The main advantages of this method are: compactness and ease of operation of the plant for the process of electrocoagulation; no need for reagents; regeneration of valuable components.
- Membrane separation. The main advantage is selective heavy metal removal, and the main disadvantage of this method is fouling and lesser durability of membranes.

We consider a method of nickel removal from wastewater at factories producing sanitary equipment.

3. Research of separation process of sewage sludge with nickel release

Practically at all factories, which are producing sanitary equipment, treatment of wastewater containing nickel, performed by reagent method. In this case nickel ions are transformed into hydroxides and precipitating, after which they are taken away for burial. The thickened raw sediments dumped in piles. Usually they contain significant amounts of toxic substances which pose a serious danger to the environment. On the other hand, the valuable components that make up their composition forever lost.

Authors made a research about removal of nickel from precipitates, which were formed during the chemical treatment of wastewater. Were inspected the following methods:

- treatment by ammonia water for the purpose of nickel release;
- sludge acidification by sulfuric acid, followed by its treatment by ammonia water;
- ammonium salts sludge treatment;
- nickel release from the sludge by used electrolyte, which had been pre-treated by ammonia water.

Nickel content in the sediment varied from 1% to 10% by weight. Moisture of sediment was within the limits of 92-95%. In the first case considered dependence of percentage of nickel release from the sediment on the amount of ammonia water.

Experimental results show that during the increase of the dose of ammonia water from 0,29 to 1,79 ml per 1 mg of nickel content in the sediment, release of nickel salt in sediment increasing. Further increasing of the dose of ammonia water leads to reducing nickel release. In general, nickel release in this method of treatment is rather insignificant.

In another method, the sample of sludge was treated by hydrochloric or sulfuric acid to pH 4,5 - 5,0 and then by ammonia water. The obtained results were compared with the indicators of nickel content in the initial sediment, defining thus effect of nickel release from the sediment.

Treatment of sludge by hydrochloric acid leads to dissolution of nickel compounds and the formation of chloride or nickel sulfate, respectively. However, when added acid formed also iron hydroxide solution, which is located in the sediment. Further adding ammonia water leads to the creation of ammoniate nickel and precipitation of iron hydroxides. In this case, the effect of nickel release reaches 95-98% using sulfuric acid and 96-99% - hydrochloric acid.

Treatment of sludge by ammonium salts NH_2Cl or $(NH_4)_2$ SO_4 allows nickel release from the sediment avoiding transition of iron compounds in the solution. This method provides an opportunity reach 96-99% of nickel release from the sediment. At the same time performed electrolyte purification from impurities that allowing the use of this method for the purification of concentrated solutions containing nickel.

Using hydrochloric acid or ammonium chloride for treatment of sediment, during the decomposition of ammoniate nickel type $[Ni(NH)_4]Cl$, which is formed, in addition to gaseous ammonia released volatile hydrochloric acid. Interacting with the NH_4, it forms ammonium chloride NH_4Cl, which is again used for treatment solutions of sludge containing nickel. The effect of nickel release from solutions is 95-98%

Using sulfuric acid or ammonium sulfate for regeneration of nickel in the process of decomposition of nickel formed nickel hydroxide, sulfuric acid. From solution released gaseous ammonia, which in contact with water forms ammonium hydroxide, which again is used for regeneration of metal. During the accumulation of sulfuric acid is dissolving nickel hydroxide, which have been sedimented; the result is a nickel sulfate solution applicable for further use in nickel plating.

The process of removal of sediment ammonium chloride at pH 11,85 - 12,0 is optimal in terms of separation of nickel and iron. In these values pH does not occur iron hydroxides release in the solution, which are presented in the sediment.

Research results of regeneration of nickel from wash water sludge and sediment are presented in Table 1.

Table 1. Results of regeneration of nickel from wash water sludge and sediment

<table>
<tr><th>No.</th><th>Reagent</th><th>The dose of reagent, mg/l</th><th>Effect of regeneration, %</th><th>Note</th></tr>
<tr><td>1</td><td>Ammonia water</td><td>1,8</td><td>25-35</td><td rowspan="4">Is conducted regeneration of ammonia by heating solution</td></tr>
<tr><td>2</td><td>Sulfuric acid</td><td>1,55 H_2SO_4
2,0 NH_4OH</td><td>95-98</td></tr>
<tr><td>3</td><td>Hydrochloric acid and ammonia water</td><td>1,5 HCl
2,0 NH_4OH</td><td>96-99</td></tr>
<tr><td>4</td><td>Sulfate or ammonium chloride</td><td>2,2-2,5</td><td>96-99</td></tr>
</table>

4. Conclusions

1. Research gives reason to recommend for using a method of regenerating nickel salt 2-4 (Table 1.) depending on feasibility study justification depending on features one or another production process.
2. In terms of ease of operation, the most perspective should be considered method of regeneration, based on the use of ammonium salts.
3. These recommendations can be used in technological processes nickel plating equipment for passenger railway cars at sites and in factory shop to prevent environmental pollution and to obtain economic benefits.

References

1. Кочетов Г.М. Наукове обгрунтування і розробка методів і споруд для утилізації нікелю із стічних вод гальванічних виробництв, 2007.
2. Зоря О.В. Очистка нікельвміщуючих стічних вод заводів санітарно-технічного обладнання з використанням феромагнітних реагентів, 1998
3. Луценко М.М. Совершенствование технологии очистки стоков гальванических производств от ионов меди и никеля, 2004
4. Передня Т.В., Ризо Е.Г., Тимощук В.С., Шикаленко Ф.Н. Основные направления и мероприятия по реформированию гальванических производств промышленных предприятий Санкт-Петербурга // Вода и экология: проблемы и решения, 2004.

mgr inż. Joanna Struk-Sokołowska[1], Izabella Kłodowska[2], Angela Guzman Perez[3], Daniela Geraldes[4]

[1]Technical University of Bialystok, Department of Technology in Engineering and Environmental Protection, Poland, e-mail: j.struk@pb.edu.pl

[2]University of Warmia and Mazury in Olsztyn, Faculty of Environmental Sciences, Poland, e-mail: izabella.klodowska@uwm.edu.pl

[3]Universidad de Córdoba, Escuela Politecnica Superior de Belmez, Av. de la Universidad, Belmez 14240 – Cordoba, Spain, guzmeri_8565@hotmail.com

[4]Instituto Politécnico de Viseu, Escola Superior de Tecnologia e Gestão, Av. Cor. José Maria Vale de Andrade, 3504 - 510 Viseu, Portugal, daniela_fag7@hotmail.com

Comparison of technical solutions used in WWTP in selected countries in the world

Key words: *wastewater treatment plant, WWTP, BOD, COD ,N_{Tot},, P_{Tot}, TSS, efficiency, domestic wastewater, municipal wastewater, industrial wastewater*

Abstract: The purpose of this paper was to present the technical solutions used in wastewater treatment plants in following countries in the world: Poland (Siemiatycze and Białystok), Spain (Cordoba) and Portugal (Vila Real). In the analyzed wastewater treatment plants evaluated the effectiveness of removal of BOD (biological oxygen demand), COD (chemical oxygen demand), TSS (total suspended solids), N_{Tot} (total nitrogen) and P_{Tot} (total phosphorus). The article presents the regulations and directives in each country used for assessment of the effluent quality. Based on research conducted in the influents and effluents from the WWTP made a statement comparing the efficiency of carbon, nitrogen and phosphorus removal.

1. Introduction

The quantity and quality of wastewater is determined by many factors. Not all humans or industries produce the same amount of waste. The amount and type of waste produced in households is influenced by the behavior, lifestyle and standard of living of the inhabitants as well as the technical and juridical framework by which people are surrounded [4].

Wastewater treatment is done in a series of steps that can have increasing effectiveness and complexity depending on the resources available. Widely used technology refers to three levels of wastewater treatment: primary, secondary and tertiary.

Primary treatment is designed to remove suspended and floating solids from raw wastewater. It includes screening to trap solid objects and sedimentation by gravity to remove suspended solids. This level is sometimes referred to as “mechanical treatment”, although chemicals are often used to accelerate the sedimentation process. Primary treatment can reduce the BOD of the incoming wastewater by 20-30% and the total suspended solids by some 50-60%. Primary treatment is usually the first stage of wastewater treatment. Many advanced wastewater treatment plants in industrialized countries have started with primary treatment, and have then added other treatment stages as wastewater load has grown, as the need for treatment has increased, and as resources have become available [15].

Secondary (biological) treatment removes the dissolved organic matter that escapes primary treatment. This is achieved by microbes consuming the organic matter and converting it to carbon dioxide, water and energy for their own growth and reproduction. The biological process is followed in additional settling tanks to remove more of the suspended solids. About 85% of the suspended solids and BOD can be removed by a well running plant with secondary treatment. Secondary treatment technologies include the basic activated sludge process, the variants of pond and constructed wetland systems, trickling filters and other forms of treatment [15].

Tertiary treatment can remove more than 99 percent of all the impurities from wastewater, producing an effluent of almost drinking water quality. The technology can be very expensive, requiring a high level of technical know-how and well trained wastewater treatment plant operators, a steady energy supply and chemicals, specific equipment which may not be readily available [15].

Wastewater treatment is related to the standards and expectations set for the effluent quality. Wastewater treatment processes are designed to achieve improvements in the quality of the wastewater. The various treatment processes may reduce:

- Suspended solids (physical particles that can clog rivers or channels as they settle under gravity).
- Biodegradable organics (e.g. BOD) which can serve as “food” for microorganisms in the receiving body. Microorganisms combine this matter with oxygen from the water to yield the energy they need to thrive and multiply. Unfortunately, this oxygen is also needed by fish and other organisms in the river. Heavy organic pollution can lead to “dead zones” where no fish can be found; sudden releases of heavy organic loads can lead to dramatic “fishkills”.
- Pathogenic bacteria and other disease causing organisms. These are most relevant where the receiving water is used for drinking, or where people would otherwise be in close contact with it.
- Nutrients, including nitrates and phosphates. These nutrients can lead to high concentrations of unwanted algae, which can themselves become heavy loads of biodegradable organic load. Treatment processes may also neutralize or removing

industrial wastes and toxic chemicals. This type of treatment should ideally take place at the industrial plant itself, before discharge of their effluent in municipal sewers or water courses.

The ratio between the various components in wastewater has significant influence on the selection and functioning of wastewater treatment processes. A wastewater with low carbon to nitrogen ratio may need external carbon source addition that biological denitrification functions fast and efficiently. Wastewater with high nitrate concentration or low concentration of volatile fatty acids (VFAs) will not be suitable for biological phosphorus removal. Wastewater with high COD to BOD ratio indicates that a substantial part of the organic matter will be difficult to degrade biologically. When the suspended solids in wastewater have a high volatile component these can be successfully digested under anaerobic conditions [4]. Unit processes and operations used in wastewater treatment and potential for contaminant removal shown in table 1.

Table 1. Unit processes and operations used in wastewater treatment and potential for contaminant removal

	BOD	COD	TOC	Turbid.	Color	*Coli*	NH_3-N
	removal of influent concentration, %						
Primary treatment	25 - 50	25 - 50	25 - 50	25 - 50	25	no data	25
Activated sludge	≥ 50	≥ 50	≥ 50	≥ 50	25 - 50	≥ 50	≥ 50
Nitrification	≥ 50	≥ 50	≥ 50	≥ 50	25 - 50	≥ 50	≥ 50
Denitrification	25	25	25	25	no data	no data	25 - 50
Trickling filter	≥ 50	≥ 50	25 - 50	25 - 50	25	25	no data
Coag.-floc.-sed.	≥ 50	≥ 50	≥ 50	≥ 50	≥ 50	≥ 50	25
Filtration A/S	25 - 50	25 - 50	25 - 50	25 - 50	25 - 50	no data	25 - 50
GAC adsorption	≥ 50	25 - 50	≥ 50	≥ 50	≥ 50	≥ 50	25 - 50
Ion exchange	25 - 50	25 - 50	25	25	no data	no data	≥ 50
Chlorination	no data	no data	no data	no data	no data	≥ 50	≥ 50
Reverse osmosis	≥ 50	≥ 50	≥ 50	≥ 50	≥ 50	no data	≥ 50
Ozone	25	≥ 50	25 - 50	no data	no data	≥ 50	no data

Source: Tchobanoglous G., Burton F. L., Stensel H. D.: Wastewater Engineering Treatment and Reuse. Metcalf & Eddy, 2002

2. Wastewater treatment plants (WWTP) in Poland

Municipal wastewater treatment plants **in Siemiatycze** (units – 15000 to 99999 pe) and **in Białystok** (units – more than 100000) are located in eastern Poland in the southern part of the Podlasie region (Fig. 1).

Figure. 1. Location of the wastewater treatment plants in Siemiatycze and Białystok

Mechanical – biological treatment plants in Siemiatycze (scheme shown in Fig. 2), and in Białystok (scheme shown in Fig. 3) were opened in the 90s of the last century. WWTPs were modernized in 2002 – 2004 (Siemiatycze) and in 2002 – 2008 (Białystok). The maximum daily capacity of the wastewater treatment plant in Siemiatycze is 6595 m^3, in Białystok is 100000 m^3. Population equivalent (pe) for the WWTP in Siemiatycze is 60 000, while for the WWTP in Białystok is 200000. WWTP in Siemiatycze treats municipal and industrial wastewater from fruit and vegetable and dairy industry. WWTP in Białystok treats municipal wastewater with a 1,3% share of industrial wastewater [16].

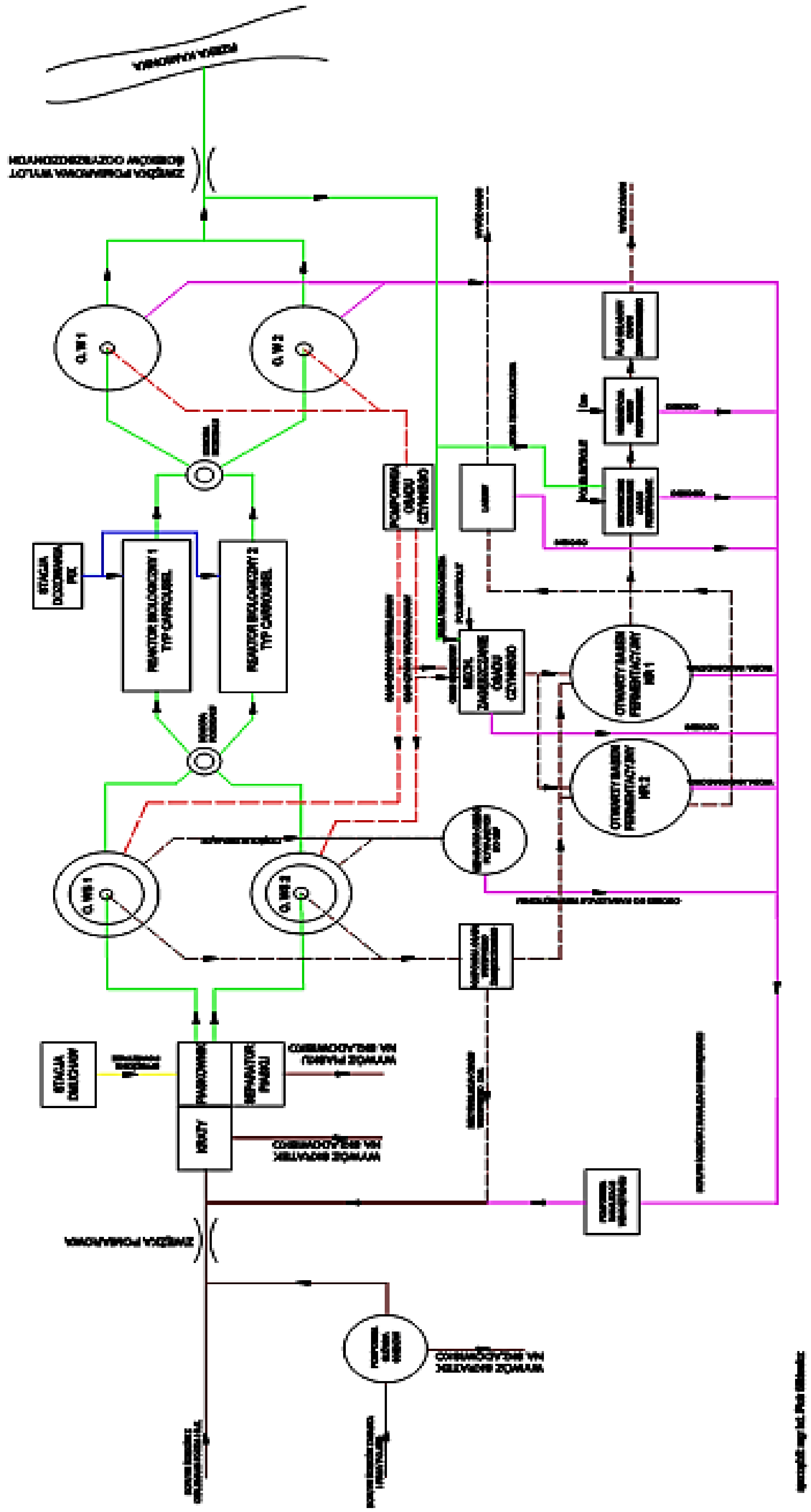


Figure. 2. Flow diagram for WWTP in Siemiatycze

Source: Utility Company in Siemiatycze

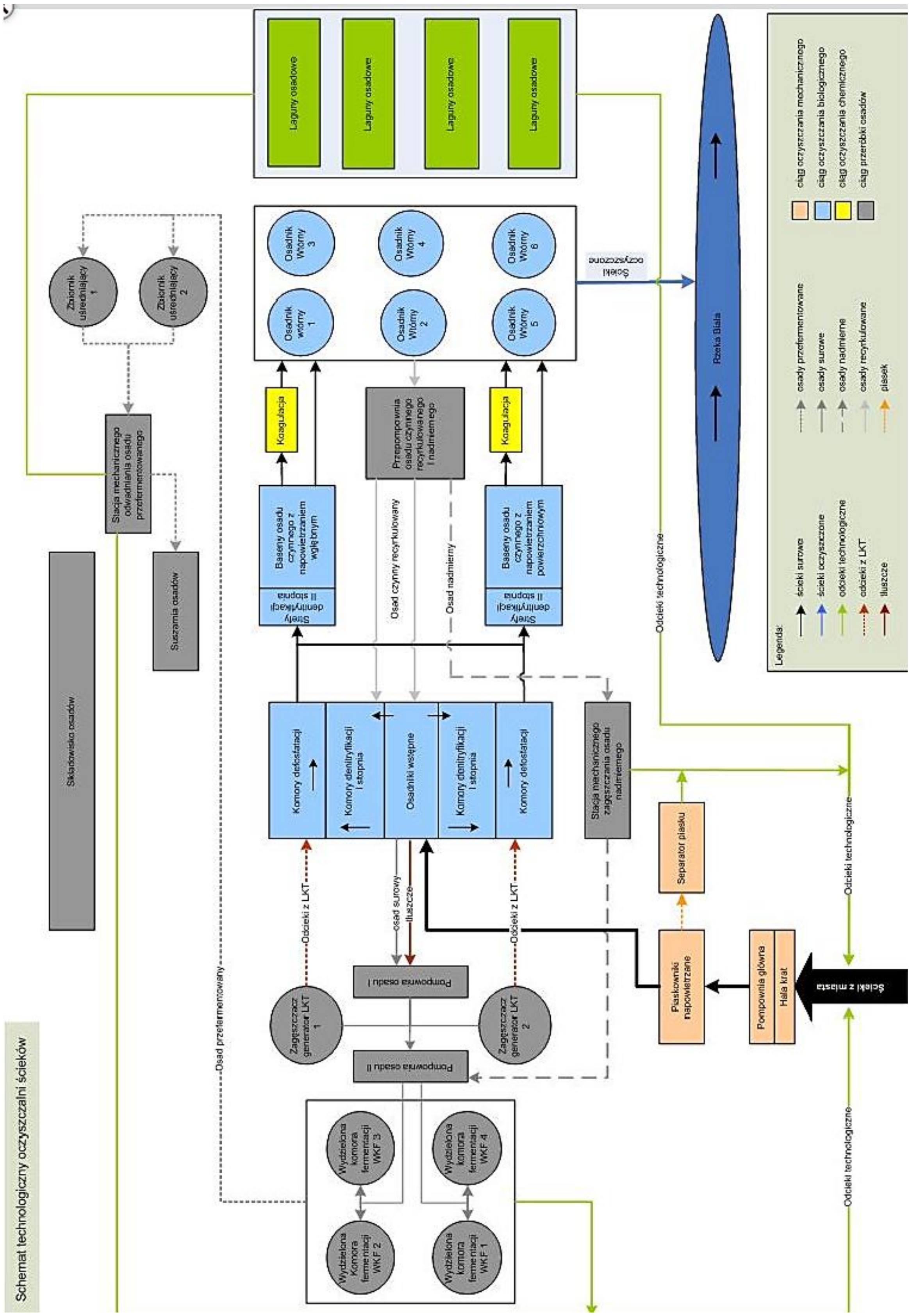


Figure. 3. Flow diagram for WWTP in Białystok

Source: Białystok Water Supply

Wastewater flows into the main pumping station located at the distance 1 km from the WWTP in Siemiatycze and on the WWTP in Białystok [6].

Mechanical wastewater treatment stations have a mechanical grates equipped with a scrubber screenings (Siematycze Fig. 3, Białystok Fig. 4) and the grate with the manual removal of screenings used in emergency situations (in Siemiatycze).

Figure. 3. Mechanical grille in Białystok

Source: Białystok Water Supply

Figure. 4. Mechanical grille in Siemiatycze

Source: Utility Company in Siemiatycze

From the mechanical treatment building wastewater flows into sand holders (Białystok – Fig 5, Siemiatycze Fig. 6).

Figure. 5. Sand holder in Białystok

Source: Białystok Water Supply

Figure. 6. Horizontal sand holder in Siemiatycze

Source: Utility Company in Siemiatycze

Mechanically pretreated wastewater flows into anaerobic chambers working in parallel. The process of biological treatment is carried out at anaerobic-aerobic system of continuous flow biological reactors. In these chambers are separated: the pre-denitrification zone and the nitrification zone (Siemiatycze – Fig. 7 and 8, Białystok Fig. 9 and 10).

Figure. 7. Denitrification chamber with a low speed mixer in Siemiatycze

Source: Utility Company in Siemiatycze

Figure. 8. Nitrification chamber with surface aerator in Siemiatycze

Source: Utility Company in Siemiatycze

Internal recirculation is realized by means of pumping mixers. The contents of the two chambers is aerated and mixed with 3 surface aerators. Aerobic conditions vary over a range of 0.5 – 2.5 $gO_2 \cdot m^{-3}$.

Figure. 9. Pre-denitrification chamber in Białystok

Source: Białystok Water Supply

Figure. 10. Nitrification chamber in Białystok

Source: Białystok Water Supply

From the nitrification chamber a mixture of wastewater and activated sludge flows into to secondary settling tanks (Siemiatycze Fig. 11, Białystok Fig. 12). Wastewater through pilates transfers, bed blanket and measuring channel effluent is discharged into Kamionka river in Siemiatycze and into Biała river in Białystok.

Figure 11. Secondary sedimentation tank in Siemiatycze

Source: Utility Company in Siemiatycze

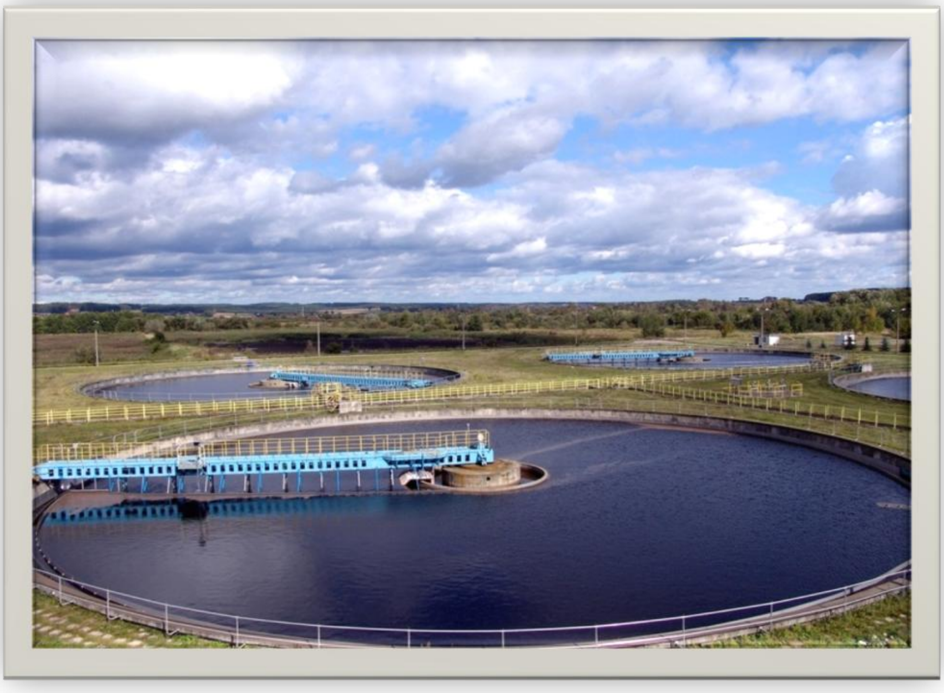


Figure 12. Secondary sedimentation tank in Białystok

Source: Białystok Water Supply

3. Wastewater treatment plant (WWTP) in Spain

The wastewater treatment plant “La Golondrina” is located in Cordoba in the south of Spain (Fig. 9). WWTP La Golondrina is designed with a capacity to manage all the wastewater of the city of Cordoba. Urban wastewater together with the rain water are collected by the sewerage network and channelled through an underground pipe to La Golondrina. In this WWTP wastewater of the municipality is treated in a complex triple process: bar screening and sands removing, primary decantation and biological treatment, before being dumped to the Guadalquivir river [10, 11].

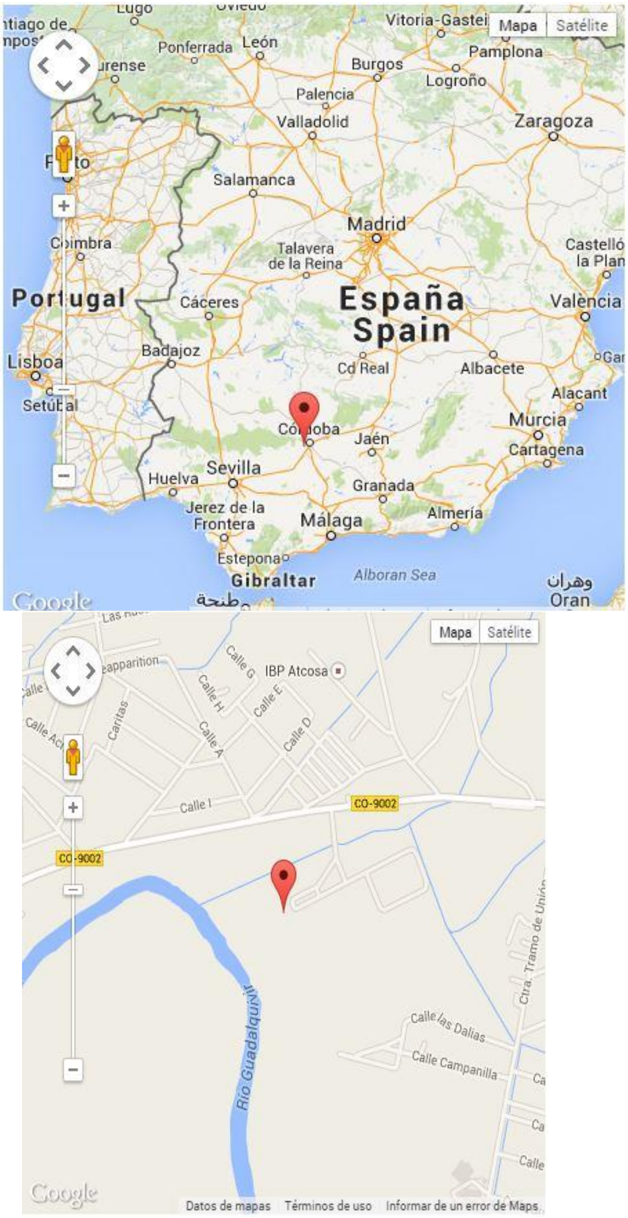


Figure. 13. Location of the wastewater treatment plant in Cordoba

General Information of WWTP in Cordoba

- Equal resident: 516128
- Capacity of treatment: 148602 m^3/ day

A yeast factory is located 10 km from the Cordoba city. This factory creates two problems. The first is the high amount of industrial discharge, and the second is the odor such as result of the fermentation. The fermentation of the yeast makes a high organic discharge, the values are COD: 15000/20000 mg/l, and BOD 10000/16000 mg/l. The relation of COD/BOD is 1.5. The values of nitrogen are very elevated 1600 mg/l and 400 mg/l of ammonia. The yeast factory was owned by a multinational which could close the factory and operate in the Iberian market from Lisbon, where it had another factory. However, the final decision taken, still running, was to entrust to EMACSA the construction of a anaerobic treatment plant in the wastewater treatment plant of La Golondrina to properly treat the waste materials and residues of the yeast factory, together with the piping construction from the factory to La Golondrina. The wastewater are treating by anaerobic process. This process must delay 70% of the COD, and then the volume treat will go to the wastewater treatment “La Golondrina” and join with the other wastewater from the city. Volume of industrial wastewater is 27287,147 m^3/ year [13, 14].

Figure. 14. Extension to La Golondrina WWTP, Cordoba, Spain (2011)

Source: Utility Company in Cordoba

The pretreatment of wastewater is the first process carried out water reconditioning, and is a mechanical treatment (fig. 15). The pretreatment searches to prepare the wastewater to facilitate further treatment, and preserves the installation of erosion and plug up. The pretreatment includes equipment such as grills and sieves (for separation of large particles such as plastic bottles), sand holders (to remove sand present in the wastewater) and degreasers (to remove fats and oils). The conventional pretreatment line consists in the stage of smoothing, sandfree and greasefree.

The grills consist in some manual or mechanical grills that these are located in the supply channel of the plant. These are made for a set of the vertical or leaning steel bars with at regular intervals holes across the width of the channel, through which the wastewater is passed (Fig 16).

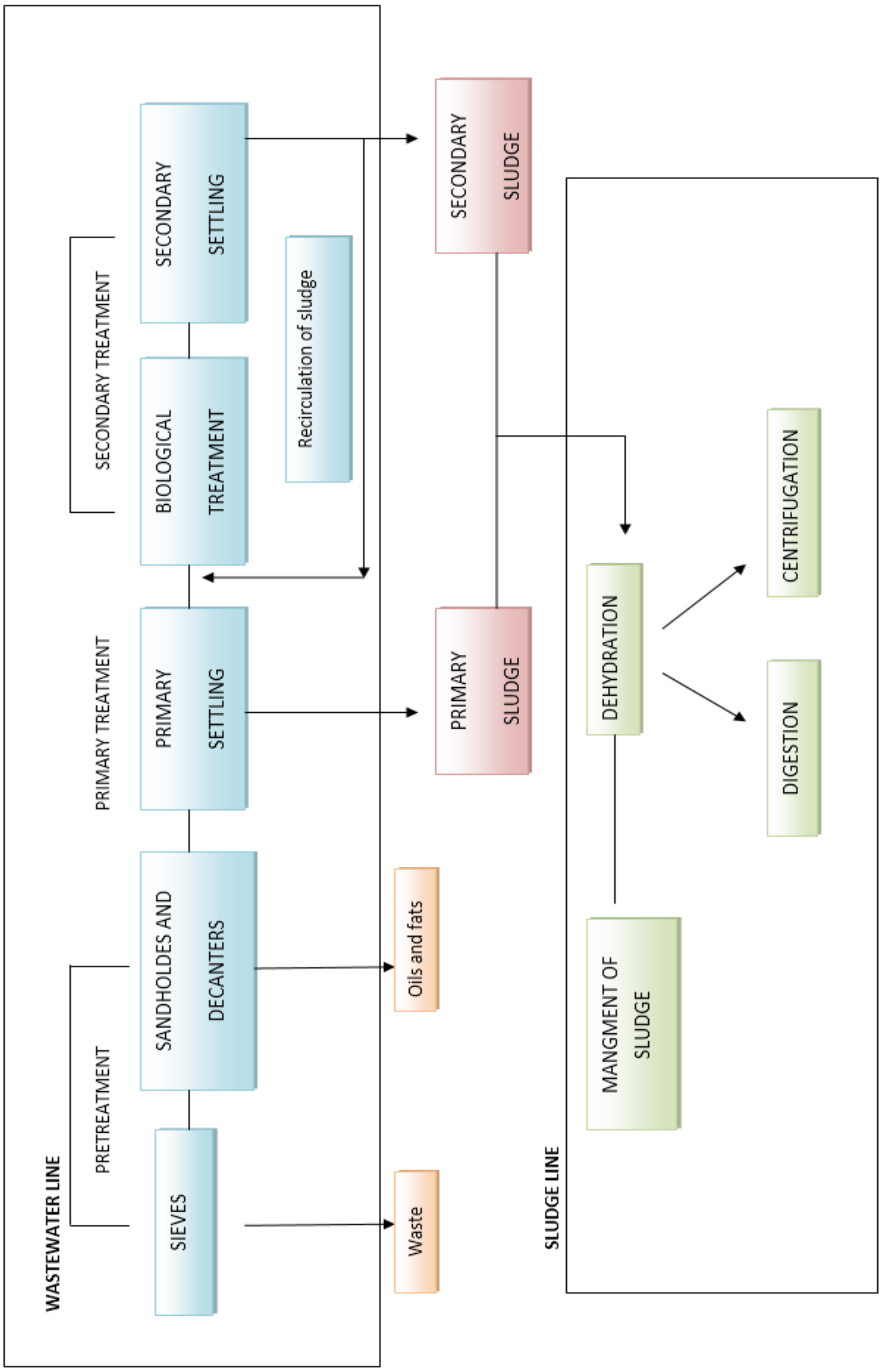


Figure 15. Facilities and processes in WWTP in Cordoba

Source: Utility Company in Cordoba

Figure 16. Mechanical grille in WWTP in Cordoba

Source: Utility Company in Cordoba

The sieves are consisted in a filtration through a thin support according to the dimensions of hole, there are two types: macro-sieve and micro-sieve. The first is consisted a perforated sheet with a hole greater than 0,3 mm. Sand holders, his objective is to separate the sand. The process consists to reduce the velocity of the water under the limits of settling, but above the limits of sedimentation of the organic matter. If the organic matter is dammed therefore there is fermentation and odors (Fig. 17).

Figure 17. Sand holder in WWTP in Cordoba

Source: Utility Company in Cordoba

4. Wastewater treatment plant (WWTP) in Portugal

Vila Real is a city of the north of Portugal. Wastewater Treatment Plant of Vila Real is located near the junction of Corgo River and Cabril River (fig. 18).

Figure 18. Location of the WWTP in Vila Real

General Information of WWTP in Vila Real

- Area of 7900 m^2
- Built to serve 45000 Inhabitants
- Working since March 2004
- Treats the wastewater of the city of Vila Real and the others villages

In Vila Real and surroundings there is much practice of agriculture. In addition there are many food and drink industries. This is a reason that the values of some parameters such as BOD_5 and TSS are so high [8, 9].

- Flow per Day: 9360 m^3/day
- Biological Oxygen Demand (BOD_5): 2430 kg/day
- Total Suspended Solids (TSS): 3150 kg/day

1- Input Work and Harrowing;
2- Retencion Basin;
3- Sand Trap/Grease Separator and Primary Decantation;
4- Biological Treatment by Activated Sludge;
5- Sludge Treatment;
6- Desodorisation;
7- Discharged to Corgo River

Figure 19. Wastewater treatment facilities in Vila Real

Source: Utility Company in Vila Real

The wastewater treatment plant in Vila Real is constructed by 3 lines:

A) Wastewater Line

1 – Input Work and Harrowing occurs the flow measurement and removal of larger solids through rotation drum sieves (3 channels in parallel) shown in figure 20.

Figure 20. Input work and harrowing in Vila Real

Source: Utility Company in Vila Real

2 – Retention Basin for storing wastewater in rainy season.

3 – Sand Trap/Grease Separator and Primary Decantation takes place the removal sand, grease and some settleable solids. The Preliminary Treatment and the Primary Decantation are made in a compact body (fig. 21).

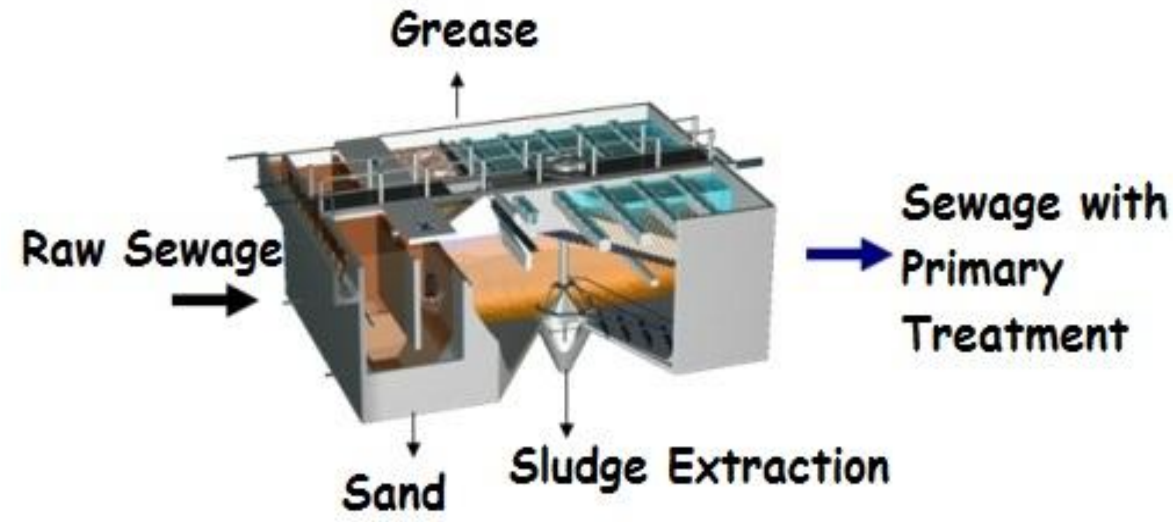


Figure 21. Sedipac in Vila Real

Source: Utility Company in Vila Real

Figure 22. Primary Treatment in Vila Real

Source: Utility Company in Vila Real

4 - Biological treatment by activated sludge occurs the removal of settleable solids and carbonated pollution. There is a biological reactor where the aeration is ensured by a aeration turbines.

Characteristics of the Biological Reactor:

- Number of lines - 2
- Volume per treatment line - 1600 m^3
- Total Volume - 3200 m^3
- Dimension of each line - length -21,4 m; width -10,7 m

Secondary kettler tank shown in figures 23 and 24.

Figure 23. Secondary kettler tank in Vila Real

Source: Utility Company in Vila Real

Figure 24. Secondary kettler tank in Vila Real

Source: Utility Company in Vila Real

Effluents are discharged into the Corgo river. The sludge is recirculated for the sludge treatment line.

B) Sludge Treatment Line - gravity thickening of primary sludge, biological floculation, anaerobic digestion and dehydration by centrifugation – (sludge for valorization -agriculture and organic corrector) or biogas production.

C) Odor Treatment

WWTP has a system of deodorization by chemical wash with sulfuric acid, caustic soda and sodium hypochlorite. This system prevents the bad odors.

5. Required quality of effluent

European Union countries were required to implement the Directive 91/271/EEC [1]. The Council Directive 91/271/EEC concerning urban wastewater treatment was adopted on 21 May 1991. Its objective is to protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors and concerns (Fig. 25) the collection, treatment and discharge of domestic wastewater, mixture of wastewater and wastewater from certain industrial sectors.

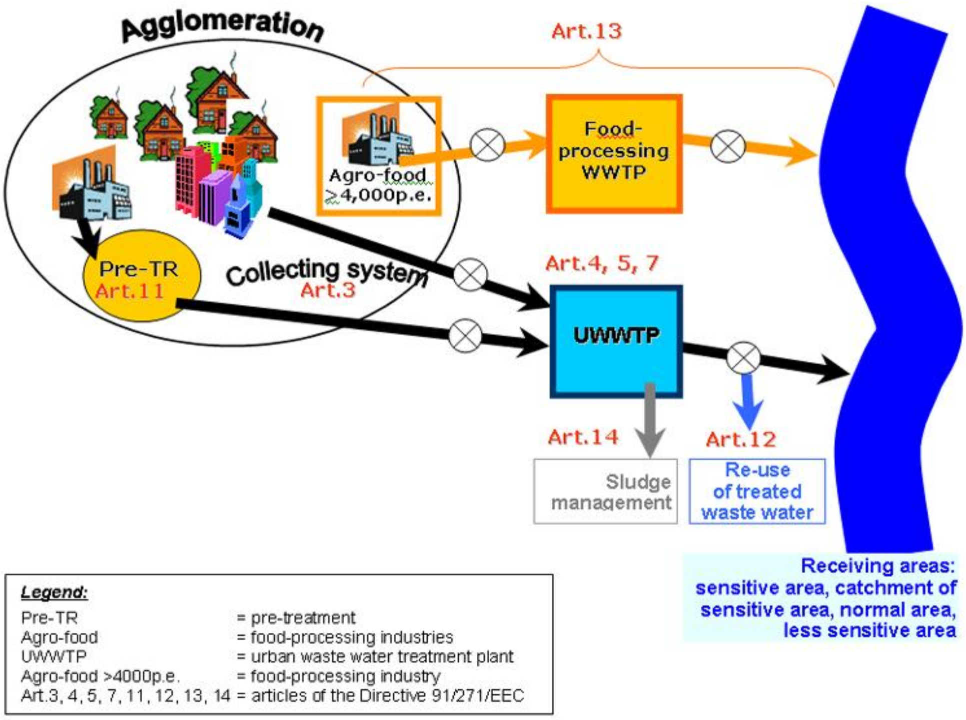


Figure 25. Areas covered by the Directive 91/271/EEC

Source: [12]

According to the Directive 91/271/EEC for European Union countries and other regulations and documents [1, 2, 3, 5] concerning the conditions necessary during discharge of wastewater into water or soil, WWTP in Poland, Spain and Portugal must ensure the quality of effluent compatible with the values given in the table 2 and 3.

Table 2. Requirements for discharges from urban wastewater treatment plants subject to articles 4 and 5 of Directive 91/271/EEC. The values for concentration or for the percentage of reduction shall apply

Parameters	Concentration	Minimum percentage of reduction (1)	Reference method of measurement
Biochemical oxygen demand (BOD_5 at 20 ºC) without nitrification (2)	25 $mgO_2 \cdot dm^{-3}$	70 – 90 40 under Article 4	Homogenized, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20ºC ± 1ºC, in complete darkness. Addition of a nitrification inhibitor.
Chemical oxygen demand (COD)	125 $mgO_2 \cdot dm^{-3}$	75	Homogenized, unfiltered, undecanted sample Potassium dichromate

Total suspended solids	35 mg·dm^{-3} (3) 35 under Article 4 (more than 10000 p.e.) 60 under Article 4 (2000 – 10000 p.e.)	90 (3) 90 under Article 4 (more than 10000 p.e.) 70 under Article 4 (2000 – 10000 p.e.)	- Filtering of a representative sample through a 0,45 μm filter membrane. Drying at 105ºC and weighing - Centrifuging of a representative sample (for at least five mins with mean acceleration of 2800 to 3200 g), drying at 105ºC and weighing
(1) Reduction in relation to the load of the influent (2) The parameter can be replaced by another parameter: total organic carbon (TOC) or total oxygen demand (TOD) if a relationship can be established between BOD5 and the substitute parameter (3) This requirement is optional			

Table 3. Requirements for discharges from urban wastewater treatment plants to sensitive areas which are subject to eutrophication as identified in annex II A (a). One or both parameters may be applied depending on the local situation. The values for concentration or for the percentage of reduction shall apply

Parameters	Concentration	Minimum percentage of reduction (1)	Reference method of measurement
Total phosphorus	2 mgP·dm^{-3} (10000 – 100000 p.e.) 1 mgP·dm^{-3} (more than 100000 p.e.)	80	Molecular absorption spectrophotometry
Total nitrogen (2)	15 mgN·dm^{-3} (10000 – 100000 p.e.) 10 mgN·dm^{-3} (more than 100000 p.e.) (3)	70 - 80	Molecular absorption spectrophotometry

(1) Reduction in relation to the load of the influent

(2) Total nitrogen means: the sum of total Kjeldahl – nitrogen (organic N + NH_3), nitrate (NO_3) – nitrogen and nitrite (NO_2) - nitrogen

(3) Alternatively, the daily average must not exceed 20 $mgN \cdot dm^{-3}$. This requirement refers to a water temperature of 12ºC or more during the operation of the biological reactor of the wastewater treatment plant. As a substitute for the condition concerning the temperature, it is possible to apply a limited time of operation, which takes into account the regional climatic conditions. This alternative applies if it can be shown that paragraph 1 of Annex 1D is fulfilled.

Main principles in the Directive 91/271/EEC are planning, regulation, monitoring, information and reporting.

Specifically the Directive requires:

- The Collection and treatment of waste water in all agglomerations of >2000 population equivalents (p.e.);
- Secondary treatment of all discharges from agglomerations of > 2000 p.e., and more advanced treatment for agglomerations >10 000 population equivalents in designated sensitive areas and their catchments;
- A requirement for pre-authorisation of all discharges of urban wastewater, of discharges from the food-processing industry and of industrial discharges into urban wastewater collection systems;
- Monitoring of the performance of treatment plants and receiving waters
- Controls of sewage sludge disposal and re-use, and treated waste water re-use whenever it is appropriate.

6. The effects of WWTP operation

The concentration of BOD_5, COD and TSS in influent and effluent as well as the efficiency of removal are given in Table 4.

Table 4. BOD_5, COD and TSS in the influents and effluents from the WWTPs and the efficiency of removal

parameter	wastewater	unit	Wastewater Treatment Plant			
			Poland		**Spain**	**Portugal**
			Siemiatycze	Białystok	Cordoba	Vila Real
BOD_5	influent	$mgO_2 \cdot dm^{-3}$	1299,0	523,0	343,8	262,5
	effluent	$mgO_2 \cdot dm^{-3}$	4,9	3,4	10,4	10,5

	efficiency of removal	%	99,6	99,3	97,0	96,0
COD	influent	$mgO_2 \cdot dm^{-3}$	1780,0	1494,0	565,2	777,0
	effluent	$mgO_2 \cdot dm^{-3}$	39,4	33,0	69,9	47,5
	efficiency of removal	%	97,8	97,8	87,6	93,9
TSS	influent	$mg \cdot dm^{-3}$	481,0	870,0	323,8	218,0
	effluent	$mg \cdot dm^{-3}$	9,5	10,5	13,6	14,0
	efficiency of removal	%	98,0	98,8	95,8	93,6
Results of the year			2013	2014	2014	2013

Source: Department of Water Supply and Utility Company in Siemiatycze, Białystok, Cordoba and Vila Real

The concentration of total nitrogen and phosphorus in influent and effluent as well as the efficiency of removal are given in Table 5.

Table 5. N_{Tot}, and P_{Tot} in the influents and effluents from the WWTPs and the efficiency of nitrogen and phosphorus removal

parameter	wastewater	unit	Wastewater Treatment Plant			
			Poland		**Spain**	**Portugal**
			Siemiatycze	Białystok	Cordoba	Vila Real
N_{Tot}	influent	$mgN \cdot dm^{-3}$	74,0	100,0	46,2	-
	effluent	$mgN \cdot dm^{-3}$	3,5	8,5	2,5	6,0-10,0
	efficiency of removal	%	95,3	91,5	94,6	-
P_{Tot}	influent	$mgP \cdot dm^{-3}$	23,0	15,0	29,5	-
	effluent	$mgP \cdot dm^{-3}$	1,4	0,4	0,4	0,5-2,5
	efficiency of removal	%	93,9	97,5	98,6	-
Results of the year			2013	2014	2014	2013

Source: Department of Water Supply and Utility Company in Siemiatycze, Białystok, Cordoba and Vila Real

7. Conclusions

1. Comparing the equipment and facilities for mechanical and biological treatment of wastewater in four analyzed WWTP (Siemiatycze, Białystok, Cordoba, Vila Real) were noticed a lot of similarities.
2. Efficiency of organic compounds removal in wastewater treatment plants in Poland, Spain and Portugal were high.
3. Comparing the efficiency of removal of organic matter determined BOD_5 and COD in wastewater treatment plants, where pe > 100000 (Białystok, Cordoba), found that higher values were in Bialystok.

4. Comparing the efficiency of removal of organic matter determined BOD_5 and COD in wastewater treatment plants, where pe is in range from 15000 to 99999 (Siemiatycze, Vila Real) reported that higher removal efficiency values noted in Siemiatycze.
5. Efficiency of nitrogen and phosphorus removal in wastewater treatment plants in Poland and Spain were high (WWTP in Portugal - detailed data on the efficiency - undefined).
6. Comparing the efficiency of removal of nitrogen and phosphorus in wastewater treatment plants, where pe > 100000 (Białystok, Cordoba), found that higher values were in Cordoba.
7. The quality of effluents from analyzed WWTP is consistent with the requirements. Concentrations of pollutants in effluents from analyzed WWTP are lower than those specified in the legislation.

Acknowledgments

We would like to thank for the information provided by the Department of Water Supply and Utility Company in Siemiatycze, Białystok, Cordoba and Vila Real

References

1. Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment.
2. Decreto de Lei n 152/97 de 19 de Junho. Diário da República n 139/97 - I Série A. Ministério do Ambiente, Lizbona.
3. Directiva 2000/60/CE: Análisis de trasposición y procedimientos de desarrollo. Madrid, 2003.
4. Henze M.: Biological Wastewater Treatment: Principles, Modelling and Design. IWA Publishing, 2008.
5. Rozporządzenie Ministra Środowiska z 18 listopada 2014 roku w sprawie warunków, jakie należy spełnić przy wprowadzaniu ścieków do wód lub do ziemi, oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego.
6. Struk-Sokołowska J.: Ocena efektywności pracy oczyszczalni ścieków w Siemiatyczach. Interdyscyplinarne zagadnienia w inżynierii i ochronie środowiska. Ofic. Wyd. Polit. Wrocł., 4, 789 – 806, 2014.
7. Tchobanoglous G., Burton F. L., Stensel H. D.: Wastewater Engineering Treatment and Reuse. Metcalf & Eddy, 2002.
8. http://www.adp.pt/content/index.php?action=detailfo&rec=1832&t=Aguas-de-Tras-os-Montes-e-Alto-Douro--SA
9. http://www.aguas-tmad.pt/pt/noticias/dossier-etar-de-vila-real/

10. http://www.aqualia-infraestructuras.es/referencias_ficha.cfm?idArtCat=12&idReferencia=180/
11. http://www.cyclusid.com/noticias/el-proyecto-tecnologico-de-depuracion-anaerobica-mas-avanzado-en-espana-3085/
12. http://ec.europa.eu/environment/water/water-urbanwaste/index_en.html
13. http://www.emacsa.com/
14. http://www.prtr-es.es/informes/fichacomplejo.aspx?Id_Complejo=5852
15. http://water.worldbank.org/shw-resource-guide/infrastructure/menu-technical-options/wastewater-treatment
16. Wiater J., Butarewicz A.: Sposoby wykorzystania osadów z Oczyszczalni Ścieków w Białymstoku. Inżynieria i Ochrona Środowiska, t. 17, nr 2, 281 – 291, 2014.

Eng. Olexandra Vorozhbianova[1]
Kiev National University of Construction and Architecture
31 Povitroflotsky Pr., 03680, Kiev, Ukraine
e-mail: [1]white__night@bigmir.net

Aerobic and anaerobic method for domestic wastewater treatment

Key words: *aerobic wastewater treatment, anaerobic wastewater treatment, biological methods of wastewater treatment*

Abstract: There are multitudes of aerobic biological treatment processes and technologies in literature and practice; however, for the purpose of this article, four biological treatment technologies are described. Beside description of each process and corresponding advantages/highlights, a qualitative comparison of these technologies is tabulated. This comparison is based on an actual wastewater treatment application for a refinery project, where the treatment requirement was meant for discharge of treated effluent. The literature review of contemporary aerobic and anaerobic wastewater treatment methods presented in this paper. It contains comparative characteristics of different options used for wastewater purification and its main features.

1. Introduction

Biological treatment of wastewater can be expressed as the destruction of contained organic substances and other biologically decomposable pollutants by microorganisms, leading to the formation of products, which are less harmful to the environment. Biological treatment facilities can be divided into two groups: aerobic and anaerobic. Aerobic microorganisms in its active cycle for catabolism of organic matter using oxygen, and thus survive, grow and reproduce [1].

Anaerobic treatment is a process where wastewater or material is broken down by microorganisms without the aid of dissolved oxygen. However, anaerobic bacteria can use oxygen that is found in the oxides introduced into the system or they can obtain it from organic material within the wastewater. Anaerobic systems are used in many industrial systems including food production and municipal sewage treatment systems. The process is based on anaerobic digestion of biological conversion of the organic material to different final products, including methane and carbon dioxide [6].

Anaerobic processes are substantially less costly than aerobic , because it does not require the oxygen to be removal of less precipitate form. In addition, high levels of methane which is generated in the anaerobic system, can be used to generate heat or electricity and income when they are sold. Anaerobic mineralization requires a consistent, cooperative involvement of different groups of bacteria with have very different chemical and thermodynamic properties, nomenclature of substrates [1, 2].

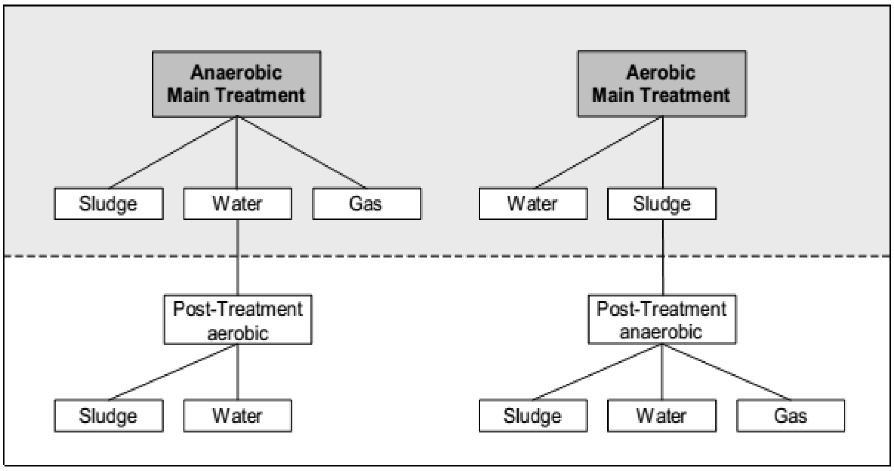


Figure 1 . Principal difference between anaerobic and aerobic intensive wastewater treatment

2. Anaerobic treatment technologies analysis

There are different methods of anaerobic treatment used in wastewater treatment facilities, which has advantages and disadvantages and different economic efficiency as well as purification efficiency. The best choice of treatment method depends on the natural conditions of zone, accessible area for facility structure, material component and other factors. The general comparison of selected wastewater treatment options is presented at Figure 3.

Figure 2. Principal difference between aerobic and anaerobic wastewater treatment

Parameter	Aerobic Treatment	Aerobic Treatment
Process Principle	• Microbial reactions take place in the presence of molecular/ free oxygen • Reactions products are carbon dioxide, water and excess biomass	• Microbial reactions take place in the absence of molecular/ free oxygen • Reactions products are carbon dioxide, methane and excess biomass
Applications	Wastewater with low to medium organic impurities (COD < 1000 ppm) and for wastewater that are difficult to biodegrade e.g. municipal sewage, refinery wastewater etc.	Wastewater with medium to high organic impurities (COD > 1000 ppm) and easily biodegradable wastewater e.g. food and beverage wastewater rich in starch/sugar/ alcohol
Reaction Kinetic	Relatively fast	Relatively slow
Net Sludge Yield	Relatively high	Relatively low (generally one fifth to one tenth of aerobic treatment processes)
Post Treatment	Typically direct discharge or filtration/ disinfection	Invariably followed by aerobic treatment
Foot-Print	Relatively large	Relatively small and compact
Capital Investment	Relatively high	Relatively low with pay back
Example Technologies	Activated Sludge e.g. Extended Aeration, Oxidation Ditch, MBR, Fixed Film Pro-cesses e.g. Trickling Filter/Biotower, BAF, MBBR or Hybrid Processes e.g. IFAS	Continuously stirred tank reactor/di-gester, Upflow Anaerobic sludge Blanket (UASB), Ultra High Rate Fluidized Bed reactors e.g. EGSBTM, ICTM etc.

Source: Anaerobic methods of municipal wastewater treatment, Frankfurt, March 2001

Figure 3. Typical features of treatment technologies for domestic wastewater (evaluation according to: ++ … excellent, + … positive, - … negative)

	PST	UASB	WSP			TF	AS
environmental conditions	anaerobic	anaerobic	anaerobic	facultative	maturation	aerobic	aerobic
suited for raw sewage	++	+	++	++	-	+	++
suited for settled sewage	-	++	++	++	-	++	++
suited for wastewater temperatures	> 5°C	> 20°C	> 5°C	> 5°C	> 5°C	> 5°C	> 5°C
BOD removal efficiency	30-40%	> 70 %	> 50 %	> 70 %	> 50%	80-90%	> 90 %
nutrient (N, P) removal efficiency	-	-	-	-	-	+ (++)	+ (++)
coliform removal	25-75%	90%	90%	90-99%	> 99%	90-95%	90-98%
helminth egg removal	90%	90%	99%	99%	99%	90-99%	90-99%
typical HRT	1-2 h	ca. 6 h	> 1 d	> 4 d	> 3 d	ca. 6 h	ca. 15 h
odour nuisance	+	++	+	+	++	++	++
energy demand & gas production	++	++	++	++	++	+ (++)	-
land requirement	++	++	+	-	-	+	+
requiring skilled operators	++	+/-	++	++	++	+	-
investment cost	++	++	++	+	+	+	-

Source: Water today, Aaron Mittal – Biological wastewater treatment, august 2011 p. 36

The main features of selected treatment options can be summarized as follows:

- Primary Sedimentation Tanks (PST) are relatively efficient in relation to investment cost. But they are never suited to comply with typical WWTP treatment standards.
- UASB (Upflow anaerobic sludge blanket) is very efficient, its volume is small, but it typically requires post-treatment. As long as operation runs smoothly, it is not particularly skill demanding for the operators, but during start-up and in case of operational problems a certain level of process knowledge is indispensable.
- Waste stabilization ponds (WSP) are cheap, efficient in BOD removal – in particular if constructed in series -,simple to operate, do not require electrical energy, are most efficient in removing pathogens, but they require plenty of land. Additionally, depending on sulphate concentration in the crude wastewater and frequency of overloading they might pose an odour problem (Mara and Pearson 1998).
- Trickling filters (TF) are efficient for BOD removal, easy to operate and show small land requirement. What is more, in case of favorable topography they can operate completely without electric energy. In flat areas, where electric energy is needed for pumping of the wastewater on to the top of the TF, it requires still just about 10 % of the energy need of an activated sludge plant (Hanisch 1990).
- Activated sludge systems (AS) are definitely the best choice for very efficient BOD and nutrient removal. But it is more expensive.

Anaerobic systems prove to be an excellent treatment technology for many areas. In future the traditional system of WSP shall definitely compete more and more with UASB systems. Post-treatment still requires aerobic systems, which e.g. can be ponds, trickling filters or activated sludge plants. The bigger the plants, the more economical technologies. Several projects realized that way at present. But for domestic wastewater treatment these systems are not so convenient because of lack of space and odours [2].

For the small local treatment facilities, which is effective for one or few houses, aerobic and anaerobic treatment of wastewater is also used. Purification facilities which base on anaerobic treatment technology and use septic tanks is most frequently. Septic tank-soil absorption systems (wetlands) are relatively inexpensive and are easy to maintain. They are the most common onsite wastewater treatment systems used in rural areas. However, there are many households for which a septic system may not be the best wastewater treatment option. In this case aerobic treatment is suitable for use.

Aerobic wastewater treatment can be a technology for small local facility when:

- the soil quality is not appropriate for a septic system,
- there is high groundwater or shallow bedrock,
- a higher level of wastewater treatment is required,
- there is not enough land available for a septic system.

Advantages

- can provide a higher level of treatment than a septic tank;
- helps to protect valuable water resources where septic systems are failing;
- provides an alternative for sites not suited for septic systems;
- may extend the life of a drainfield and allow for a reduction in drainfield size.

Disadvantages

- more expensive to operate than a septic system;
- requires electricity and includes mechanical parts that can break down;
- requires more frequent routine maintenance than a septic tank;
- subject to upsets under sudden heavy loads or when neglected;
- may release more nitrates to groundwater than a septic system [3].

3. Aerobic biological treatment technologies overview

There are multitudes of aerobic biological treatment processes and technologies in literature and practice; however, for the purpose of this article, four biological treatment technologies are described. Beside description of each process and corresponding advantages/highlights, a qualitative comparison of these technologies is tabulated. This comparison is based on an actual wastewater treatment application for a refinery project, where the treatment requirement was meant for discharge of treated effluent.

- Conventional Activated Sludge Process (ASP) System:

ASP is the most common and oldest biotreatment process used to treat municipal and industrial wastewater. Typically wastewater after primary treatment i.e. suspended impurities removal is treated in an activated sludge process based biological treatment system comprising aeration tank followed by secondary clarifier. The aeration tank is a completely mixed or has a form of plug flow. Bioreactor where specific concentration of biomass (measured as mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS)) is maintained along with sufficient dissolved oxygen (DO) concentration (typically 2 mg/l) to effect biodegradation of soluble organic impurities measured as biochemical oxygen demand (BOD5) or chemical oxygen demand (COD).

The aeration tank is provided with fine bubble diffused aeration pipework at the bottom to transfer required oxygen to the biomass and also ensure completely mixed reactor. Roots type air blower is used to supply air to the diffuser pipework. In several older installations, mechanical surface aerators have been used to meet the aeration requirement. The aerated mixed sewage from the aeration tank overflows by gravity to the secondary clarifier to separate out the biomass and allow clarified, treated water to the downstream filtration system for finer removal of suspended solids. The separated biomass is returned to the aeration tank by means of return activated sludge (RAS) pump. Excess biomass (produced during the biodegradation process) is wasted to the sludge handling and dewatering facility.

- Cyclic Activated Sludge System (CASS TM):

Cyclic Activated Sludge System (CASS TM) as the name suggests is one of the most popular sequencing batch reactor (SBR) processes employed to treat municipal wastewater and wastewater from a variety of industries including refineries and petrochemical plants. This technology offers several operational and performance advantages over the conventional activated sludge process. The CASS™ SBR process performs all the functions of a conventional activated sludge plant (biological removal of pollutants, solids/liquid separation and treated effluent removal) by using a single variable volume basin in an alternating mode of operation, thereby dispensing with the need for final clarifiers and high return activated sludge pumping capacity.

- Integrated Fixed Film Activated Sludge (IFAS) System:

There are several industrial installations where two stage biological treatment comprising stone or plastic media trickling filter (also known as packed bed biotower) followed by activated sludge process based aeration tank, followed by secondary clarifier have been in operation. Another modification of this configuration which has been implemented in newer industrial wastewater treatment systems is fluidized media bioreactor (also known as moving bed bioreactor (MBBR)) in lieu of biotower followed by activated sludge process. In some of the industries (e.g. refineries and petrochemical plants, where the existing wastewater treatment system was single stage conventional activated sludge process (based on aeration tank and clarifier unit), that underwent capacity expansion and/or faced stricter discharge regulations, the up-gradation of activated sludge process by addition of fluidized bio-media has been implemented to meet these requirements. This hybrid process of fluidized media and activated sludge process taking place in a single aeration tank is known as Integrated Fixed Film Activated Sludge (IFAS) process.

- Membrane Bioreactor (MBR):

Membrane Bioreactor (MBR) is the latest technology for biological degradation of soluble organic impurities. MBR technology has been in extensive usage for treatment of domestic sewage, but for industrial waste treatment applications, its use has been somewhat limited or selective. The MBR process is very similar to the conventional activated sludge process, in that both have mixed liquor solids in suspension in an aeration tank. The difference in the two processes lies in the method of separation of bio-solids. In the MBR process, the bio-solids are separated by means of a polymeric membrane based on microfiltration or ultrafiltration unit, as against the gravity settling process in the secondary clarifier in conventional activated sludge process.

4. Conclusions

1. Aerobic microbial communities have several specific advantages. They have large free energy potentials, enabling a variety of often parallel biochemical mechanisms to be operated. These communities are therefore capable of coping with low substrate levels, variable environmental conditions and multitudes of different chemicals in the influent. They have some very useful capabilities such as nitrification, denitrification, phosphate accumulation, ligninase radical oxidation, etc. which make them indispensable in waste treatment.

2. Anaerobic microbial communities are specifically advantageous at high temperatures and high concentrations, of soluble, but particularly of insoluble, organic matter. They also have special physiological traits, such as reductive dechlorination.
3. In the near future, important progress can be expected with regard to the optimal linkage between anaerobic and aerobic processes. Aerobic treatment needs to be specifically focused on the removal of the soluble pollutants.
4. Both in aerobic and anaerobic treatment there is an urgent need for better control and regulation. Particularly on- line monitoring of the biologically removable load (BOD, NOD) and of the possible presence of toxicants is necessary, to improve both types of processes as well as their combined application.
5. It is evident that a long solids residence time (SRT) is necessary for the treatment of sewage by anaerobic processes, because of the low specific growth rates associated with anaerobic bacteria.
6. Fixed-film microbial growth provides intimate contact between the various anaerobic bacteria, thereby providing rates of reaction and degrees of stability which cannot be obtained in suspended growth systems.
7. Up to 1988, either the expanded (or fluidized) bed reactor or the UASB reactor appeared to offer the most desirable configurations for anaerobic sewage treatment. Expanded or fluidized beds have the advantage of hydrodynamic control of film thickness and density, factors which allow them to achieve extremely high biomass concentrations; however, they are more mechanically complicated. They can be improved to a certain degree by increasing the recirculation rate (such as the EGSB).
8. Control of film thickness and density is not currently possible in the anaerobic filter. This places a relatively high lower limit on the HRT that can be utilized, and can eventually lead to process failure by plugging. In general, however, there is a need for more information on the influence of various engineering variables on film density and thickness, especially hydrodynamic factors.
9. In general, the UASB reactor did not use primary treatment, while anaerobic expanded or fluidized bed reactors did. The reason for this lies in the mechanisms of particle entrapment and hydrolysis in the two systems.
10. If secondary treatment is required, the prevention of solids inventory and handling problems, due to the buildup of inert solids in a reactor with long SRT and short HRT would dictate the need for primary treatment. If secondary treatment is not required, one

could use a shorter SRT to achieve the required treatment objectives, and both solids reduction and soluble organics removal could be accomplished in the same reactor.

11. The fate of various wastewater fractions in an anaerobic reactor must be examined, to determine what are the constituents which make up the influent and effluents from these reactors, and whether some pass through untreated. Much of the data in the literature shows that removal efficiencies for sewage have little correlation with organic volumetric loading rate, suggesting that certain constituents in sewage have such low degradation rates, anaerobically, that they are only slightly removed, even under the lowest loading conditions. If these constituents are aerobically degradable, then the effluent from even a "perfect" anaerobic reactor may require further polishing before discharge to a stream, requiring secondary treatment.
12. Another open question is the impact of temperature on the kinetics of biodegradation of various fractions. At low temperatures there may be some materials whose rate of degradation is so low that appreciable removal could not be achieved even at a very long SRT. If that is the case, then anaerobic sewage treatment may be economically feasible only in warmer climates.
13. A better understanding is also needed of the distinction between the destruction and conversion of organic matter, and the coagulation and removal of particulate organic matter. The use of solids filtration in conjunction with an anaerobic reactor might be a useful combination.

References

1. Water and Ecology, 3’2006.
2. B. Wett, K. Buchauer, Comparison of aerobic and anaerobic technologies for domestic wastewater treatment, 2003, p.3-5.
3. Pipeline, Small community wastewater treatments explained to the public. 1996, vol. 7, No.1.
4. Anaerobic methods of municipal wastewater treatment, Frankfurt, March 2001.
5. Water today, Aaron Mittal – Biological wastewater treatment, August 2011 p. 36.
6. Jules B. Van Lier, Biological Wastewater treatment – principles, modeling and design, Chapter 16, Anaerobic wastewater treatment, 2008, , p. 400.

mgr inż. Agnieszka Kisło[1], dr hab. inż. Iwona Skoczko
Politechnika Białostocka,
Wydział Budownictwa i Inżynierii Środowiska,
Katedra Technologii w Inżynierii i Ochronie Środowiska
ul. Wiejska 45A, 15-354 Białystok
e-mail: [1]agnieszka.kislo@wp.pl

Removal of mangan from groundwater by using managnese-coated filter materials

Key words: *remove mangan, groundwater, filtration*

Abstract: Interest in iron and manganese, in the water, especially groundwater, dates back a long time.
This is due to the negative role of these components in the water in case of substantial their concentration. Manganese and iron are the most common components of the earth's crust.
It generally takes (i.e. Polish Norm) that drinking water should not contain: iron compounds in quantities of more than 0.3 mg / l and manganese 0.1 mg/l. Some industries require water for even smaller contents of iron and manganese. Water containing greater amounts of these compounds is characterized by a metallic taste. Mn and Fe often are precipitated from the yellow-brown sediments which stay in water supply system and sanitary devices. Methods of manganese and iron removal need be effective. The basic process of their removal from water is filtration, usually preceded by aeration. This method is effective, simple and relatively low cost. Treatment process is most economical when it is implemented as a single-stage filtering, and therefore an important element for obtaining high efficiency of the treatment is the use of a suitable filter material.

1. Introduction

The best in terms of quality drinking water is water comes from underground, making ground water a vital resource due to its wide dispersion and availability. Traditionally, surplus dissoluble manganese ions in ground water are removed by oxidation followed by rapid sand filtration. Insoluble tetravalent MnO2, formed via aeration, presents a reddish Brown color and silica sand coating previously packed in rapid Sand filter. Coated material, known as “manganese-coated sand” by filter operators, shows greater filter efficiency for soluble metal ions in plain water than silica. Manganese-coated sand is a type of silica medium adsorbing manganese oxide on its surface during long-term filtration and has proven an efficient native filter. Dissoluble ferrite and manganese ions manifest special properties of oxidation and adsorption that have proven commercially beneficial as well. Scientists test and investigate different characteristics of manganese coated sand. Results provide fundamentals of adsorption/ desorption properties for the use of manganese coated sand.

2. Characteristics of groundwater

2.1. Definition and distribution of groundwater

Groundwater include all the water below the surface of the earth, which fill vacancies and crevices in the rocks. Groundwater is only 1.7% of the total water resources on earth [1].

In the literature, there are many divisions of groundwater. They take into account different criteria, i.e. the origin of the water, the type of pressure, position relative to the ground surface, the physical and chemical characteristics and the nature of circulation [2].

Many authors refer to the division of groundwater proposed by Zdzislaw Pazdro in 1977. This division is most commonly used in Poland. It includes groundwater present in the aeration zone and saturation. This division is presented in table 1.1.

Table 1.1. **The division of groundwater**

<table>
<tr><th>Zone</th><th>Type of water</th><th>Physical state</th><th>Types of water</th></tr>
<tr><td rowspan="2">aeration</td><td>hygroscopic water
pellicular water
capillary water</td><td>water associated</td><td rowspan="3">pore water
water slot
fissure-karst water
karst water</td></tr>
<tr><td>water percolate
suspended water</td><td rowspan="2">free water</td></tr>
<tr><td>saturation</td><td>subsurface water
ground water
water plunge
deepwater</td></tr>
</table>

Source: Pazdro Z., : Hydrogeologia ogólna. Wydawnictwa Geologiczne 1977.

Groundwater is located at different depths. The vertical section can distinguish two zones of occurrence: aeration zone, and the zone of saturation. Aeration zone is characterized by the fact that the pores and cracks are filled with air and partly water-related - hygroscopic, pellicular, capillary.

In the saturation zone all free space- slots and pores are completely filled with water, which is subject only to the force of gravity and can easily seep from higher to lower points. Groundwater from this zone is divided into four types: subsurface, land, plunge and deep water [2].

A characteristic feature of groundwater is relatively small flow rate. This refers to the vertical filtration with water infiltration through the aeration zone, as well as for the horizontal flow rate in groundwater tanks. Additional property of groundwater water is slow exchange in comparison to surface water [3].

2.2. Chemical composition of groundwater

Groundwater takes its composition participating in the natural water cycle in nature. It is the result of interaction between water and the surrounding environment [3].

Due to the fact that water often comes from layers located at different depths. That is why it has diverse physic-chemical composition, which is formed under the influence of many interacting factors and processes. The basic factors include the chemical structure and physical structure (grain size, degree of weathering) rock, through which water flows and which dissolves many substances [4].

There are crucial hydrological conditions, especially power and water circulation, climatic conditions, especially the amount of precipitation. In the case of the waters in small depth their composition depends on the type, composition, geological structure and the thickness of the soil layer under which they arrears [5].

This is related to fact that water penetrates from the surface into the ground. From the upper soil layers are leached different substances, and then mixing with groundwater change its quality and properties. Deep groundwater has additional protection, which is an impermeable layer that protects against the entrained from the surface of the earth, chemical pollution and bacteriological contamination [6].

Composition of groundwater is formed as a result of many chemical processes, physicochemical and biochemical. The most important of these are:

- weathering and leaching of rocks,
- precipitation and dissolution salt,
- chemical and biochemical processes of oxidation and reduction,
- sorption, desorption and ion exchange in suspension and colloidal particles [4].

2.3. The quality of groundwater

Groundwater is characterized by high transparency, lack of bacteria, a significant content of dissolved salts, a large amount of iron and manganese, carbon dioxide, hydrogen sulfide, and small amounts of ammonium, nitrate and organic matter [5].

Inorganic (mineral) organic substances are in a natural underground water, dissolved gases and micro-organisms. Inorganic substances are the basic mass solutes. As the basic ions present in groundwater should be mentioned cations of calcium, magnesium, sodium, potassium, and anions such as: bicarbonates, chlorides, and sulfates (VI). Dopants are the most common compounds of iron (II), manganese (II) and silica [3], The group of organic substances include compounds of natural origin, mainly humic substances (humic and fulvic acids), and of foreign origin, that is pollution i.e. pesticides and polycyclic aromatic hydrocarbons. Dissolved gases in the water may come from the atmosphere, or be formed by decomposition of substances contained in the water and impurities. In the groundwater might be present gases such as nitrogen, oxygen, carbon dioxide, methane and hydrogen sulfide [4].

Groundwater is characterized by small number and diversity of microorganisms. This is due to the fact that most of the organisms contained in the water, infiltrated into groundwater are retained in the layers of soil or rock. The growth of microorganisms is limited by low water temperature and low content of organic and mineral substances. The water present in bacteria involve in processes such as oxidation and reduction: ferruginous bacteria, sulfur and manganese [7].

The quality of underground water is stable throughout the all year. Water temperature also remains basically unchanged. It is assumed that groundwater has a temperature close to the mean annual air temperature of the region. The most common groundwater temperature is 8-11° C [5].

Changes properties in water occur under the influence of natural and anthropogenic factors. Substances brought to the water as a result of the action of natural conditions adopted called dopants, and other contaminants. The water treatment processes aims mainly to remove impurities from the water, but also natural additives are cumbersome in terms of water treatment. These include humic substances, dissolved substances present in abnormal concentrations, and in the case of deep water as radionuclides [8].

2.4. Impurities in groundwater

Groundwater is less vulnerable to impurities than surface water, but it is not free from them. The effects of impurities can be long-term and at the same time eliminate the possibility of recognizing the water for many years [9].

To groundwater can reach impurities from the earth surface, as well as atmospheric air and subsoil water. This has the consequence that the water quality and occurring in it impurities are related to the nature of the land use (landfills, agricultural crop areas, urban areas). This represents a basic threat to groundwater.

Groundwater impurities increase with the degree of contact of the water with anthropogenic pollution. Therefore, at the same time the depth of recognizing groundwater and the "tightness" of rock and soil environment reduce the exposure to the negative impact of foreign factors [10].

The main causes of anthropogenic pollution of groundwater are chemical substances which discharge uncontrolled of municipal wastewater, industrial and post-culture to the ground. There are also chemicals in agriculture, pollution of the atmosphere (mainly acid rain), leachate from improperly made or operated landfills for municipal and industrial waste [11].

The pollutant gases i.e. sulfur and nitrogen oxides from industrial areas get into the soil in the form of acidic rain. The increase in acidity of the environment may contribute to increased migration activity of heavy metals [12].

Water for drinking and for economic purposes must be free from anthropogenic pollution, and certain natural additives. Obtaining the required degree of treatment of water, which contain pollutants differing in properties and susceptibility to their removal, is usually very difficult. Great importance is the type of water to be treated. More problems creates groundwater treatment than surface water, due to the presence more of pollution and contamination levels of volatility. This fact makes the surface water treatment systems very flexible [8].

3. Manganese in groundwater

Migration of iron and manganese in groundwater is one of the steps of their long journey in the history of the Earth. Both of these elements migrate in groundwater in the form of ions, and only occasionally in the form of colloids.

The presence of manganese adversely affects the organoleptic qualities water. Manganese is perceptible in water only when the contents of several mg Mn / dm^3, but even with small quantities of water may develop manganese bacteria. They give water an unpleasant taste and smell. In the presence of manganese in the water supply network are formed manganese bacteria. At higher contents of manganese, both under the influence of bacteria, as well as oxidizing agents used for water disinfection, manganese oxides are formed resulting dark brown discoloration of the water [8]. These are shown in picture 1.

Figure 1. Dark sludge in pipe causes higher contents od manganese

Source: http://www.technologia-wody.pl/index.php?req=praktyka&id=28

3.1.Effect of Manganese on Human Health

Manganese is an element necessary for normal metabolism in the human body. This element takes part in physiological processes, mainly as activator of enzymes that regulate the metabolism of carbohydrates, lipids and proteins.

Human daily requirement for manganese is from 2 to 9 mg. This feature of manganese may be replaced by other metals, such as. magnesium. Manganese deficiency can cause deformation of the bones, inhibited growth, and loss of coordination.

Excess of manganese accumulated in the body causes a disorder in the metabolism of other elements, eg. iron, resulting in inhibition of the formation of hemoglobin. There should be mentioned other possible symptoms of neurotoxic and carcinogenic action of manganese. But there is no conclusive evidence of a detrimental effect of manganese.

It was also found that the complete lack of magnesium in the diet causes disturbances in the production of milk and atrophic changes of certain bodies, thinning bones and infertility. Manganese mostly accumulates in the liver and it is excreted through the intestinal tract. Manganese with a lower oxidation level has toxic properties, particularly oxides of divalent manganese. Very dangerous is dust of manganese compounds formed during the extraction of manganese ore. In plants, manganese deficiency causes inhibition of growth and loss of chlorophyll. In the animal organism manganese affects their growth, and indirectly on calcium and phosphorus metabolism.

3.2. Effect manganese on device

Occurring in water iron and manganese compounds have harmful effects to both human health and the installation and device. It cause fouling of installation, yellowing of sanitation and households. Removal of iron and manganese makes:

- a decrease color and turbidity of water,
- in sanitary (sinks, tubs, showers) occur dark, hard removable or even permanent stains,
- limited ferruginous bacteria that cause bacterial corrosion,
- ceases the effect of fouling iron wires, water meters and domestic installations which protects the valve and the installation from silting and mechanical damage,
- change the taste of water, water can be used to produce drinks, juices and other food purposes.

The presence of manganese becomes a problem, because the device must be replaced more often than typical, which is associated with additional costs. In addition, energy costs increase when more power is provided to transport water through the narrowed pipe. Water forms also deposits in the heaters and heating device. These deposits pollute the water supply systems, sanitation and industrial systems as well. Deposits become detached from the walls of the pipeline in the case of network failure or increased flow or changes in the direction. The effect is dirty water in the recipients [13].

4. Methods of removing manganese from water

Processes of iron and manganese removal from the water play a fundamental role in groundwater treatment technology. Anthropogenic salts of iron and manganese are the most troublesome substances that determine their use for municipal and industrial purposes [14] .

Removal of iron from the water is easier than the manganese removal because dissolved in water manganese compounds difficult hydrolyze to their hydroxides. For an efficient hydrolysis reaction pH should be 9.5-10, which involves the alkalinization of water. Choice of appropriate methods of water treatment is related to the form and amount of compounds which are present in groundwater and type of contaminants accompanying to influence the course of the process [15].

There are the following methods for treatment of groundwater:

- aeration and filtration,
- aeration, alkalization, filtration,
- aeration, chemical oxidation and filtration,

- coagulation,
- ion exchange.

Filtration

Filtration consist of passing water through the filter where precipitated impurities are retained. Filtration process is carried out in devices known as filters. Due to the used speed of filtration filters can be divided into:

- slow-filters with the rate of 0.1 m / h;
- quick- filters with the rate of 5 to 15 m / h.

Slow filters work in open and gravity system, and quick filters work in an open and pressure system. In gravitational filters water is filtered under water head pressure resulting from the difference of water level in the filter and the water level in the water tank filtered. However, in pressure filters water is filtered under pressure by the pump [15].

Important aspect is the use of suitable filter material. Currently, there are many types of filtration and oxidation materials. Commonly used is quartz sand, often in combination with anthracite. They can be successfully replaced by new filter materials, deposits of chemically active (catalytic). Their use comes down not only to the mechanical action, but also to active impact through chemical reactions that take place on the surface of the material [15].

5. Research methodology

Manganese-coated sand" is a type of silica medium coated with manganese oxides, formed from the sorption of manganese oxides during long-term filtration via the process of rapid sand filtration, followed by aeration in a water treatment plant.

Manganese-coated sand was collected from the commercial productW-32 (serial number) and prepared under moderate temperature and acidic conditions by impregnation processes with igneous rock and KMnO4. Sand consists of grains with an average radius of 0.6–0.7 mm, specific gravity 2.4–2.5, density 1.0 g/ml covered with a uniform, but friable, reddish brown coating. All solutions were prepared with deionizedwater (Milli-Q) and reagent-grade chemicals, stock cation solutions with Mn2+ standard solution. Impure substances that could easily affect adsorption results were removed by the purification procedures. Acid and alkali resistance tests involved soaking manganese-coated sand in HCl solution and NaOH (pH 2–11±0.1) at 15, 25, and 35^0C for 4 h, respectively. Adsorption isotherms were studied In 20–400 mg/l of Mn2+ solution at pH 5 ± 0, and temperature effect on adsorption was studied at 15, 25, and 35^{0}C, individually [16].

6. Results and discussion

Figure 2 displays kinetic test results of Mn2+ at fixed pH and temperature. After addition of Mn2+ to manganese coated sand suspensions, residual concentration in aqueous phase dropped immediately and decreased gradualny with time. Pseudo-equilibrium of Mn2+ adsorption was attained within 240 min, proving that manganese-coated Sand adsorbed 96.7% till final sampling time. Equilibrium was reached within 4 h; 100% adsorption was never achieved. Residual concentration of Mn2+ did not significantly change between 4 and 24 h [16].

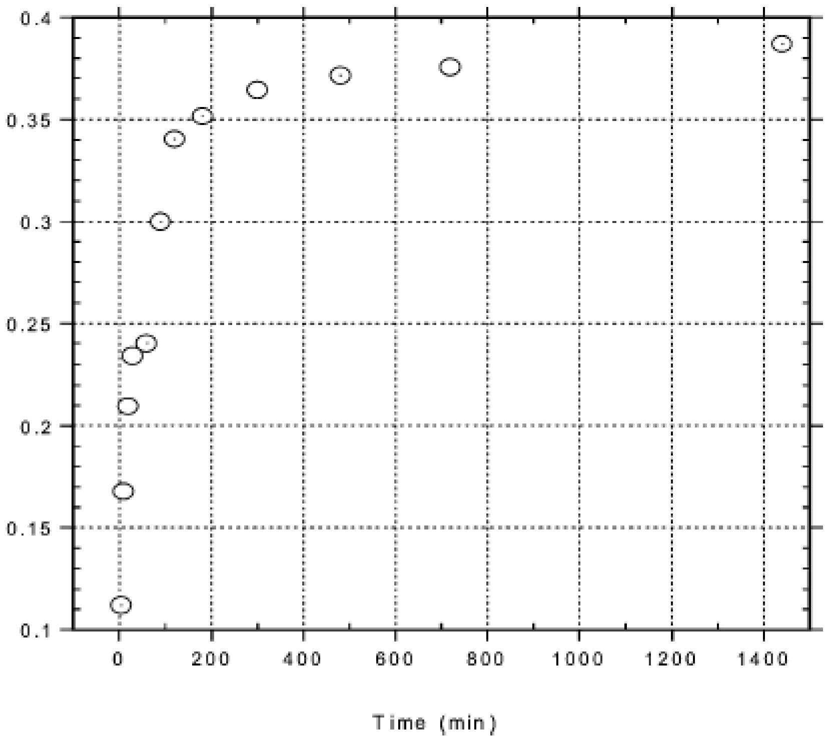


Figure 2. Adsorption of Mn^{2+} on manganese-coated sand for 24 h (pH 5±0.1;*T* = 25± 1 ^{0}C)

Source: http://www.technologia-wody.pl/index.php?req=praktyka&id=28

7. Conclusions

Results of this research build a basis for developing an innovative technology of manganese oxides on sand surfaces for metal ion removal from water. Manganese-coated sand is potentially suitable for application to a packed bed for the removal of h from water could adsorb Mn2+ ion efficiently.

References

1. Macioszczyk A. (2012), Podstawy hydrogeologii stosowanej. Wydawnictwo Naukowe PWN, Warszawa.
2. Kowalski J. (2007), Hydrogeologia z podstawami geologii. *Wydawnictwo Uniwersytetu przyrodniczego we Wrocławiu*, Wrocław.
3. Witczak S., Adamczyk A. (1994), Katalog wybranych fizycznych i chemicznych wskaźników zanieczyszczeń wód podziemnych i metod ich oznaczania. *Biblioteka Monitoringu Środowiska,* Warszawa.
4. Kociołek-Balawejder E., Stanisławska E. (2012). Chemia środowiska. *Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu,* Wrocław.
5. Wąsowski J. (1999). Problematyka uzdatniania wód podziemnych. *Przemysł fermentacyjny i owocowo-warzywny*, 1/1999, 14-15.
6. Pepliński M., Malecki A., Bojanowska I. (2004). Wpływ rodzaju złoża filtracyjnego na skuteczność uzdatniania wód podziemnych na przykładzie ujęć w Tczewie. *Ochrona Środowiska,* 1/2004, 33-38.
7. Grabińska-Łoniewska. (2000), Biologiczne przemiany żelaza i manganu w środowisku oraz w urządzeniach wodociągowych i ciepłowniczych. *Polskie Zrzeszenie Inżynierów i Techników Sanitarnych,* Warszawa.
8. Świderska - Bróż M. (1999), Wybrane problemy w oczyszczaniu wody do picia i na potrzeby gospodarcze. *Ochrona Środowiska,* 3/1999, 7-12.
9. Kowal A. L. (2006), Zanieczyszczenia wód powierzchniowych i podziemnych. *Gaz, woda i technika sanitarna*, 9/2006, 16-20.
10. Cyran J., Senderecki P., Piąstka W., Solnica J. (2006). Analiza jakości wód podziemnych z wybranych studni czwartorzędowych, górnokredowych i dolnokredowych wodociągu dąbrowa w latach 1980 – 2002. *XIX Krajowa Konferencja, VII Międzynarodowa Konferencja: "Zaopatrzenie w wodę, jakość i ochrona wód" WODA 2006.*
11. Łomotowski J. (1995). Podstawy teoretyczne wymywania związków żelaza z gruntu. *Ochrona środowiska*. 4/1995, 9-12.
12. Burchard J. (2002), Zagrożenie, ochrona i jakość wód podziemnych w Polsce w latach dziewięćdziesiątych XX w. *Stan i antropogeniczne zmiany jakości wód w Polsce, Wydawnictwo Uniwersytetu Łódzkiego*, T II., 167-181.
13. Weber Ł. (2012), Usuwanie z wody żelaza, manganu oraz jonu amonowego. *Wodociągi i Kanalizacja*, 3/2012, 43-47.

14. Sozański M. M., Dymaczewski Z., Jeż-Walkowiak J. (2007), Kierunki rozwoju i nowe technologie uzdatniania wody. *Kierunki rozwoju zaopatrzenia w wodę do picia. IV Konferencja Naukowo- Techniczna 9-11 maja 2007 Nowogród k/Łomży.37-55.*
15. Łasińska E., Marjanowski J. (2006), Wybrane problemy usuwania z wód podziemnych związków żelaza i manganu. *Instal*, Nr 4-5, 10.
16. Po-Yu Hu, Yung-Hsu Hsieh, Jen-Ching Chen, Chen-YuChang. Characteristics of manganese-coated sand using SEM and EDAX analysis. *Journal of Colloid and Interface Science* 272 (2004) 308–313.

mgr Beata Cieniawska[1], mgr Katarzyna Dereń, mgr Tomasz Klimza
Wrocław University of Environmental and Life Sciences,
The Faculty of Life Science and Technology Institute of Agricultural Engineering
Chełmońskiego 37/41, 51-630 Wroclaw, Poland
e-mail: [1]beata.cieniawska@up.wroc.pl

The parametric characterisation of the sprayed plants the way to reduce the plant protection products residues in surface waters

Keywords: spray characteristics of plants, the quality of the spray treatment

Abstract: The paper presented the spray characteristics of sugar beet in two phases of development. Taking into account the spray characteristics of plants, according to the authors, is necessary for choosing the right type of nozzle during the spray treatments of plants, because it allows both the increase of efficiency and the reduction of the risk for the natural environment.
The studies were conducted in two stages at the Institute of Agricultural Engineering of the University of Natural Sciences in Wroclaw. The experiments in the first stage were performed on a specially designed research workplace, which essential element was the measuring chamber. The studies consisted of taking photos of the horizontal and vertical plane projections of the plants. Then, the photos were graphically analysed to determine the size of the surface of these projections. While in the second stage the spray surface coefficient was calculated, which was proposed by the authors.

1. Introduction

A guarantor for obtaining high quality and large quantity harvest is to use the plant protection products. In this regard, the priority is the uniform application of the measure on the plant. However, one should bear in mind that preparations used during spray treatments contain highly harmful active substances. From pesticides there is expected:

- high toxicity to pests,
- low toxicity in relation to other living organisms,
- adequate durability,
- high susceptibility to degradation.

While from people performing the spray treatments it is required to use them:

- where necessary,
- in such an amount as is necessary,
- in such a way that does not harm the environment and consumers.

Thus, it can be seen that the requirements for the chemical method of plant protection are very high and depend on the type of the performed procedure. While for predicting the effectiveness one can also use the treatment quality indicators, such as: uniformity of liquid precipitation, the degree of coverage of the sprayed objects and the application of the spray liquid. These indicators include weather conditions, technical and technological ones, e.g., the applied pressure of the spray liquid, liquid dose per hectare, spraying speed, humidity and air temperature during the procedure and the applied nozzles [1, 2, 3, 4]. However, the so-called spray characteristics of plants, that is the species and its phonological phase, is not taken into account. Taking into account the spray characteristics creates the opportunities to increase the efficiency of spraying and the drastic reduction of environmental risks [5, 6, 7].

In view of the foregoing, in the Institute of Agricultural Engineering of the Wrocław University of Environmental and Life Sciences were undertaken studies to determine the parametric characteristics of the sprayed plants.

2. Research methodology

The studies were conducted in the laboratory conditions, on the workplace for studying the plant characteristics. The scheme of the research place is presented in fig. 1. The most important element was the measuring chamber, built of aluminium profiles, and the walls were made of polypropylene foam panels. The studied plant was placed in the central place of the measuring chamber, on the turntable. Them, the photos of the horizontal and vertical projections were taken. The camera for the vertical projections was in front of the chamber and moved across the inclined plane in the horizontal position (front-back), depending on the size of the plant. Photos of the surface of these projections were performed six times, thanks to the possibility to rotate the disc. They were performed against the vertical grid, which could be moved along the guide, also depending on the size of the plant. One side of the square had the dimension of 5 cm.

While the camera for horizontal projections was set inside the chamber and moved vertically (up and down), also depending on the size of the plant. The background when taking photos of the horizontal plane projections was the horizontal grid, which one side also had the dimension of 5 cm.

Due to the fact that the further analysis was applied only to the relations of the recorded surfaces, the distance between the camera and the studied plant did not matter.

To ensure the best lighting conditions on the aluminium profiles, of which the chamber was made, the section LED strips were mounted. During the acquisition, some sections were switched off not to “dazzle” the camera taking photos (Fig. 2).

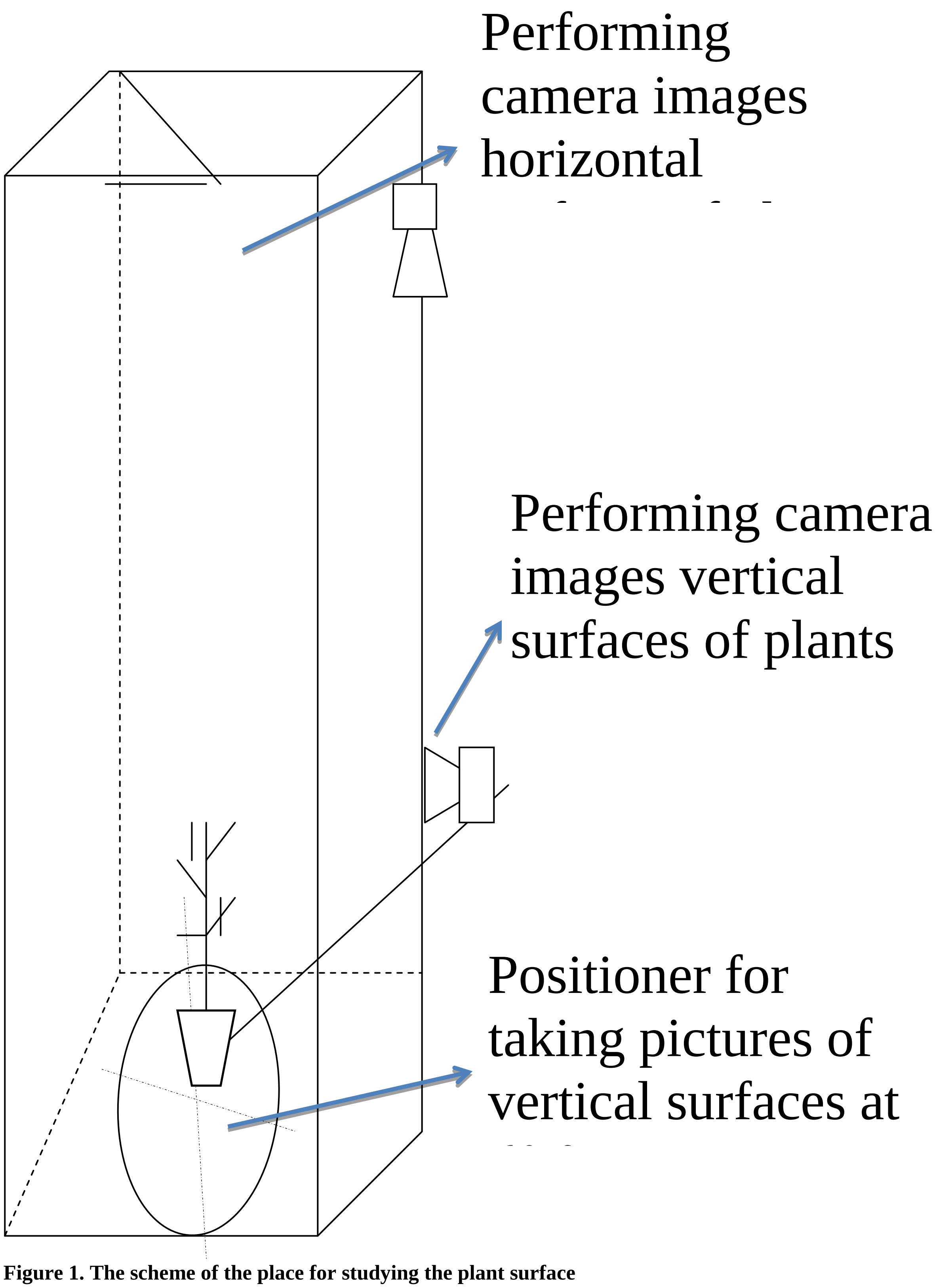


Figure 1. The scheme of the place for studying the plant surface

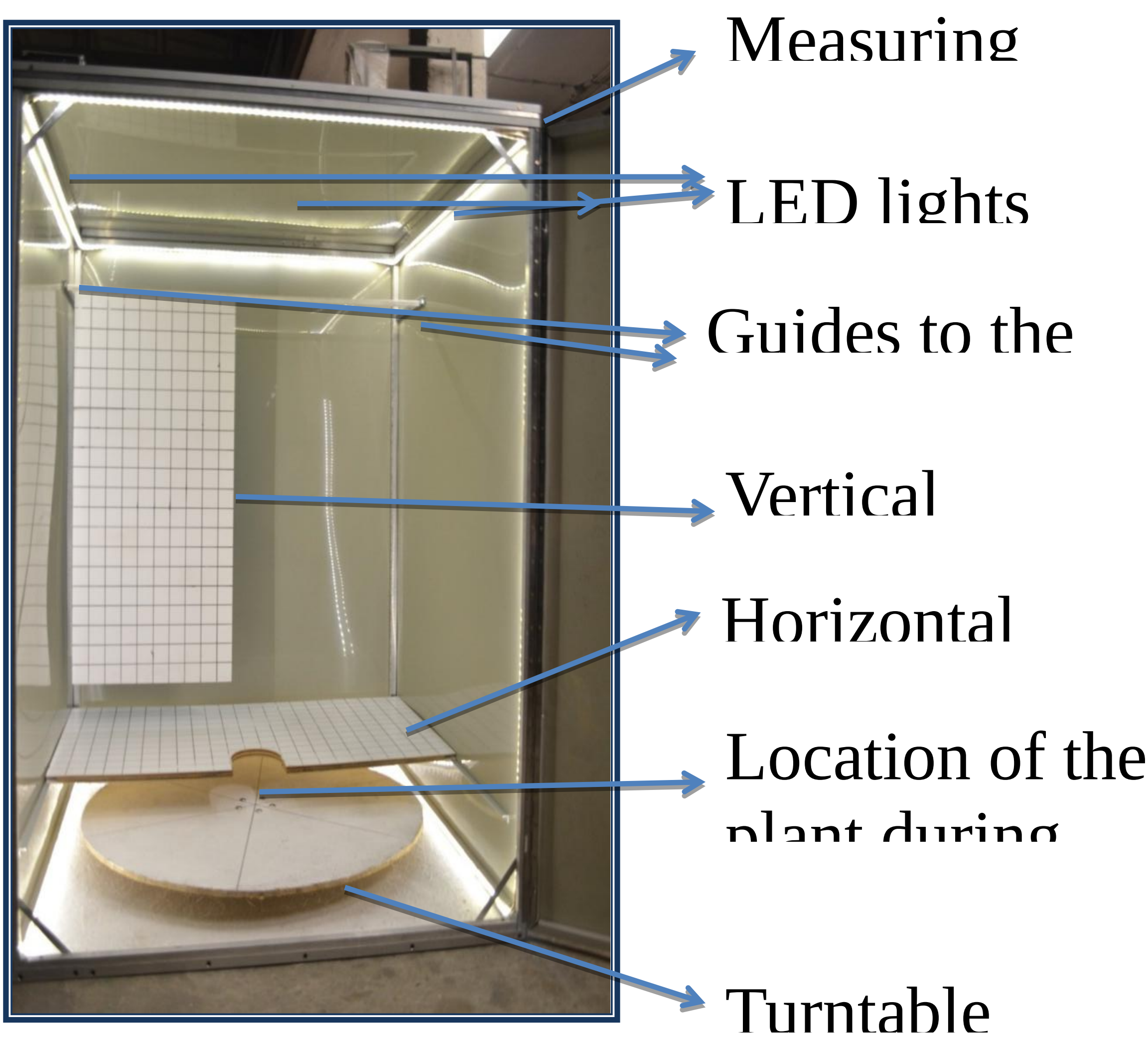


Figure 2. General view of the position

Then, photos were graphically analysed in the AutoCad 2011 program. This analysis was based on dividing the square with an area of 25 cm^2 into 25 squares with the surface of 1 cm^2. The graphic analysis in the open access program was selected, which allows to scale the taken photos. AutoCad 2011 is a tool, which ensured the authors achieved all goals made in the processing of these photos.

Figure 3. The photo of the vertical projection of sugar beet

Figure 4. The photo of the horizontal projection of sugar beet

After obtaining the results of the graphic analysis in the AutoCad 2011 program, the coefficient of the location of the spray surfaces was calculated according to the following equation taking into account the relation of the sprayed surfaces in the vertical and horizontal projection.

$$W_{po} = \frac{area\ vertical\ projection}{area\ horizontal\ projection}\ [-] \tag{1}$$

Sugar beet in two developmental phases were selected for studies: II pairs of proper leaves and the initial phase of covering the spacing.

3. Research results

Research results of the spray characteristics are presented in the graphs (fig. 5 – 8). In fig. 5 and 6 there are presented three repetitions of the obtained results of measurements of surfaces of the horizontal and vertical projections for sugar beet in two phases of development. Sugar beet in the phase of II pairs of proper leaves characterised by a greater surface of horizontal projections than the vertical ones, while in the initial phase of covering the spacing, the situation was reversed.

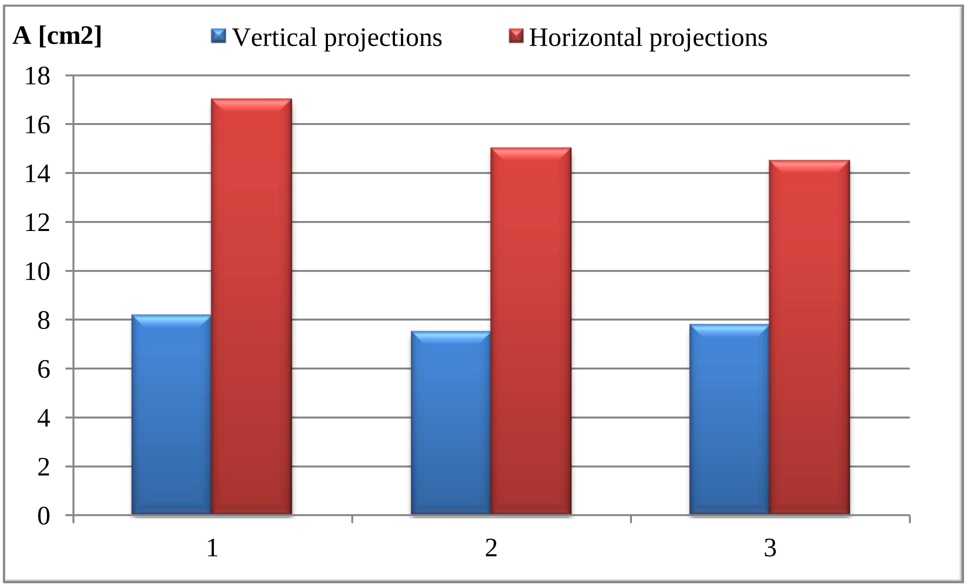


Figure 5. The surface of horizontal and vertical projections of sugar beet in the phase of II pairs of the proper leaves

Source: Own study

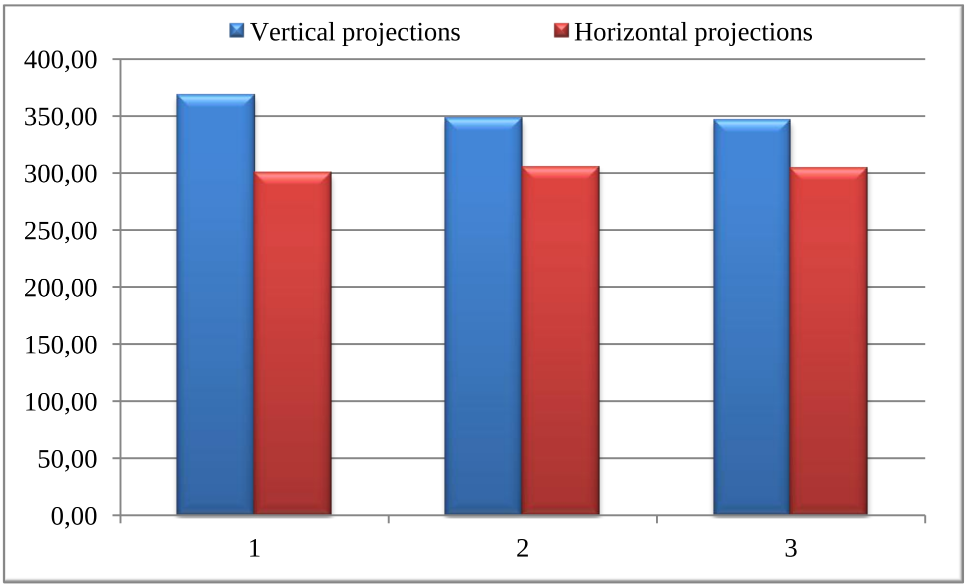


Figure 6. The surfaces of the horizontal and vertical projections of sugar beet in the initial phase of covering the spacing

Source: Own study

In fig. 7-8 there is presented the comparison of the surface of horizontal and vertical projections of sugar beet in a particular phase of development. The surface of projections, both horizontal and vertical, is greater for sugar beet in the initial phase of covering the spacing.

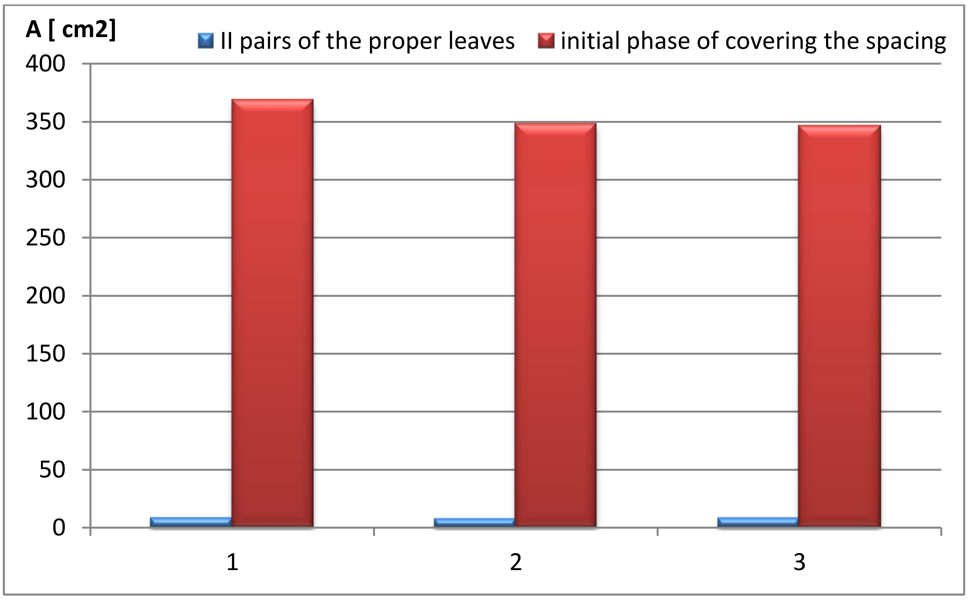


Figure 7. Surfaces of the vertical projections of sugar beet in two phases of development

Source: Own study

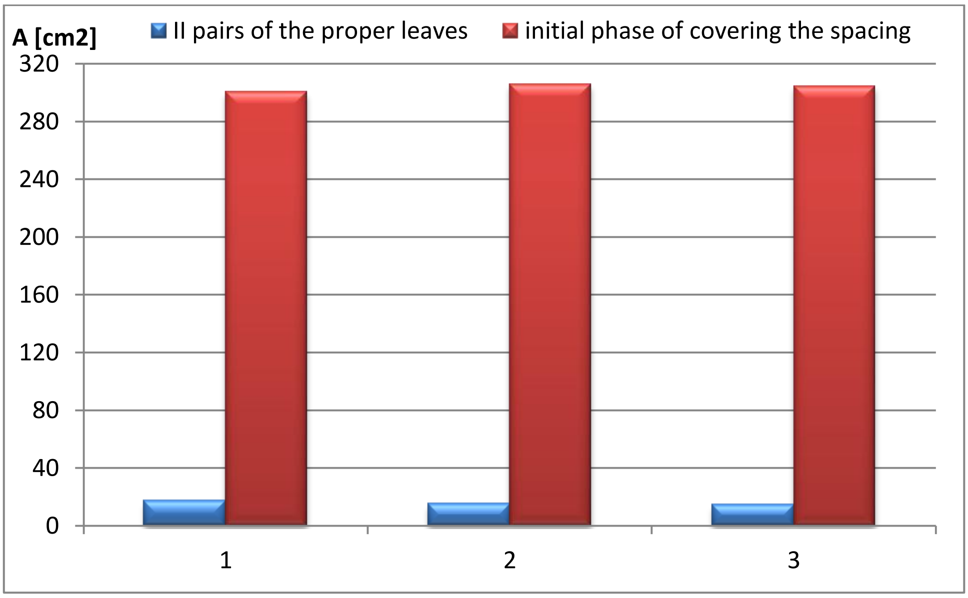


Figure 8. Surfaces of horizontal projections of sugar beet in two phases of development

Source: Own study

In tab. 1 there are presented the values of the spray surface location coefficient. Sugar beet in phase of II pairs of proper leaves, which vertical projection surface was smaller than the horizontal projection surface – the coefficient of the location of spray surfaces was smaller than 1. While in case of sugar beet in the initial phase of covering the spacing,, which surface of vertical projections was greater than the surface of horizontal projections – this coefficient was greater than 1.

Table. 1 Coefficient of the spray surfaces for two phases of development of sugar beet

No.	II pair of proper leaves			Initial of covering the spacing		
	Vertical surfaces	Horizontal surfaces	W_{po}	Vertical surfaces	Horizontal surfaces	W_{po}
1	8,16	17	0,48	368,67	300,25	1,23
2	7,5	15	0,50	347,89	305,75	1,14
3	7,78	14,5	0,54	346,57	304,5	1,14
Average	7,81	15,5	0,51	354,38	303,5	1,17

Source: Own study

The usefulness of the spray surface coefficient in the plant protection technique was discussed by the authors in the published materials [8].

Based on the analysis of the available literature on the research of plant characteristics, the attention should be paid to great interest in the subject. Experiments conducted by the video-computer method aimed to determine the photosynthetic surface of the plants [9]. The results of these tests can be applied both to a single plant as well as per unit of the cultivation area. The research method applied by the authors cannot be used for the experiments for winter wheat due to its anatomical structure. Authors' studies cannot be used for experiments connected with the application of pesticides, because the sprayed objects constitute the defined plans – vertical and horizontal, and the authors' studies refer to one plant. In the authors' studies there was calculated the surface of every leaf separately, what cannot be used for research connected with the application of pesticides. Because during the treatments the nozzle located in relation to a plant "sees" it so that the sprayed surfaces constitute a definite projection for it – vertical or horizontal. The aim of the droplets emitted by the nozzle is the fallout on these planes in the scope, which results from the size of the sprayed surface. The scope of coverage of this sprayed object depends also on the adopted operating parameters and conditions, in which the procedure is performed.

The studies of the discussed scope also related to the indicators of the state of vegetation: LAI – leaf area indicator and MTA – leaf inclination angle indicator. On the basis of the listed indicators there was determined, among others, the influence of the diverse fertilisation on the yield, assessed the influence of the chemical protection of plants in different cultivation systems, size of the yield, changes taking place in the canopy [10, 11, 12, 13, 14].

Just like in the case of studies with the video-computer method, these experiments cannot be used during the studies connected with the application of pesticides, because they do not refer to the surface of plant projections only to the surface of leaves and the angle of their inclination.

4. Conclusions

1. Plants selected for the research were characterised by a great diversity of parameters adopted for the spray characteristics, i.e., the surface of the horizontal projection, the surface of the vertical projection and coefficient of the spray surfaces.
2. The use of the spray surface coefficient $W_{po,}$ informs about the relation of particular surfaces, what opens up the possibilities to select the most appropriate parameters of the spraying process depending on the target pests and morphological features of the plant.
3. The use of the results of the spray characteristics of the protected plants during the procedures can significantly increase the efficiency of the spraying process largely limiting the p.p.p. loses and treats resulting from the uncontrolled spread of pesticide beyond the spraying target through the surface and ground water.

References

1. Nuyttens D., de Schampheleire M., Verboven P., Brusselman E., Dekeyser D. *Droplet size-velocity characteristics of agricultural sprays*. Trans. ASABE 52(5). 1471–1480. 2009.
2. Özkan H. E. *Technological Solution to Problems Associated with Application of Pesticides*. Jor. of Agricultural Machines Sciences 4(2). 193-198. 2008.
3. Szewczyk A. *Analiza ustawienia, parametrów i warunków pracy rozpylacza w aspekcie jakości opryskiwania upraw polowych.* Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu. ISSN 1898-151. 2010.
4. Szewczyk A., Łuczycka D., Rojek G., Cieniawska B. *Wpływ prędkości i typu rozpylacza na stopień pokrycia poziomych i pionowych powierzchni opryskiwanych.* Inżynieria Rolnicza. 4 (147). 355-364. 2013.
5. Cieniawska B., Łuczycka D., Szewczyk A. *Characteristics crop plants in the aspect of the process of spraying.* Mechanization in Agriculture 6. 29-33. 2014a.
6. Cieniawska B., Łuczycka D., Szewczyk A. *The quality of procedure spraying on crops flat in the aspect of sprayed plants.* Mechanization in Agriculture 6. 34-38. 2014b.
7. Łuczycka D., Szewczyk A., Cieniawska B. *Charakterystyka opryskowa wybranych roślin metodą graficzną.* Aktualne problemy inżynierii biosystemów. Poznań. 42-51. 2014.
8. Łuczycka D., Szewczyk A., Cieniawska B. *Nierównomierność pokrycia opryskiwanych obiektów wybranymi rozpylaczami jedno- i dwustrumieniowymi.* Inżynieria Rolnicza. 1 (149). 101-110. 2014 .

9. Kiełbasa P., Juliszewski T. *Pomiar powierzchni liści wybranych roślin metodą video-komputerową.* Inżynieria Rolnicza. 74 (14). 169-175. 2005.
10. Andruszczak S., Kwiecińska-Poppe E., Kraska P., Pałys E. *Wpływ niektórych środków ochrony roślin na kształtowanie powierzchni liści i kąta ich nachylenia u wybranych odmian ozimych pszenicy orkisz (Triticum aestivum ssp. spelta L.).* Postępy w ochronie roślin / Progress in plant protection. 52 (1). 163-166. 2012.
11. Biskupski A., Kaus A., Włodek S., Pabin J. *Zróżnicowane nawożenie azotem a plonowanie i wybrane wskaźniki architektury łanu kilku odmian pszenicy jarej.* Inżynieria Rolnicza. 91 (3). 29-36. 2007.
12. Biskupski A., Włodek S., Pabin J. *Wpływ zróżnicowanej uprawy roli na wybrane wskaźniki architektury łanu oraz plonowanie roślin.* Fragmenta Agronomica. 26 (4). 7-13. 2009.
13. Gołębiowska H., Sekutowski T. *Ocena selektywności herbicydów stosowanych w monokulturze kukurydzy z wykorzystaniem wskaźnika powierzchni liści (LAI) i kąta nachylenia liści (MTA).* Inżynieria Rolnicza. 91 (3). 51-58. 2007.
14. Woźniak A. *Wpływ zróżnicowanego udziału pszenicy jarej w zmianowaniu na indeks powierzchni liści (LAI).* Acta Agrophysica. 12 (1). 269-276. 2008.

mgr inż. Piotr Ofman[1], mgr inż. Dawid Łapiński
Bialystok University of Technology, Facility of Technology
in Environmental Engineering and Protection
15-351 Białystok, str. Wiejska 45A
e-mail: [1]p.ofman@pb.edu.pl

Changes analyses of metallic elements in sewage sludge form small wastewater treatment plant

Key words: *sewage sludge, parametrical correlation, metallic elements*

Abstract: Main purpose of this study was to evaluate changes of total Cr, Pb, Cd, Zn, Cu, Ni and Hg in sewage sludge form Municipal Wastewater Treatment Plant in Stawiski in period from 2011 to 2014. Amount of each element decreased in study period. Most from studied elements reached their highest amounts in second part of year 2011. Statistically significant correlation were observed between Cr, Pb, Zn, Cu, Ni and amount of sewage sludge dry mass.

1. Introduction

Chemical composition of sewage sludge depends on quality of wastewater that inflows to wastewater treatment plant. Differential concentrations of metallic elements in raw sewage are related to industrialization level and characteristics of settlement unit, from which they are flowing to wastewater treatment plant [2].

Metallic elements, due to their characteristic, are not subjected to biological degradation during sewage treating processes. Removal mechanics of each element consist on their accumulation in activated sludge flocks. As an effect of this process there are obtained lower metal concentrations in treated sewage, but higher amounts in sludge [37].

Sludge recirculated from technological system is one of the basics waste. Sludge mostly is disposed by landfill. However due to its properties and large amounts of nitrogen and phosphorus compounds it can be used for fertilization purposes [1, 17]. Main problems in agricultural usage of sewage sludge are their sanity conditions and chemical composition, which includes inter alia metallic elements [38]. Microbiological criteria are obtained in stabilization processes [20]. While heavy metals and metallic elements problem stays unsolved. Polish legislation determinates the amount of sewage sludge used for agricultural purposes depending on concentration of each metallic element. Keeping appropriate doses of sludge in fertilization process is very important in long time interval, mainly due to their accumulation in soils. Concentrations of metallic elements in sewage sludge are standardized by Annex no 1 to Regulation of the Environment Minister form 13 July 2010, on municipal sewage sludge.

Limit values are listed in Table 1.

Table 1. Acceptable amounts of heavy metals in municipal sewage sludge.

No.	Metals	Concentration of heavy metals in mg/kg of sludge dry mass not higher than: with usage of municipal sewage sludge in		
		In agriculture and land reclamation for agricultural purposes	For non-agricultural land reclamation	In land adjustment for specific needs resulting from waste managements plans
1	Cadmium (Cd)	20	25	50
2	Copper (Cu)	1000	1200	2000
3	Nickel (Ni)	300	400	500
4	Lead (Pb)	750	1000	1500
5	Zinc (Zn)	2500	3500	5000
6	Mercury (Hg)	16	20	25
7	Chromium (Cr)	500	1000	2500

Source: Rozporządzenia Ministra Środowiska z dnia 13 lipca 2010 roku

Main purpose of this study was to evaluate changes of studied metallic elements in municipal sewage sludge from Wastewater Treatment Plant in Stawiski.

2. Methodic and study area

Sewage sludge studies were carried out in Municipal Wastewater Treatment Plant in Stawiski. This plant is characterized by an equivalent number of inhabitants at about 2600. Non industrial sewage inflows to wastewater treatment plant. Therefore, chemical composition of sewage sludge was mainly associated with the residents of town and municipality living activities. Wastewater treatment plant capacity was calculated on following sewage amounts:

- hourly maximum- 30,82 $m^3 \cdot h^{-1}$
- average per day- 370 $m^3 \cdot h^{-1}$
- daily maximum- 554 $m^3 \cdot h^{-1}$
- annualy maximum- 202210 $m^3 \cdot year^{-1}$

Domestic waste water transported from the community of Stawiski are delivered to the storage point (two concrete chambers equipped with gratings), from where sewage are getting to wastewater treatment plant technological system. Waste water from the city of Stawiski runs through gravity sewer system to two sewage pumping stations, located on Dluga and Ogrodowa Street, from where they are pressed into the expansion chamber - a tank of rectangular base. Then the sewage flows to the radial sand trap, where the removal of solids is performed. From radial sand trap wastewater flow to the anaerobic chamber equipped with a horizontal stirrer, whose task is the selection for metabolic filamentous bacteria and the initial phase of biological phosphorus removal [30].

After phosphorus removal, sewage flows into the first aerobic chamber in which occurs aeration process via diffusers disk with a diameter of 270 mm powered by side-channel fan of type SC40C with 7.5 kW motor, with a capacity of 300 $m^3 \cdot h^{-1}$ and overpressure equal to 300 mbar. Air demand is adjusted on the basis of readings obtained from oxygen probe SENCO type IOMm, sensor SENCO OS-8t processes signal on the measured value. From the first aeration chamber sewage flows into the second aeration chamber. The chamber is equipped in such disk diffusers, as in the first aeration chamber. After the aeration process flows to secondary settling tanks, from which are discharged through larval with combs to control well. From the control well sewage flows into measuring device (electromagnetic flow meter MPP04), where the current quantity of treated sewage discharged into a drainage ditch is registered [30].

From second aeration chamber sludge is recirculated to anaerobic chamber and to first aeration chamber with usage of INFRA200TEKO pump. External recirculation of sludge from the secondary settling tanks to the aeration chamber is carried out by airlift pumps. In contrast, the removal of excess sludge from the second aeration chamber is followed by a INFRA100TEKO pump. Excess sludge is directed to sludge stabilization chambers, where it is aerobically stabilized and concentrated. It is then dewatered on a belt press type MONOBELT NP08CK, from where it goes to the sludge drying beds. Sewage treatment plant in Stawiski has four sludge drying beds made of concrete, insulated by izolbet [30].

Sludge dewatering takes place in the period from November to April. In the rest of the year sludge goes to cane lagoon, which bottom and sides are lined with foil of thickness equal to 0.5 mm. At the lagoon bottom, there are located drainage pipes and filtration layer. Filtration layer consists of the following fractions: 20 - 63 mm - 25 cm thick; 2.4 - 6.8 mm - 20 cm thick, friable sand with a thickness of 25 cm [30].

The sand has been planted with cane in amount of 25 pieces per 1 m^2. Arranged drainage pipes are connected with a aggregate well. Dewatered sludge, after positive test results, is used to fertilize the soil intended for purposes other than farming in accordance with Decision no. BŚ.6233.8.2011 [30].

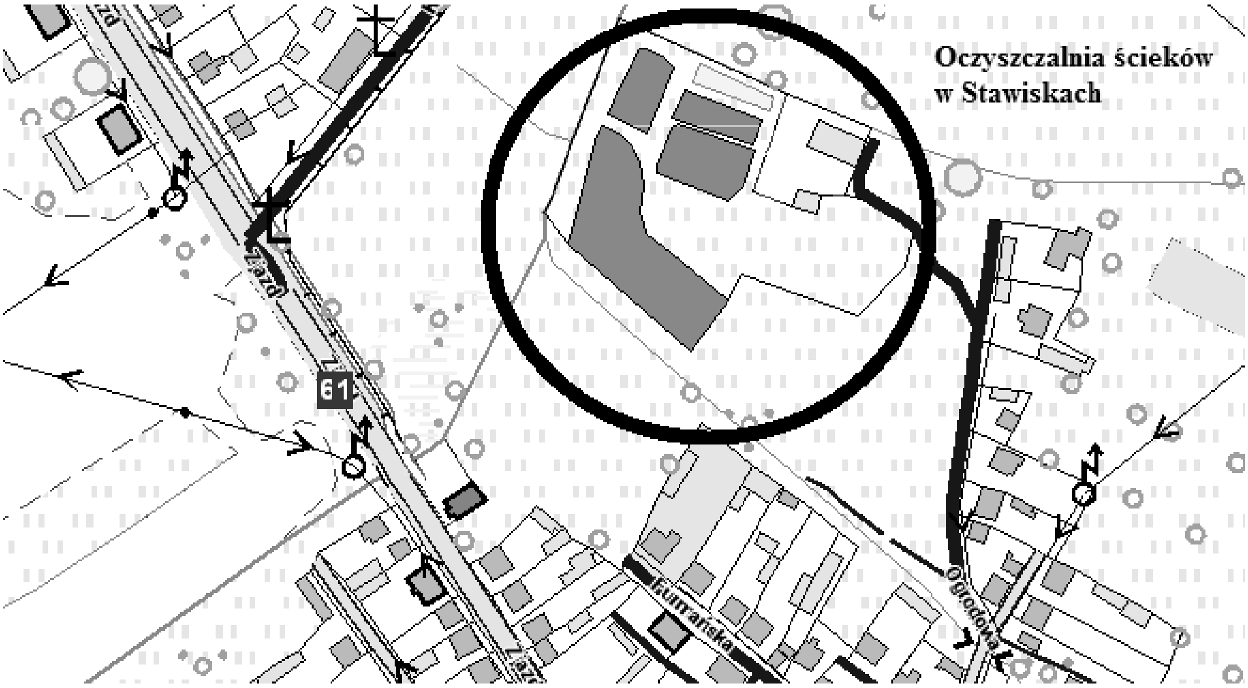


Figure 1. Municipal Wastewater Treatment Plant in Stawiski

Source: [12]

Samples were collected in years form 2011 to 2014 twice a year- in June and December. In year 2011 only one sample was collected in December. In sewage sludge following parameters were analyzed: pH, amount of dry mass, amount of organic substances, total nitrogen, total phosphorus and concentration of Ca, Mg, total Cr, Zn, Cd, Cu, Ni, Pb and Hg. Studies were carried out by Regional Environmental Protection Inspectorate in Bialystok Delagature in Lomza. Analyzed parameters were indicated according to following standards and research procedures:

- pH- PN-EN 12176:2004,
- Dry mass- PN-EN 12880:2004,
- Organic substances- PN-EN 12879:2004,
- Total nitrogen- PN-EN 13342:2002,
- Total phosphorus- PN-EN ISO 6878:2005,
- Ca and Mg- PB-FC-25/Bł. wyd. 1 z dnia 15.03.2013,
- Pb, Cd, Zn, Cu and Ni- PN-ISO 11047:2001,
- Hg- PB-FC-22/Bł. wyd. 1 z dnia 15.03.2013,
- Total Cr- PB-FC-21/Bł. wyd. 1 z dnia 15.02.2013.

On the basis of carried out studies statistical parameters such as arithmetic mean, minimum, maximum, standard deviation and median were calculate. In addition the analysis of Pearson parametrical correlation was made. Correlation coefficient significance was determinate for α= 0,05 and for the high value of interdependence of two variables was interval (-1,00;-0,65) ∪ (0,65; 1,00). For statistical processing of achieved data base the Statistica 10 in Polish language was used. Software was working on Windows 7 Home Edition platform.

3. Results and discussion

Variability of each controlled parameter in research period is shown in figures 2- 15 and basic statistical measures were summarized in tables 2 and 3. Observed dependences between each variables were expressed as Pearson correlation coefficient. Values for individual coefficients were shown in tables from 4 to 6.

Table 2. Statistical measures for basic variables

Statistical measure	pH	D.M.	O.D.M.	Ca	Mg	Total N	Total P
	-	%	%	%	%	%	%P_2O_5
Arithmetic Mean	-	14,9	75,0	7,1	2,2	7,0	6,4
Median	7,2	14,5	78,6	7,4	2,1	7,1	6,8
Minimum	6,0	13,1	59,2	3,8	0,6	3,8	1,6
Maximum	7,3	18,3	82,5	9,8	3,8	8,8	10,2
Standard deviation	0,4	1,7	9,0	2,0	1,1	1,5	2,6

Source: Own elaboration

Table 3. Statistical measures for metallic elements

Statistical measure	Total Cr	Zn	Cd	Cu	Ni	Pb	Hg
	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.	$mg\cdot kg^{-1}$ d.m.
Arithmetic Mean	15,4	907,6	1,0	289,6	12,1	16,7	0,6
Median	13,0	790,0	1,0	283,0	10,0	12,8	0,6
Minimum	7,5	637,0	0,4	120,0	6,4	11,3	0,1
Maximum	31,9	1575,0	1,7	493,0	25,6	40,9	1,9
Standard deviation	8,3	317,6	0,4	124,0	6,3	10,8	0,6

Source: Own elaboration

Sewage sludge pH was not changing significantly during study period. One minimum value of this parameter was observed- in first half of 2012, where pH was equal to 6,0. For the remaining part of studies pH did not change more than 0,3. Similar pH values in sewage sludge where observed by Kaznowska and Szaciło [19] in studies carried out at Suwałki wastewater treatment plant. Sludge from that plant had pH slightly acidic (6,9) and neutral (7,9). Close values to those obtained in Stawiski were also achieved by Wysokiński and Kalembasa [39] in studied carried out at Siedlce and Lukowo wastewater treatment plant. Values of pH in studied plants were equal respectively 6,4 and 6,2. As authors note, the sewage sludge in its natural conditions should be similar to slightly acidic or neutral.

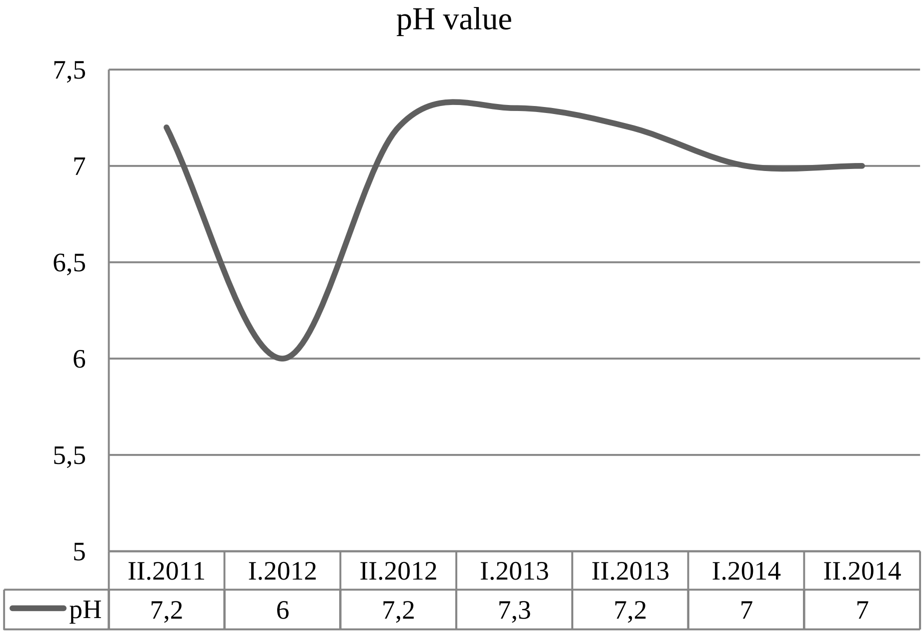


Figure 2. Values of pH in study period

Source: Own elaboration

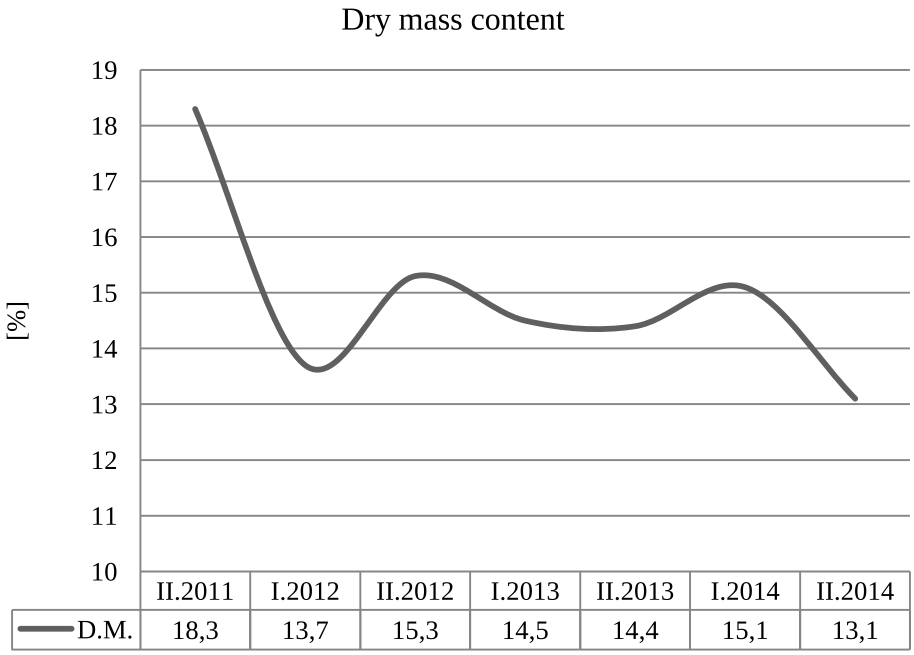


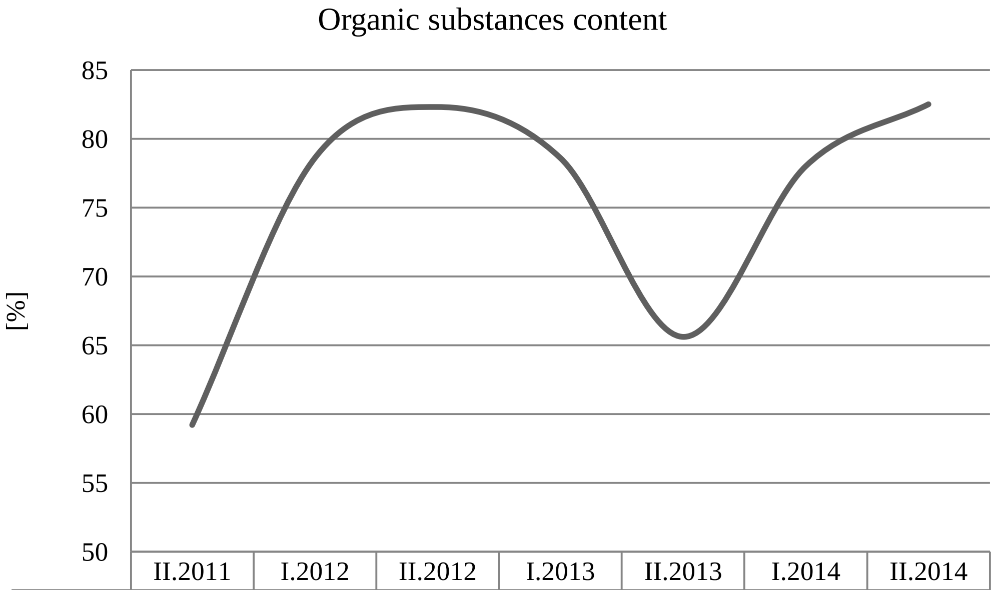
Figure 3. Dry mass content in study period

Source: Own elaboration

Sludge dry mass content decreased progressively over study period. The highest amount of this indicator was observed in second half of 2011. In period from 2012 to first half of 2014 dry mass was changing in range from 14% to 15%. The lowest amount of this indicator was observed in second half of 2014, where dry mass was equal to 13,1%. Higher dry matter amount were observed by Szwedziak and Woźniaka [36] at wastewater treatment plant in Strzelce Pomorskie. Authors have obtained in their studies dry matter at level of

25,6%/ Lower dry mass content was observed by Miodoński and Iskra [28] in studies carried out at sewage treatment plant in Brzeg. Analyzed samples were characterized by dry matter content at level raging from 2,26% to 3,93%. Miodoński and Iskra notes that in exanimated plant no seasonal changes were observed in dry matter content.

Organic matter content was ranging from 60% to 82,5%. Its lowest value was observed twice, in the second half of 2012 and in second half of 2013. The highest value of this indicator was observed in second half of 2014. This parameter did not show any seasonal changes during study period. Similar organic dry matter content was observed by Parkitna et all [31] in studies carried out in Warta wastewater treatment plant in Czestochowa. Authors achieved dry organic mass at level equal to 74%. Much lower amount of organic matter was observed by Grosser et all [13] in studies conducted over mixture of thickened excess sludge and pre- treated sludge from municipal wastewater plant with addition of vegetables fat, which came from methyl esters fatty acid facility. Level of organic matter in that mixture was ranging from 2,08% to 2,88%.



	II.2011	I.2012	II.2012	I.2013	II.2013	I.2014	II.2014
O.S.	59,2	78,6	82,3	78,6	65,6	78	82,5

Figure 4. Content of organic dry mass during research period

Source: Own elaboration

Calcium contend in study period was clearly increasing from the first half of 2012 to first half of 2014, where it reached its maximum. The lowest Ca content was observed in first half of 2012. Lower Ca content was achieved by Jackowska i Olesiejuk [16] in studied carried out in wastewater treatment plant in Lubartowo. Authors in studied samples obtained calcium content at level equal to 22,8 mg·kg^{-1} d.m. in 2011 and 19,8 mg·kg^{-1} d.m. in 2012. Similar range of Ca in sewage sludge was achieved by Bodzek et all [4] in wastewater treatment plants at Upper Silesia. Authors observed varying Ca content in range from 3 mg·kg^{-1} d.m. to 34 mg·kg^{-1} d.m. depending on studied plant. Authors emphasizes that Ca content in studied treatment plants were not differ significantly from other such plants. It is worth mentioning that the highest Ca content was observed in industrial areas, while the smallest in non-industrialized.

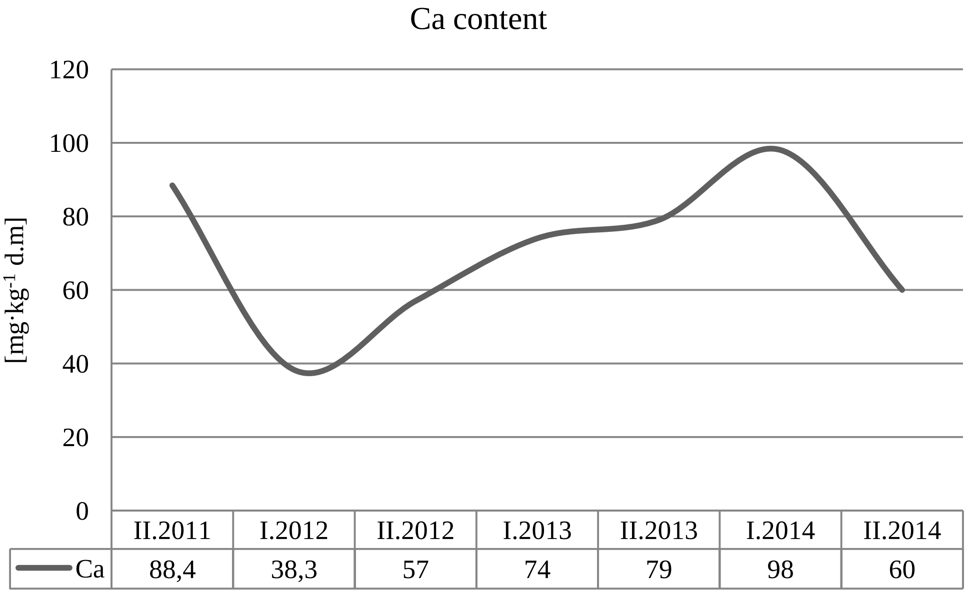


Figure 5. Ca concentration during research period

Source: Own elaboration

Magnesium content changes in research period were similar to Ca changes. The highest content of Mg was observed in second half of 2011, and the lowest in second half of 2012. From first half of 2013 to the end of studies magnesium content was successively increasing. Referring obtained Mg content to studies carried out by Siebieleca and Stuczyńskiego [34] it has been noted that Mg content in wastewater treatment plant in Stawiski was higher than average amount of this element in other sewage treatment plants in Poland. Siebielec and Struczyński were analyzing chemical composition of sewage sludge in 43 different wastewater treatment plants from Poland. Average amount of Mg obtained by authors was equal to 5,8 mg·kg^{-1} d.m. Similar amounts were observed by Filipiak et all [9]. In studies carried out in wastewater treatment plant in Bytkowo authors obtained Mg concentration at level
0,5 mg·kg^{-1} d.m.

Total nitrogen content during research period did not vary significantly. The lowest content of this element was observed in second half of 2011 and it was equal to 3,8%, while the highest content was 8,8%. Starting from 2012, average nitrogen content was equal to about 7% and stayed at this level to the end of studies. Similar total nitrogen content was obtained by Błaszczyk i Krzyśko- Łupicką [3] in an analytical methods review paper. Total nitrogen concentration obtained from Polish wastewater treatment plants by authors were similar to results achieved in Stawiski. Comparable amount of total nitrogen was obtained by Mazur

i Mokra [27] in studies carried out from wastewater treatment plants form warmińsko-mazurksie voivodship.

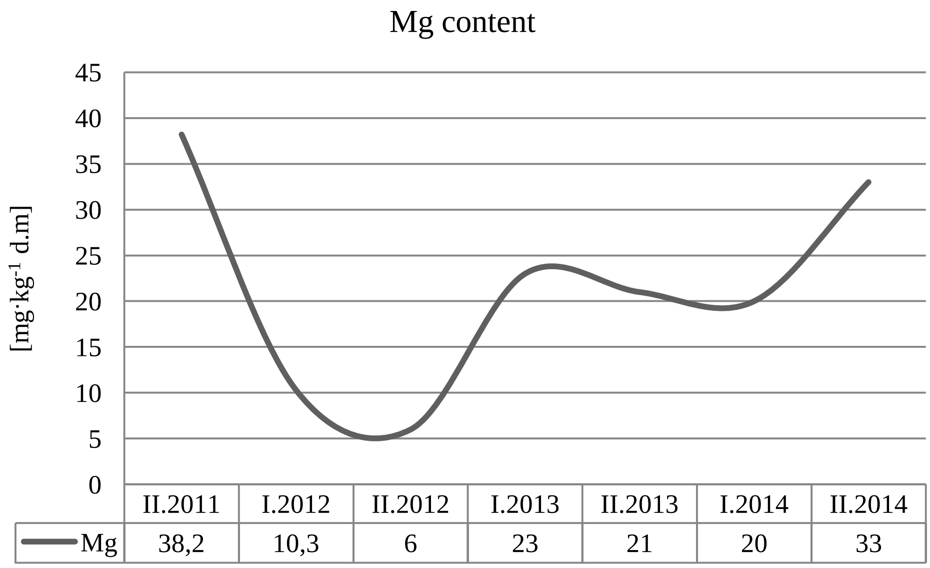


Figure 6. Mg concentration during research period

Source: Own elaboration

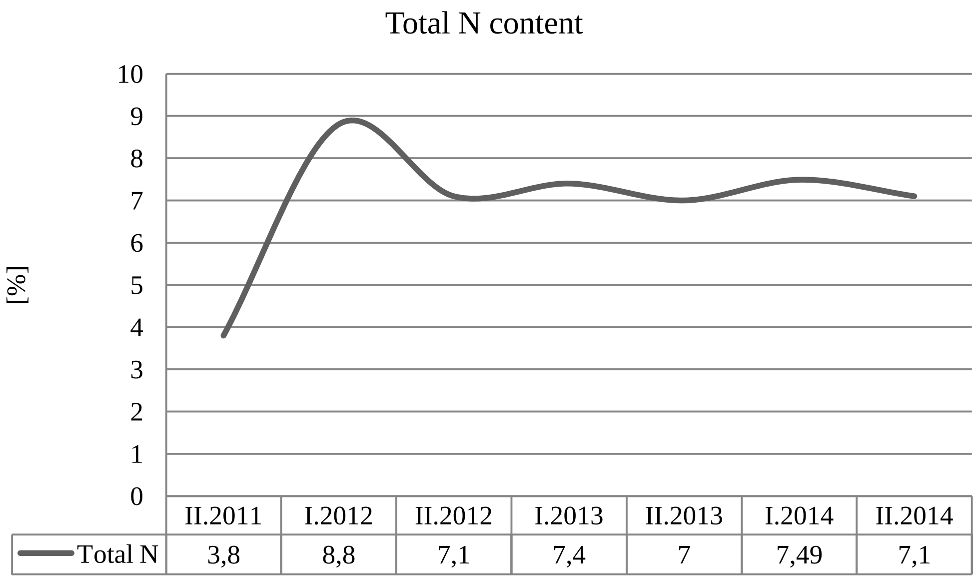


Figure 7. Total N content during research period

Source: Own elaboration

Total phosphorus concentration in sewage sludge was varied during research period. Minimum value of this element was observed in second half of 2014, while the highest in second half of 2013. Similar phosphorus content was obtained by Kuziemska and Kalembasa, [22] in studies carried out in Siedlce and Lukowa wastewater treatment plant.

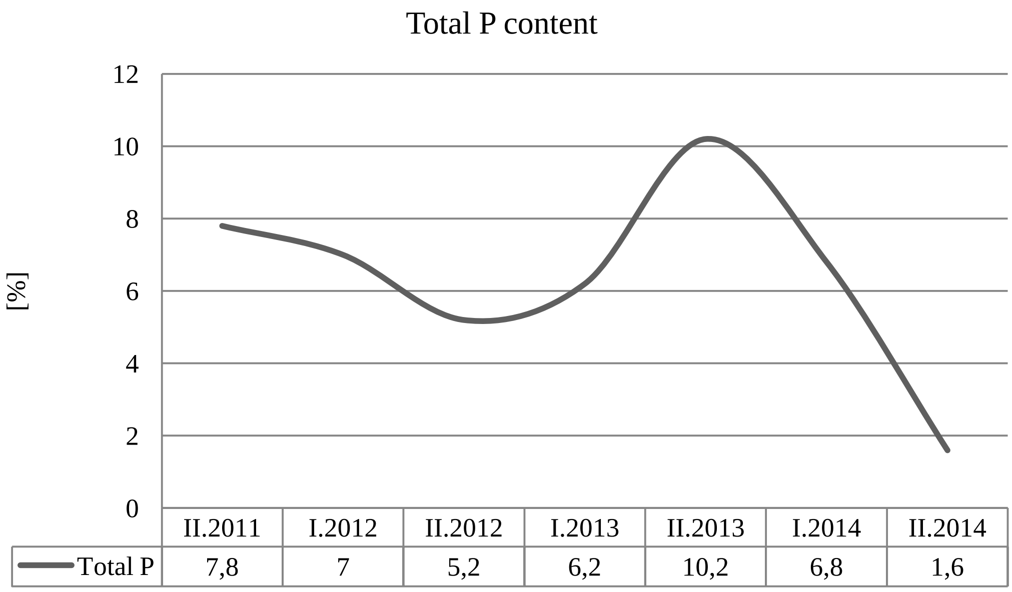


Figure 8. Total P content during research period

Source: Own elaboration

Total Cr content in overall study period was not subjected to harmonized trend of changes. The highest concentration of this element was observed on second half of 2011, which was equal to 31,9 mg·kg^{-1} d.m. Minimal amount of Cr was achieved in the first half of 2012 and was equal to 7,5 mg·kg^{-1} d.m.. In the remaining study period total Cr content was increasing to second half of 2013, where it reached its second maximum which was equal to 20,3 mg·kg^{-1} d.m.. From that moment concentration of this element was decreasing for rest of study period. Similar to maximum concentration observed in Stawiski was obtained by Gawdzik [10] in studiem carried out in sewage treatment plant located in Busko- Siesławice in świętokrzyskie voivodship. Author has achieved Cr concentration at level 35,24 mg·kg^{-1} d.m.. Similar range of this element was obtained by Stańczyk- Mazanek i et all [35] in studies carried out in wastewater treatment plant based on hybrid technology of floating bed with simultaneously activated sludge process in sludge that was formed in Imhoff settling tank, and in wastewater treatment plant where polyelectrolyte additive was used in treatment processes. Total Cr range obtained by authors was form 1,6 to 21 mg·kg^{-1} d.m..

Zinc content in study period was subjected to similar changes trend to total Cr. The highest amount of that element was noted in second half of 2011 and in the second half of

2013, However the second peak was characterized by lower concentration, approximately 500 $mg \cdot kg^{-1}$ d.m.. Observed maximum were equal respectively 1575 and 1029 $mg \cdot kg^{-1}$ d.m.. The lowest Zn concentration was observed in first half of 2012 and amounted to 637 $mg \cdot kg^{-1}$ d.m.. Similar concentrations of this element was noted by Latosińska and Gawdzik [24] in studies carried in wastewater treatment plants in central Poland. Zn concentrations obtaindeb by authors in wastewater treatment plant in Strawczynie and Sitkówa- Nowiny were corresponding to maximal levels of this element in Stawiski. On the other hand, amount of Zn observed in Kostomłotach- Laskowa and Busko- Siesławice were similar to minimal values of this element in Stawiski. Amount of Zn close to maximum level observed in Stawiski were abtained by Boruszko [6] in studies on sewage sludge from wastewater treatment plant in Wysokie Mazowieckie, processed for two years by wermiculture.

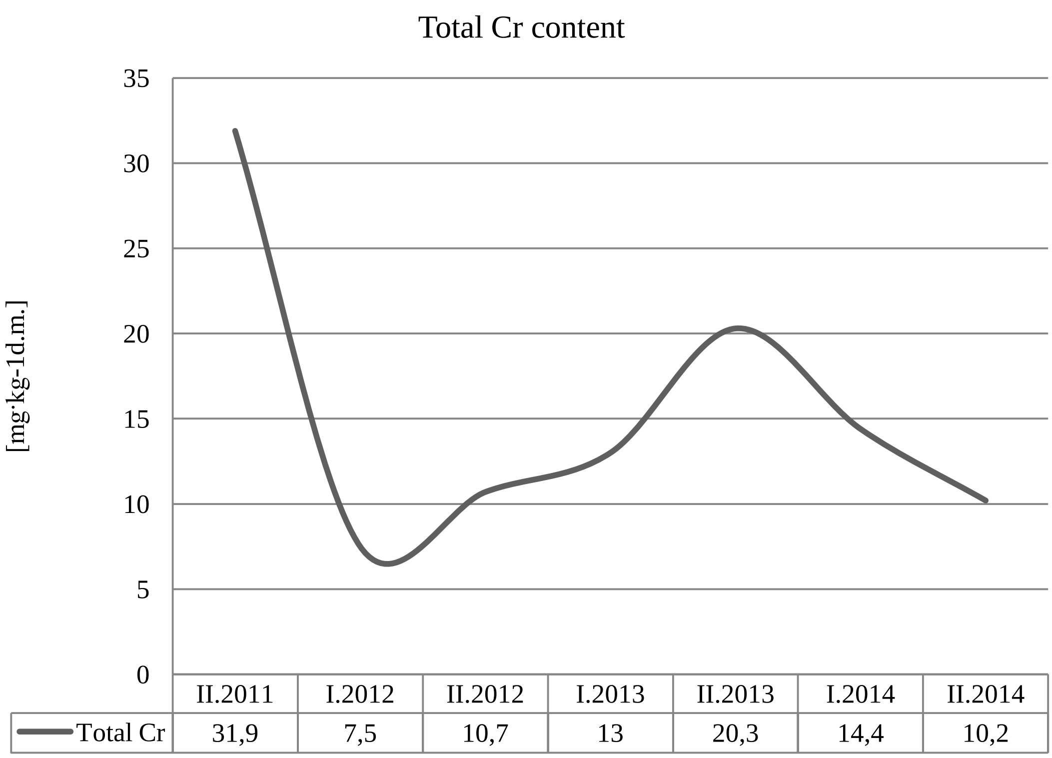


Figure 9. Total Cr concentration during study period

Source: Own elaboration

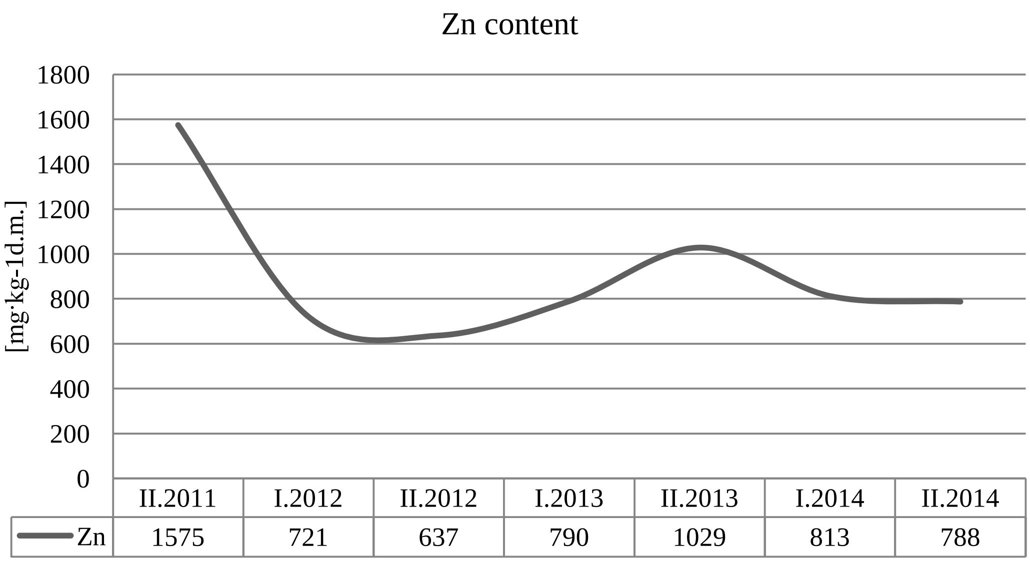


Figure 10. Zn content during research period

Source: Own elaboration

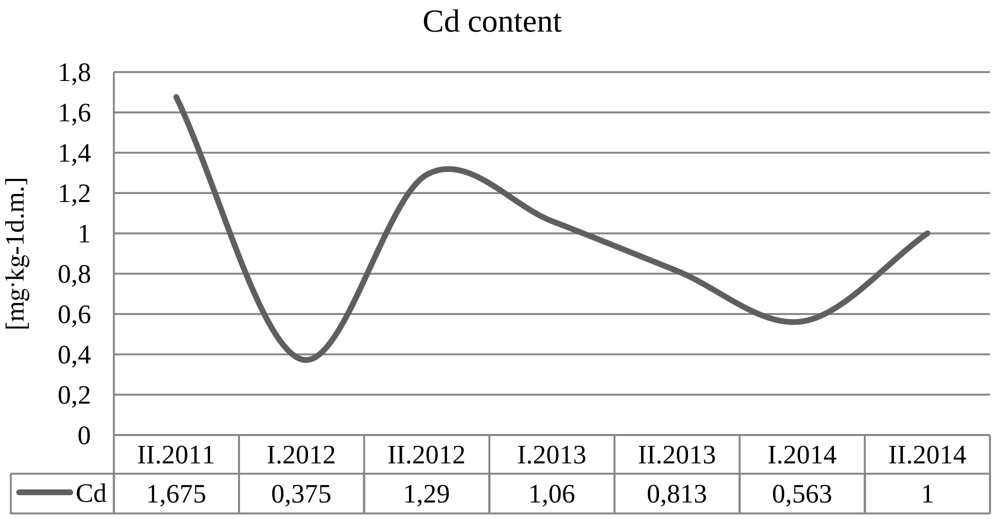


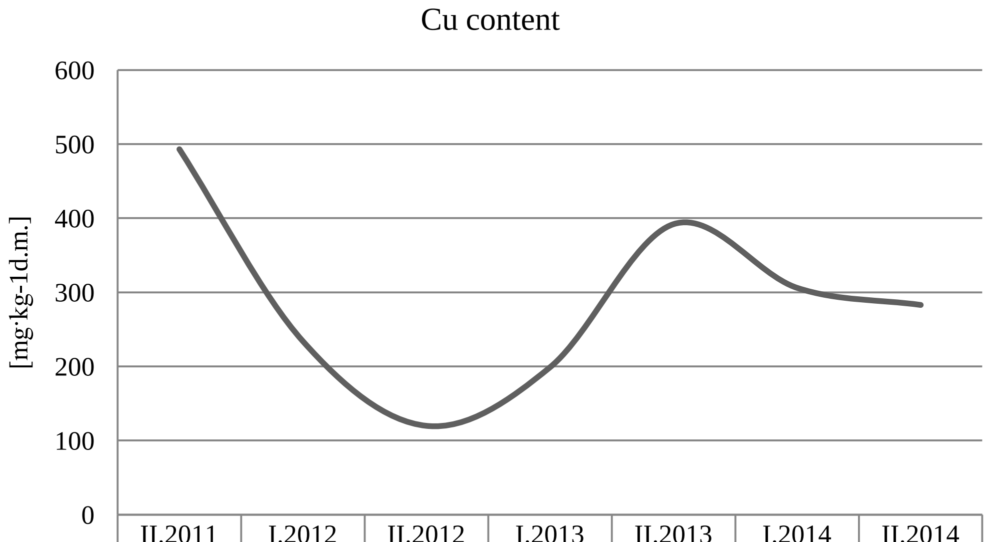
Figure 11. Cd content during research period

Source: Own elaboration

Cd content during research period was subjected to vary changes. Similar to Cr, and Zn two maxima were observed- in second half of 2011, where Cd content was equal to 1,675 mg·kg^{-1} d.m. and in second half of 2012 where content of this element was equal to 1,29 mg·kg^{-1} d.m.. In study period two minima were observed, in first half of 2012 and first half of 2014. Zinc content in each series was equal respectively 0,375 and 0,563 mg·kg^{-1} d.m. Obtained Cd results were smaller than those achieved by Gawdzik [11] in studies carried out in Ostrowiec Świętokrzyski. Average amount of total Cd obtained by author was equal to 2,5 mg·kg^{-1} d.m.. Similar amounts of Cd to those obtained in Stawiski, were obtained by

Latosińska [23] in studies carried out in Sitówce- Nowiny. Average amount of Cd obtained by Latosińska was equal to 1,36 mg·kg^{-1} s.m..

Cu content in analyzed sludge samples was described by similar changes to Zn. During study period two maxima of this element were observed. First in second half of 2011 and another in second half of 2013. Observed maximum values were equal respectively 493 and 392 mg·kg^{-1} d.m.. Only one minimum of this element was observed which occurred in second half of 2012 and was equal to 120 mg·kg^{-1} d.m.. Smaller Cu concentrations were observed by Bojakowska et all [5] in studies carried out in Konstancinie- Jeziornie wastewater treatment plant. Range observed by Bojakowska was from 95 to 168 mg·kg^{-1} d.m. and was similar to minimum values of this element in sludge from Stawiski wastewater treatment plant. Approximate Cu concentrations to those obtained in Stawiski were achieved by Dąbrowska and Nowak [7] in studies carried out in Częstochowa and Łężyca near Zielona Góra. Amount of Cu noted by Dąbrowska and Nowak were equal respectively 283,00 and 206,3 mg·kg^{-1} d.m..



	II.2011	I.2012	II.2012	I.2013	II.2013	I.2014	II.2014
Cu	493	234	120	199	392	306	283

Figure 12. Cu content during research period

Source: Own elaboration

Ni content changes in each sample were similar to changes observed in Zn and Cr trend. The highest amount of that element was observed in second half of 2011 and was equal to 25,6 mg·kg^{-1} d.m.. On the other hand minimum was observed in first half of 2012 where Ni content was at level of 6,4 mg·kg^{-1} d.m.. Beginning from second half of 2012 Ni content was remaining at relatively even level and was equal to 10 mg·kg^{-1} d.m. to the end of study period.

Related content of this element was observed by Ignatowicz et all [14] in studies carried out on Sokółka wastewater treatment plant. Results achieved by Ignatowicz in sludge stabilized in spin-drier were according to Ni concentration in Stawiski. Similar concentrations of this element were also obtained by Filipek [8] in sewage sludge form milk processing industry at wastewater treatment plant in Krasnystaw. Results obtained by Filipek were averagely equal to 11 mg·kg^{-1} d.m. and were equivalent to amounts most observed in Stawiski.

Pb content in research period was not submitted to significant trend of changes. Only one maximum concentration of this element was observed, in second half of 2011. In the remaining period Pb concentration was close to 12 mg·kg^{-1} d.m. Significantly higher amounts of Pb were observed by Kacprzak and Grobelak [18] in studies carried out after oxygenic stabilization of sludge from Miasteczko Śląskie wastewater treatment plant. Concentration observed by authors was equal to 149 mg·kg^{-1} d.m.. Slightly higher amounts to those observed in Stawiski were observed in Przemyśl by Ilba et all [15]. Values achieved in Przemyśl were ranging from 25,9 to 59,6 mg·kg^{-1} d.m. Authors pointed out that obtained Pb concentrations are typical for wastewater treatment plants form Świętokrzyskie voivodship.

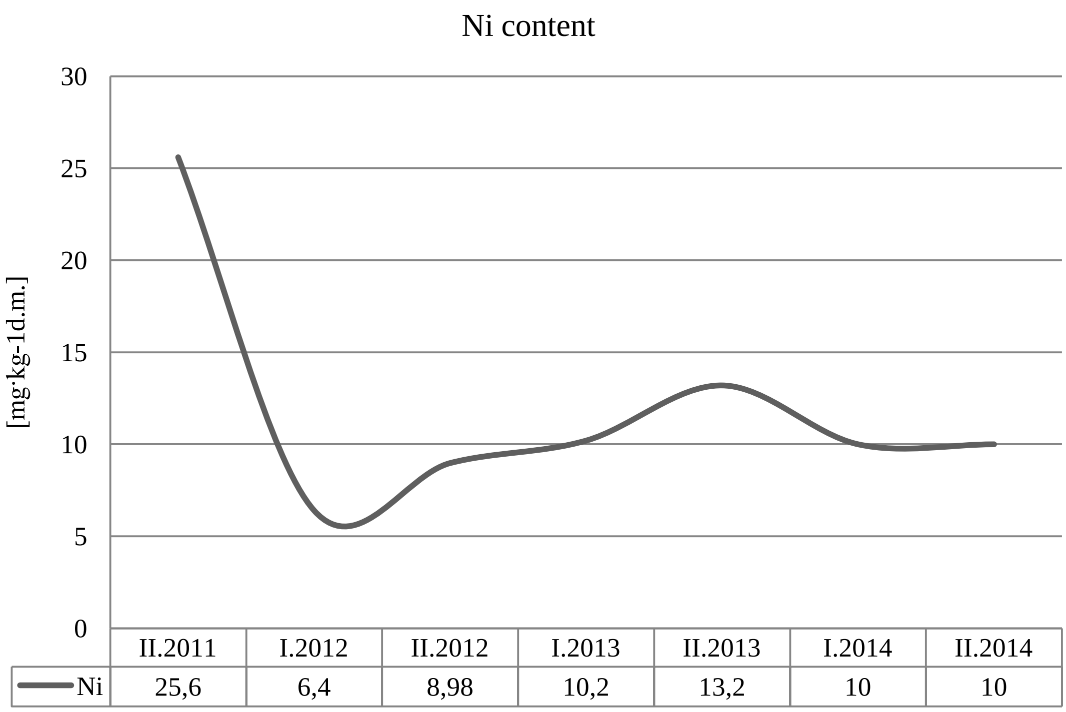


Figure 13. Ni content during research period

Source: Own elaboration

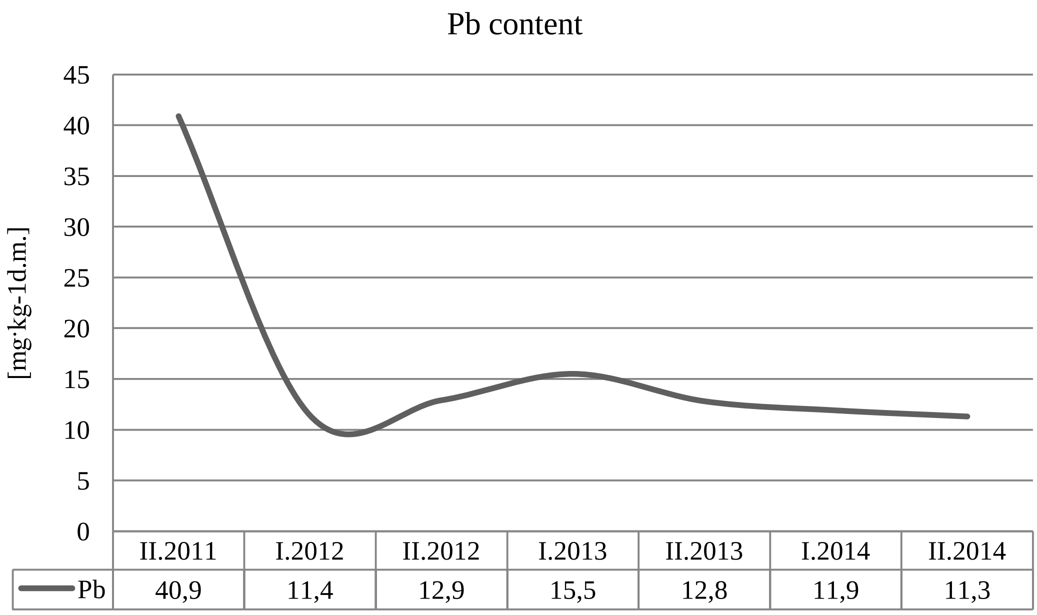


Figure 14. Pb content during research period

Source: Own elaboration

Changes in Merkury concentration differed from those observed with other elements. Maximum Hg content was observed in first half of 2013 and was equal to 1,9 mg·kg^{-1} d.m. The lowest concentration was observed in second half of 2014 and was equal to 0,09 mg·kg^{-1} d.m. In remaining research period Hg did not change significantly. Changes were observed in range from 0,2 to 0,7 mg·kg^{-1} d.m. Slightly smaller Hg concentrations were observed by Klimot et all [21] in studies carried out in Stalowa Wola wastewater treatment plant. Content achieved by authors averagely amounted to 0,06 mg·kg^{-1} d.m. Higher concentration was observed by Sadecka and Kuroczycki [33] in studies carried out in Żary. Obtained results of this element were ranging from 0,61 to 2,19 mg·kg^{-1} d.m, and accordingly to Stawiski wastewater treatment plant were not subjected to seasonal changes.

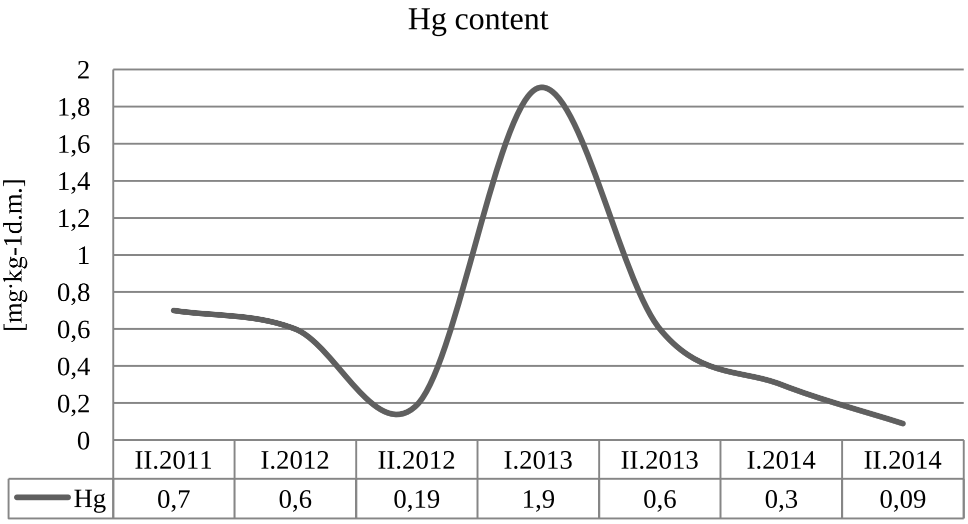


Figure 15. Hg content during research period

Source: Own elaboration

Table 4. Pearson correlation coefficiency in group of basic variables

	pH	Dry mass	Org. sub.	Ca	Mg	Total N	Total P
pH	1,00	0,39	-0,25	*0,65*	0,38	-0,56	0,02
Dry mass	0,39	1,00	*-0,72*	0,55	0,37	**-0,87**	0,40
Org. sub.	-0,25	*-0,72*	1,00	-0,51	-0,53	0,75	*-0,71*
Ca	*0,65*	0,55	-0,51	1,00	0,51	-0,55	0,36
Mg	0,38	0,37	-0,53	0,51	1,00	*-0,71*	-0,13
Total N	-0,56	**-0,87**	*0,75*	-0,55	*-0,71*	1,00	-0,16
Total P	0,02	0,40	*-0,71*	0,36	-0,13	-0,16	1,00

Source: Own elaboration

In the group of basic variables (tab. 4) which included pH, dry mass and organic dry mass, concentration of Ca and Mg and total forms of nitrogen and phosphorus only one from observed correlations was statistically significant. That link occurred between dry mass and total nitrogen. This correlation was characterized by high negative coefficient. This relation can be explain logically by efficiency of removing nitrogen by living microorganisms present in activated sludge, as with reduction of their volume decreases the efficiency of oxidized nitrogen forms removal, which are components of total nitrogen [25].

Beside statistically significant correlations there were observed variable pairs characterized by a high coefficient relation. Strong relation was observed between pH and Ca concentration in sewage dry mass. Correlation coefficient value in that case can be assiociated with sludge alkalinity, which is caused by calcium ions added to sludge in stabilization processes or by Ca ions present in raw sewage [26]. Another correlation characterized by high coefficient was observed between sludge dry mass and organic mass. This relation had negative value, which suggested that dry mass increase is causing organic substances to decrease. With organic matter were also associated nitrogen content (positively) and phosphorus (negatively).

Table 5. Pearson correlation coefficiency between metallic elements

	Total Cr	Zn	Cd	Cu	Ni	Pb	Hg
Total Cr	1,00	**0,97**	0,64	**0,86**	**0,97**	**0,88**	0,11
Zn	**0,97**	1,00	0,60	**0,91**	**0,98**	**0,92**	0,10
Cd	0,64	0,60	1,00	0,28	*0,75*	*0,75*	0,10
Cu	**0,86**	**0,91**	0,28	1,00	**0,82**	0,69	-0,07
Ni	**0,97**	**0,98**	*0,75*	**0,82**	1,00	**0,95**	0,08
Pb	**0,88**	**0,92**	*0,75*	*0,69*	**0,95**	1,00	0,17
Hg	0,11	0,10	0,10	-0,07	0,08	0,17	1,00

Source: Own elaboration

In variables arrangement describing metallic elements concentration a statistically significant correlation was observed between total Cr and Cu, Ni and Pb amount. Those relations were positive and were characterized by high coefficients. These links were clearly observable during research period. Zn, Cu, Ni and Pb were described by similar changes trend during studies. In addition, high correlation coefficients were observed between concentration of Ni, Cd and Pb. In that case this relation was positive. Similar phenomena was observed between Cu and Pb. No statistically significant correlation or high coefficient value was observed between Hg concentration and others metallic elements. That is also confirmed by Hg changes trend which was different from other elements.

In variables arrangement describing relations between basic physic- chemical sludge parameters and metallic element statistically significant correlations were observed between most of elements and sludge dry mass. Copper and mercury concentration significantly differed from this regularity. The rest of studied element were strongly and positively related to sludge dry mass. This phenomena suggest that active sludge is characterized by sorption properties related to metallic elements and causes them to accumulate in sludge flocs during sewage flow in activated sludge chamber.

Table 6. Pearson correlation coefficiency between metallic elements and basic physic- chemical sludge parameters

	Total Cr	Zn	Cd	Cu	Ni	Pb	Hg
pH	0,47	0,30	*0,67*	0,17	0,44	0,28	0,20
Dry mass	**0,85**	**0,80**	*0,71*	0,55	**0,87**	**0,91**	0,08
Org. sub.	**-0,94**	**-0,93**	-0,43	**-0,89**	**-0,87**	**-0,78**	-0,14
Ca	*0,66*	0,54	0,28	0,58	0,56	0,41	0,12
Mg	*0,65*	*0,73*	0,49	*0,75*	*0,73*	0,63	0,11
Total N	**-0,92**	**-0,90**	**-0,86**	*-0,70*	**-0,97**	**-0,92**	-0,01
Total P	0,52	0,43	-0,10	0,46	0,33	0,26	0,28

Source: Own elaboration

Another statistically significant group of correlations coefficients was observed between organic matter and total Cr, Zn, Cu, Ni and Pb. This relation was characterized by negative values, which suggest that simultaneously with organic matter decrease concentration of metallic elements increases. This regularity was not observed for Hg and in case of Cd it was not so clear as with other element.

Statistically significant correlation was observed between Mount of Cr, Zn, Cd, Ni and Pb and Total nitro gen content. Those variables were related negatively comparing to nitrogen.

4. Conclusions

1. In period of study Mount of each element was decreasing. Cr, Zn, Ni and Pb were characterized by similar trend of changes, which maximum values were observed in second half of 2011.
2. Changes in Hg concentration differ significantly from other elements. Differences could result from Hg nature and different matter state comparing to other studied elements.
3. Elements such as Cr, Zn, Ni, Cd and Pb were positively related to sludge dry mass, which suggest that their removal processes from raw sewage are linked with adsorption in activated sludge flocs.
4. Mercury did not show any correlation between basic physic- chemical sludge properties nor with other metallic elements.

Acknowlage

Autorzy składają serdeczne podziękowania Zakładowi Gospodarki Komunalnej i Mieszkaniowej za udostępnienie niezbędnych informacji dotyczących składu chemicznego osadów ściekowych pochodzących z Miejskiej Oczyszczalni Ścieków w Stawiskach.

References

1. Augustynowicz J., Pietkiewicz S., Kalaji M.H., Russel S., Wpływ nawożenia osadem ściekowym na wybrane parametry aktywności biologicznej gleby oraz wydajność aparatu fotosyntetycznego słonecznika bulwiastego (Helianthus tuberosus L.), Woda- Środowisko- Obszary Wiejskie, 2010, Vol. 10, No. 2(30), pp. 7-18.
2. Bień J. D., *Zagospodarowanie komunalnych osadów ściekowych metodami termicznymi*, Inżynieria i Ochrona Środowiska, 2012, vol. 15, no 4, pp. 439- 449.

3. Błaszczyk K., Krzyśko- Łupicka T., *Przegląd metod badania osadów ściekowych stosowanych w Polsce*, Inżynieria i Ochrona Środowiska, 2014, vol 17, no 1, pp. 117-133
4. Bodzek D., Janoszka B., Tyrpień K., Wielkoszyński T., *Zawartość związków wapnia i magnezu w wybranych wodach i osadach ściekowych Górnego Śląska*, Ochrona Środowiska, 1998, no 4(71), pp. 17-19.
5. Bojakowska I., Bobek P., Wołkowicz S., *Oddziaływanie na środowisko gruntowe stawów biologicznego oczyszczania ścieków*, Górnictwo i Geologia, 2012, vol 7, no 2, pp. 59- 69.
6. Boruszko D., *Frakcjonowanie wybranych metali ciężkich w osadach ściekowych przetwarzanych metodami niskoskładikowymi*, Rocznik Ochrony Środowiska, vol 15, pp. 1787-1803.
7. Dąbrowska L., Nowak R., *Frakcje chemiczne metali ciężkich w osadach ściekowych i stałej pozostałości po ich spaleniu*, Inżynieria i Ochrona Środowiska, 2014, vol 17, no 3, pp. 403- 414.
8. Filipek T., *Wpływ osadu ściekowego z mleczarni i wapna defekcyjnego na wybrane właściwości chemiczne gleby*, Roczniki Gleboznawcze, 2004, vol. LV, no 1, pp.117- 125.
9. Filipiak J., Przybyła Cz., Jakobsze M., *Wpływ rolniczego wykorzystania osadów ściekowych na zmiany zasobności gleb*, Zeszyty Problemowe Postępów Nauk Rolniczych, 2008, no 532, pp. 101- 110.
10. Gawdzik J. I., *Specjacja metali ciężkich w osadzie ściekowym na przykładzie wybranej oczyszczalni komunalnej*, Ochrona Środowiska, 2010, vol. 32, no. 4, pp. 15- 19.
11. Gawdzik J., *Mobilność metali ciężkich w osadach ściekowych na przykładzie wybranej oczyszczalni ścieków*, Inżynieria i Ochrona Środowiska, 2012, vol. 15, no 1, pp. 5- 15.
12. geoportal.gov.pl
13. Grosser A., Worwąg M., Neczaj E., Grobelak A., *Półciągła kofermentacja osadów ściekowych i odpadów tłuszczowych pochodzenia roślinnego*, Rocznik Ochrony Środowiska, 2013, no 15, pp. 2108- 2125.
14. Ignatowicz K., Garlicka K., Breńko T., *Wpływ kompostowania osadów ściekowych na zawartość wybranych metali i ich frakcji*, Inżynieria Ekologiczna, 2011, no 25, pp. 231-241.
15. Ilba E., Masłoń A., Tomasze J. A., Kutwicka A., *Ocena zawartości metali ciężkich w osadach ściekowych z miejskiej oczyszczalni ścieków w Przemyślu w aspekcie wykorzystania ich w rolnictwie*, Czasopismo Inżynierii Lądowej, Środowiska i Architektury, 2014, vol. XXXI, no 61, pp. 55- 65.

16. Jackowska I., Olesiejuk A., *Ocena przydatności osadów ściekowych z Oczyszczalni Ścieków w Lubartowie do rolniczego wykorzystania*, Annales, 2004, vol LIX, no 2, pp. 1001- 1006.
17. Jakubus M., Ocena przydatności osadów ściekowych w nawożeniu roślin, Woda- Środowisko- Obszary Wiejskie, 2006, Vol. 6, No. 2(18), pp. 87-97.
18. Kacprzak M., Grobelak A., *Wpływ różnych dawek osadów ściekowych na proces fito stabilizacji Cd, Zn i Pb*, Inżynieria Ekologiczna, 2011, no 25, pp. 99- 109.
19. Kaznowska J., Szaciło J., *Analiza jakości osadów ściekowych oraz możliwości ich przyrodniczego wykorzystania*, Acta Agrophysica, 2012, vol 19(2), pp. 343- 353.
20. Kaźmierczak M., *Modelowanie tlenowej stabilizacji osadów ściekowych z wykorzystaniem równań różnych rzędów*, Przegląd Naukowy- Inżynieria i Kształtowanie Środowiska, 2014, no 63, pp. 54- 63.
21. Klimot K., Góral S., Jońca M., *Rekultywacyjna efektywność osadów ściekowych na podłożu wapna poflotacyjnego*, Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin, 2002, no 223/ 224, pp. 415- 425.
22. Kuziemska B., Kalembasa S., *Analiza sekwencyjnych związków fosforu zawartych w odpadowych materiałach organicznych*, Acta Scentiarum Polonorum Agricultura,2007, no 6(2), pp. 47- 54.
23. Latosińska J., *Analiza mobilności metali ciężkich z osadów ściekowych z oczyszczalni ścieków w Olsztynie i Sitkówce- Nowiny*, Inżynieria i Ochrona Środowiska, 2014, vol. 17, no. 2, pp. 243- 253.
24. Latosińska J., Gawdzik J., *Mobilność metali ciężkich w komunalnych osadach ściekowych z przykładowych oczyszczalni ścieków Polski centralnej,* Ochrona Środowiska i Zasobów Naturalnych, 2011, no 50, pp. 20- 32.
25. Lenart A., Kowalska A., *Wykorzystanie osadu czynnego w oczyszczaniu ścieków*, Kosmos, 2012, vol. 61, no 4, pp. 677- 689.
26. Malinowska E., Kalembasa D., *Wpływ wapnowania i dawek osadu ściekowego na specjację ołowiu w glebie w doświadczeniu wazonowym*, Ochrona Środowiska i Zasobów Naturalnych, 2011, no 48, pp. 230- 239.
27. Mazur Z., Mokra O., *Wartość próchniczo twórca i zawartość makroskładników w osadach ściekowych województwa warmińsko- mazurskiego*, Inżynieria Ekologiczna, 2011, no 27, pp. 131- 135.

28. Miodoński S., Iskra K., *Ocena efektywności procesu skojarzenia fermentacji osadów ściekowych oraz odpadów tłuszczowych na przykładzie oczyszczalni ścieków w Brzegu*, Ochrona Środowiska i Zasobów Naturalnych, 2011, no 47, pp. 62-69.
29. Ociepa- Kubicka A., Ociepa E., *Toksyczne oddziaływanie metali ciężkich na rośliny, zwierzęta i ludzi*, Inżynieria i Ochrona Środowiska, 2012, vol. 15, no 2 pp. 169- 180.
30. Operat wodnoprawny na odprowadzanie ścieków z miejskiej oczyszczalni ścieków w Stawiskach do rzeki Dzierzbia, gmina Stawiski, powiat Kolno, woj. Podlaskie, Łomża 2013.
31. Parkitna K., Kowalczyk M., Krzemińska D., *Zmiana ilości wprowadzanej energii ultradźwięków do osadów ściekowych w zależności od zawartości w nich suchej masy*, Roczniki Ochrony Środowiska, 2013, no 13, pp. 2039- 2053.
32. Rozporządzenie Ministra Środowiska z dnia 13 lipca 2010 roku, w sprawie komunalnych osadów ściekowych.
33. Sadecka Z., Kuroczycki L., *Możliwości wykorzystania osadów ściekowych z oczyszczalni w Żarach*, Uniwersytet Zielonogórski Zeszyty Naukowe Inżynieria Środowiska, 2013, vol. 151, no 31, pp. 55- 68.
34. Siebielec G., Stuczyński T., *Metale śladowe w komunalnych osadach ściekowych wytwarzanych w Polsce*, Proceedings of ECOpole, 2008, vol. 2 no. 2, pp. 479- 484.
35. Stańczyk- Mazanek E., Piątek M., Kępa U., *Wpływ następczy osadów ściekowych stosowanych na glebach piaszczystych na właściwości kompleksu sorpcyjnego*, Rocznik Ochrony Środowiska, 2013, vol. 15, pp. 2437- 2451.
36. Szwedziak K., Woźniak A., *Charakterystyka osadu pościelowego pochodzącego z oczyszczalni ścieków w Strzelcach Pomorskich*, Infrastruktura i Ekologia Terenów Wiejskich, 2005, no 1, pp. 147-156.
37. Wilk M., Gworek B., *Metale ciężkie w osadach ściekowych*, Ochrona Środowiska i Zasobów Naturalnych, 2009, No. 39, pp. 40-59.
38. Wydro U., Wołejko E., Butarewicz A., Łoboda T., *Warunki i możliwości wykorzystania komunalnych osadów ściekowych do nawożenia trawników miejskich*, [w:] Interdyscyplinarne zagadnienia w inżynierii i ochronie środowiska. Tom 4, pod. Red. T.M. Tarczewskiej i B. Kaźmierczaka, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2014.
39. Wysokiński A., Kalembasa S., *Wpływ dodatków mineralnych i organicznych do osadów ściekowych oraz kompostowania uzyskanych mieszanin na ich wybrane właściwości*, Inżynieria Ekologiczna, 2011, no 27, pp. 240- 249.

inż. Szymon Skarżyński[1], dr hab. inż. Iwona Skoczko
Białystok University of Technology
Faculty of Civil and Environmental Engineering
Department of technology in engineering and environmental protection
Wiejska 45A, 15-351 Białystok
e-mail: [1]ikar2012@gmail.com

Alternative water sources

Key words: *water recovery, gray water, rainwater, wastewater, water scarcities, water protection*

Abstract: Water is a necessary compound for plants and animals. The increasing human population, the degradation of the quality of surface and groundwater, as well as climate change cause a reduction of available potable water for human consumption. To prevent shortages of water, which could undermine the economies of most countries begins search for new, unconventional sources of water. The three primary sources of unconventional potable water for human consumption, but also used only for economic purposes are the recovery of water from sewage, rainwater use, and the use of gray water.

In the article are discussed examples of installations for the recovery of water from sewage. The first discussed installation located in the capital of Namibia - Windhoek. The local water is recovered from wastewater and added to the water acquired from the traditional Water Treatment Plant. Then discusses installations in Texas, where the water recovered from wastewater are used in industry or mixed with drinking water. The most famous installation in Asia is located in Singapore. The water produced in Singapore is used in industrial plants and processes and drinking water as well due to its quality through the membrane processes. In the Australian city of Perth water is recovered from wastewater but is not provided to urban water supply system. It is pumped into the aquifers increasing their resources.

The last part of the article is devoted to the use of gray water and rainwater. There is presented the structure of water, its consumption in households, the possibility of replacing part of drinking water by rainwater or gray. The describe of installations for capturing and storing rainwater, systems for the collection and pre-treatment of gray water, their advantages and disadvantages.

1. Introduction

The water is the third most common molecule in the universe, is second only to molecular hydrogen and carbon monoxide. Earth's water resources are estimated at nearly 0.25 billion km^3, which is only about 0.24% of the mass of the Earth. Over 97% of the water on the Earth are the salt water, which are located in the seas and oceans, and are not potable for municipal purposes, industrial and agricultural, and only 2.5% is fresh water. Unfortunately, in these 2.5% of freshwater resources as 75% of them are in the form of unavailable, as water contained in glaciers [1].

It is estimated that the population for domestic and consumption purpose has to disposal only 15 thousand. km3 of water. In addition, our resources are very unevenly distributed over the planet, and only 15% of the land is sufficiently hydrated, on 60% of water is scarce, and 25% is semi-arid and desert regions [1].

Water because of its importance for humanity is under constant internationally monitoring. The European Council adopted in Strasbourg on 6 May 1968 so called European Water Charter. This card is formed following the principles of water management [2]:

- There is no life without water. Water is a valuable resource that is essential for all human activity.
- Water resources are not infinite. It is essential we conserve, control and, whenever possible, increase these.
- Altering the quality of water puts mankind and all other living beings that depend on this in jeopardy.
- Water quality must be suitable for its intended use and, above all, satisfy public health requirements.
- When water is returned to its natural medium, after being used, it must not jeopardize any later uses, either public or private, it may have.
- Maintaining adequate plant cover, preferably forests, is essential if we are to conserve water resources.
- We must make an inventory of our water resources.
- The correct administration of water resources should be laid down by the competent authorities.
- Conserving water resources will entail a large degree of scientific investigation, training specialists and public information.
- Water is our common heritage, and everyone should be aware of its value. Taking steps to save water and use it with care is everyone's responsibility.
- The administration of water resources should be carried out within the framework of the natural catchment area, preferably within administrative and political borders.
- Water knows no frontiers. It is a common asset that requires international cooperation.

In addition, the United Nations General Assembly Resolution of 22 December 1992 [3], established a World Water Day. It is a holiday celebrated annually on March 22 and aimed to raise awareness among of the Member States of the impact of proper management of water in their economic and social condition.

Water resources in Poland are very poor. In terms of the amount of water per capita the Poland is on the 20th place among European countries. In Poland per one inhabitant on average 1.6 thousand m^3 of water, and the world average of 15.0 thousand m^3 [1].

By Heidrich [4] one person needs from 300 to 425 dm^3 / (M · d) for the municipal and communal purpose of depending on the number of inhabitants in the settlement unit. The author writes also that industrial and storage areas are characterized by the demand for water in the range of 70 to 175 dm^3 / (M · d). It gives totally from 370 to 600 dm^3 / (M · d). According to the Central Statistical Office [5] on 30 June 2014 the number of Polish population was 38 483 957 inhabitants. Using these data and taking the average water demand at the level of 485 dm^3 / (M · d) can be easily calculated that on average, the population of Polish daily consumes about 19 km^3 of water. This value shows how important it is to save water, preventing its pollution, as well as the search for alternative sources.

2. The reasons for needs of waste water recovery and the use of gray water and rainwater

The World Health Organization [6] considers that each day the human population is growing by about 211 000 people. In addition, per capita water demand increases. The amount of available water per person decreases as a result of population growth, economic development and reduction of water resources which can be used. Nowadays, even the 470 million people live in areas where there is a serious deficiencies of water, and estimates say that by 2025, this number may increase up six times. In 1996 Shiklomanov [7] analyzed the growth of consumption water in the world. Picture 1 shows the diagram proposed by Shiklomanova.

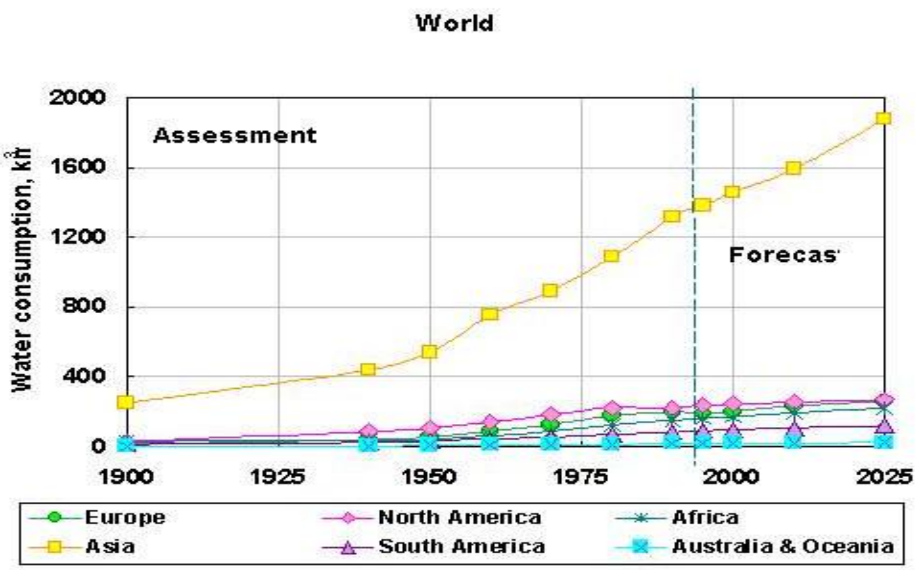


Figure 1. Water consumption in the world by continent in the period from 1900 to 2025

Source: Shiklomanov 1996 [7]

It shows clearly that the most important water consumption is characterized by Asia. This is due to a large current and forecasted future population of the continent, and thus the increase in the demand of water for economic purposes, especially for agricultural purposes with increasing amounts of food production [7,8].

Growing numbers of inhabitants, migration of people from rural to the cities and thus expansion of the concentrated urban agglomerations increases the demand for water. This results in increased her collection, which in turn causes the shortage over large areas. In the case of water shortage in the city, it is necessary to transport it from the remote areas, which increases the cost, as well as the loss of the life-giving substance during transmission [9].

An important aspect affecting the need to find alternative sources of water are climate change, which engender among other things, the phenomenon of drought. Use by the city water supply sources outside their area exposes them to the complexity of supply during periods of drought. Droughts cause a decrease in flow of watercourses, and in extreme cases, complete disappearance of the water in the river bed of the watercourse. Droughts also reduce groundwater level. Water shortage cause in significant pollution of air, soil and water in the city. The air becomes polluted by dust rising from the dry surface. A soil and water are suffering through the introduction of waste water to them that are more concentrated (less diluted) [9].

According the World Bank estimated about 90% of the wastewater produced in developing countries is discharged into water or land without any purification. This fact is another reason to show the need to find new sources of water or minimize its consumption. In Europe and North America about 70% of pollutants in water is caused by agriculture, 90% of the rivers on both continents has significant agricultural pollution, and 30% of water is so polluted that it is impossible for fish to exist in them. In the United States, about 40% of the water is not suitable for swimming and fishing, and up to 50% of the lakes are eutrophic [9].

All these factors make increased interest of national and international institutions as well as many citizens how to minimize the consumption of public drinking water or other types of water use in some sectors of the economy and everyday life. In this article are described three basic ways to get independent from the water supply system or reduce the water demand: the recovery of water from sewage, gray water re-use and the use of rainwater.

3. Recovery water from waste water

Residents of areas with warm climates or places of poor freshwater resources more frequently may face proposals with plant construction for recovering water from wastewater.

Technology that allows recover water from the wastewater has been in existence for several decades. Already in 1969, the city of Windhoek [10], which is the capital of Namibia has started to send treated wastewater into the drinking water system. Obtaining the appropriate amount of water of sufficient quality in this city is extremely difficult. The climate of its area is very dry. The city is bordered to the west of the Namib Desert and to the east of the Kalahari Desert. The city's water supply system is based on both the consumption of groundwater and surface water. Water from surface resources is taken from rivers that dry up periodically. Therefore it is necessary to use additional source of water i.e. wells receiving groundwater. Unfortunately, the total amount of water is too low to satisfy all water needs. on that account government decided to find a new, additional source of water.

In 1969, Goreangab Water Treatment Plant was completely rebuilt. In addition to the possibility of treatment of surface water was added to the possibility of using treated municipal sewage. Surface water is combined with the purified waste water and is carried into their treatment processes. By such treatment can be up to 25% more drinking water using the same amount of surface [10,11].

Goreangab Water Treatment Plant has been modernized in 2002 and now produces 16000 m^3 per day of water, equivalent to about 60% of the water demand of the city. Picture 2 presents a diagram showing the sequence of technological water treatment at the plant [12].

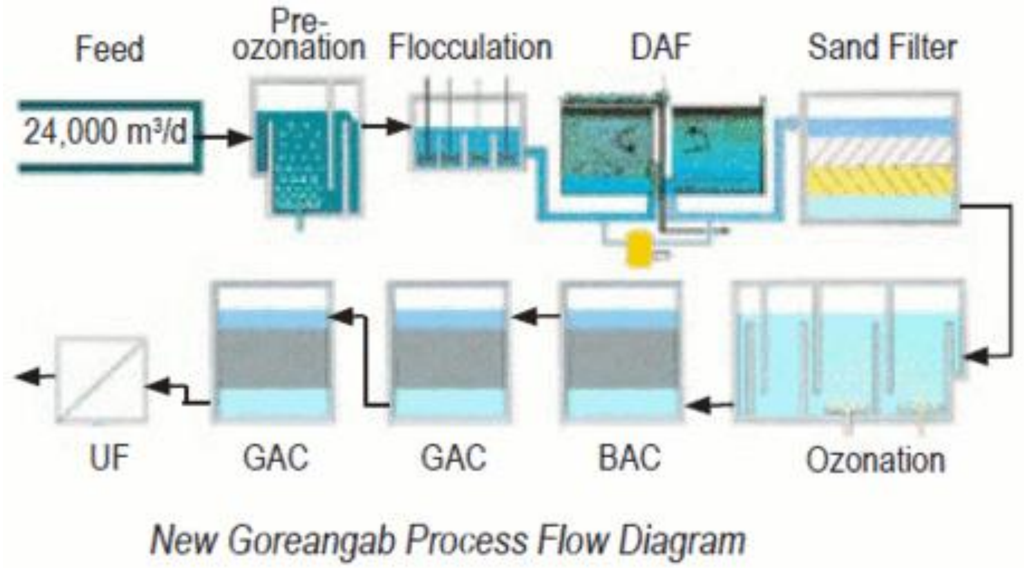


Figure 2. Technological line at the Goreangab Water Treatment Plant

Source: [12]

Nowadays the water treatment process is based on the following processes [12]:

- filtration through powdered activated carbon,
- pre-ozonation,
- coagulation / flocculation,
- dissolved air flotation,
- speedy filtration through sand / anthracite,
- ozonation,
- filtration / adsorption on activated carbon inhabited by microorganisms,
- filtration / adsorption on granular activated carbon,
- ultrafiltration,
- chlorination / stabilization,
- distribution.

Authorities undertook lengthy and costly public education campaigns since the founding of the plant. These campaigns, coupled with excellent water quality have contributed to achieving public acceptance of the project. Citizens have not only a unique trust for water supply, but also consider it a source of pride for their city.

In the famous with the drought US state of Texas increasingly frequent way to obtain additional sources of water is the recovery. Since the 60s Waterworks in El Paso have recovered water supply for municipal purposes. At present, the recovered water is used for irrigation of all urban green areas. In addition, this type of water is also used, for example, in car washes, as well as for cleaning streets [13].

In San Antonio the main attractions are the riverside boulevards. The city is located in the south-central part of the state,. During past 50 years, 4 km waterfront was changed in place commercial and cultural center. Tourists and residents of the city come there shopping, enjoy a boat or walking. However, due to prolonged drought San Antonio River threatens to dry. In order to prevent this phenomena, the city authorities supply water to the stream. The water is recovered in the wastewater treatment process. Previously, the city procured 19 million liters of water a day during drought from the underground aquifer. However, those source is now used by areas surrounding the city for households, agriculture and industry. Water from sewage treatment is also used on golf courses, parks, university gardens, theme parks, as well as for cooling in the industry. Treated waste water are the main sources of water, including for Toyota and Microsoft factories, located in San Antonio. Promotion of the use of recycled water contributed to the reduction of resource consumption by the residents.

This happened despite the fact that not one of them gets water from this source. The process of reuse of purified water becomes increasingly popular in Texas. It is also realized in Austin, Amarillo and Lubbock, and the largest metropolitan status: Dallas and Houston slowly begin to use it [13].

In the city of Wichita Falls in Texas, works a sewage treatment plant (worth 13 million dollars) which recovers water potable for human consumption as a part of wastewater treatment. The system consists of a 20-kilometer water pipe (shown in Picture 3) connecting the water treatment plant with sewage treatment plant. First wastewater is filtered, then flows in the pressure pipe system to the treatment plant. Sewage is there reprocessed and mixed with the rest of drinking water. The system produces about 18 million liters of clean water per day [14].

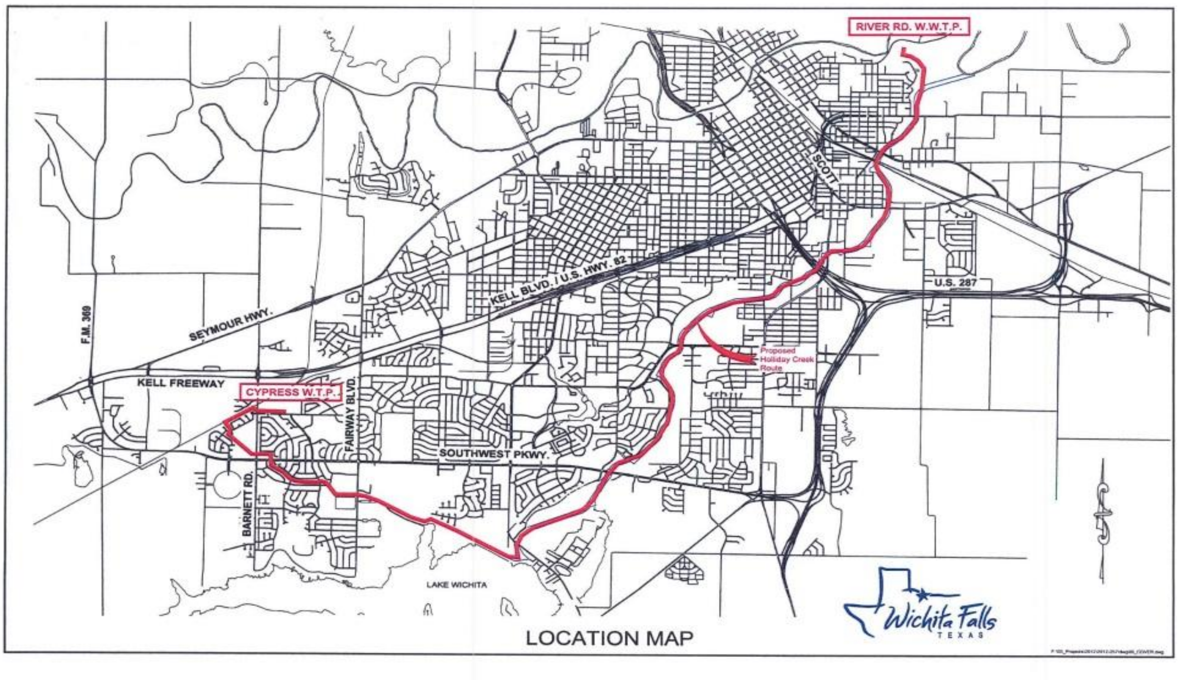


Figure 3. The route of water supply connecting the sewage treatment plant with water recovery plant in Wichita Falls in Texas

Source: [14]

Asia is a continent of the high demand for water due to the significant amount of the population concentrated in a small area. A large population of the continent causes water shortages. To prevent this cities use water recovery methods. An example of a city recovering water from wastewater is Singapore. The program of acquiring new water sources was launched there in 1998 in result of an agreement of the local Ministry of the Environment and Water Resources and the National Water Agency. The main purpose of this agreement was to determine the possibility of using recycled water to supplement drinking water. Singapore has four stations producing water called “NEWater”. Two of them were opened in 2002, the third in March 2007 and the last in August 2009 [15,16].

NEWater is the name of the water produced by the Board of Public Utilities in Singapore. This water comes from the reprocessed wastewater thanks membrane processes (microfiltration and reverse osmosis), followed by ultraviolet disinfection. This water is consumed by people (after mixing with conventional water). Industry, which require high purity water, also used it for technological line. [15,16].

According to the Singapore Department of Public Utilities quality of NEWater is cleaner than water from other sources in Singapore. It also has better quality than required by the World Health Organization (WHO) and the US Environmental Protection Agency (USEPA). Table number 1 shows the comparison of the requirements for drinking water (the WHO and USEPA) with NEWater quality [15].

Table 1. Comparison of the quality of NEWater with USEPA and WHO standards

Water quality parameters	Units	NEWater	USEPA standards	WHO standards
Physical				
Turbidity	NTU	< 5	5	5
Color	Hazen Units	< 5	15	15
Conductivity	µS/cm	< 250	Not specified	Not specified
pH value	pH	7,0 – 8,5	6,5 – 8,5	6,5 – 8,5
Total dissolved solids	mg/dm^3	< 150	500	1 000
Total organic carbon	mg/dm^3	< 0,5	-	-
Total hardness	$mgCaCO_3/dm^3$	< 50	-	-
Chemical				
Ammoniacal nitrogen	mg/dm^3	< 1,0	-	1,2
Chloride	mg/dm^3	< 20	250	250
Fluoride	mg/dm^3	< 0,5	4	1,5
Nitrate	mg/dm^3	< 15	10	11
Silica	mg/dm^3	< 3	-	-
Sulphate	mg/dm^3	< 5	250	250
Residual chlorine	mg/dm^3	< 2	4	5
Total trihalomethanes	mg/dm^3	< 0,08	0,08	-
Metals				
Aluminum	mg/dm^3	< 0,1	0,05 – 0,2	0,2
Barium	mg/dm^3	< 0,1	2	0,7
Boron	mg/dm^3	< 0,5	-	0,5
Calcium	mg/dm^3	4 – 20	-	-
Copper	mg/dm^3	< 0,05	1,3	2
Iron	mg/dm^3	< 0,04	0,3	0,3
Manganese	mg/dm^3	< 0,05	0,05	0,4
Sodium	mg/dm^3	< 20	-	200
Strontium	mg/dm^3	< 0,1	-	-
Zinc	mg/dm^3	< 0,1	5	3

Bacteriological				
Total Coliform Bacteria	counts/100 ml	Not detectable	Not detectable	Not detectable
Enterovirus	-	Not detectable	Not detectable	Not detectable
Heterotrophic plate count	CFU/ml, 38^{o}C, 48h	< 300	< 500	-

Source: own study based on **[**15**]**

NEWater plants produced at the opening of about 75 700 m^3 of water per day. It was only about 6% of Singapore's water needs, and the city amounted about 1.1 million m^3/d [15]. NEWater is a proof that modern methods used in water treatment technology makes it possible to transform any water to drinking water quality. With this technology, the Singapore Department of Public Utilities in 2007 awarded the prestigious Stockholm Industry Water Award. Currently NEWater production covers about 30% of the demand for water for Singapore, and plans by 2060 is to achieve 55% of future demand for water [15].

An example of the waste water recycling technology usage in Australia is the city of Perth in the southwest Australia. All this region contend with an extremely dry climate, which causes a reduction in rainfall, depletion of traditional sources of water, such as reservoirs and groundwater. Since 1990 rainfall decreased by 12% in Western Australia which resulted in the halved flow of water on the main dam, from which water is taken for Perth. At the same time, there has also been a significant growth of the city area and population. This situation forced the city authorities to increase the effectiveness of Perth water extraction. This efficiency has been raised by two methods. The first method is the development of seawater desalination plants and second - development of waste water recycling. Water recovery system is significantly different from those used in the locations mentioned above in this article. Water recovered from sewage is not reprocessed and does not directly supply the population. Water after treatment in wastewater treatment plants is pumped into aquifers, which purifies them and increases the downloadable water supplies [17].

Company implementatated the water recovery technology estimate that by 2030, the amount of water coming from the recovery in Western Australia will reach 30%. In 2011 and 2012 of 9.8 billion liters of recycled water has been used by industry and another 10.2 billion liters were used for irrigation of green areas. In addition, 1.2 billion liters of recovered water were pumped to aquifers. The total volume of water recycled in Western Australia increased by almost 75% over the last ten years, exceeding 21 billion liters in 2011/12. Picture 4 shows the types of recycled water use and properly percent of the total amount of recovered water [17].

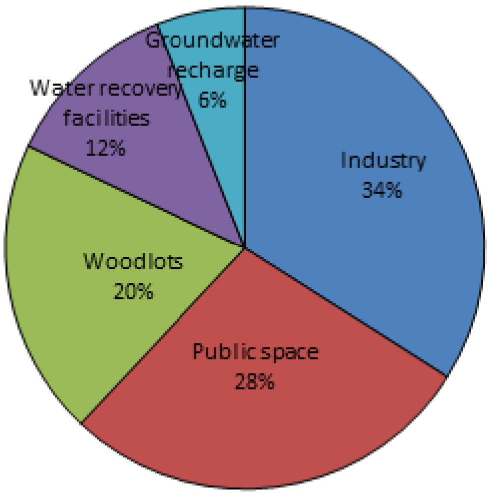


Figure 4. The amount of water recycled used for a particular purpose

Source: own study based on [17]

It is also worth mentioning that there exist organizations and companies which specialize and aspires to the development of water recovery technologies, as well as people education about the use of water, saving water, as well as the possibility of recovery. WateReuse is a leading association. It is a non-profit organization which aims to promote new technologies of water recovery and implementation of the principles of sustainable development to obtain water from sources for the good of society. The main methods of achieving these goals is to educate the public, research, alignment and affiliation of the parties [18].

WateReuse Association was founded in December 1990 in California. Organization engaged in the acquisition of alternative sources of water in the state of California in the United States. In 2000, the Board of the Association, taking into account a wide area of activities of the Association, which goes beyond the state of California has decided to extend the activities of the entire United States. The Association has set up an office in Washington. Now a team of professionals working for the Association does good job in the office located in Alexandria, Virginia. Association is divided into several separate sections. Each of them has a designated area of operation. These sections are: Australia, Arizona, California, Colorado, Florida, Nevada, Texas and the North-West Pacific. Members of the Association are the local media, federal and state agencies, health services, consultants and selected scientists the academic community. Employees Association WateReuse deal with advanced process waste water recovery, as well as rigorous process monitoring systems in order to create high-quality water for a wide range of municipal and industrial wastewater, rainwater, drainage and water characterized by high salinity [18].

Another important organization is the WaterCorporation. The company is located in Western Australia. WaterCorporation is a leading provider of water services, as well as sewage systems and drainage in Western Australia. Its range includes hundreds of thousands of homes, businesses and farms. The company include under its operations 2.6 million km2 and has regional offices in seven major cities in Western Australia. It has 3 000 employees and manages assets in the amount of 15 billion dollars earmarked for water supply, sewage systems and irrigation-dehydration systems. Business owner is the government of Western Australia, and the supervision of the company to the Minister of Water Affairs of the government. Most of the surplus funds generated by the company goes back to the government in the form of dividends, which are then allocated to the maintenance of the infrastructure, as well as investment works [19].

4. Advantages and disadvantages of water recovery from wastewater and controversies regarding to this type of drinking water source

Recovery of waste water, like any technological method has its advantages and disadvantages. In principle, there is no perfect device and each of even the most advanced technology can be unreliable. The undeniable advantages of systems for the water recovery from waste water include:

- partial independence from conventional water sources, which may be not suitable for use due to emergency situations - intentional and unintentional or extreme weather events is,
- reduce the amount of wastewater discharged from sewage treatment plants to the receiver, and thus improving the water quality of the receiver,
- relief of the conventional water sources, especially underground water deposits in aquifers, which are not subject to renewal or renew very slowly,
- in areas with a small amount of fresh water sources and coastal located water recovery is cheaper than desalination methods, mainly due to lower energy consumption,
- development and testing of methods for recovery and purification of water, and thus investment in science and research,
- new jobs for residents, which may not be a significant advantage, but in areas of high unemployment important.

Disadvantages of water system recovery :

- the need for constant, increased oversight of the installation of water recovery, as each failure could get into the water supply of water for example unsterilized and calling the health risks of the population, the risk is greater than in water treatment plants due to the large number of microorganisms in wastewater compared to surface waters,
- the need to build a new specialistic center for the water recovery from waste water, which brings with a large, basically a one-off cost,
- the need for a constant supply of electricity to keep the recovery,
- the need to disposal of waste generated during the recovery,
- the possibility to meet with opposition from residents, which will require funds for a wide educational campaign,
- lack of profitability of investments, lack of profits scares investors and potential sponsors,
- the need to employ skilled staff to process control, to ensure the proper operation of the installation and maintenance.

Term water from wastewater or recovered water does not cause a positive reaction of inhabitants. Therefore, most manufacturers of water recovered from wastewater try to mitigate the negative impact of their product. Organic water or raw water is much better and is not associated negatively. Therefore, institutions dealing with water recovered from wastewater try to use these socially acceptable names.

Recovery of waste water may also give rise to controversy among residents. A good example of this phenomenon is the city of Toowoomba in Queensland, Australia. In 2006 the city was hit by severe drought. Therefore official conducted a referendum on the construction of a waste water recovery. The initiative fell as a result protest local groups such as the "Residents against wastewater to drinking". This example shows how important it is to educate the public with described initiatives.

5. The use of gray water

The next method which allows to reduce water consumption is the re-use of gray water. The European Standard EN 12056-1 defines gray water as contaminated water free from fecal. Grey water owes its name for turbidity appearance and its status, which does not qualify it as clean drinking water, or as highly contaminated water. Accordingly, with the above definition, if the gray water contains significant quantities of kitchen waste, or strong chemicals, it shall be classified as wastewater. Grey water is formed for example, during dishwashing, bathing and washing. It is a 50 to 80% of the total volume of the wastewater produced in the household [20,21].

Gray water can be used to flush toilets. For this purpose consumes about 30% of the water in the household. Others usage of gray water is watering the garden. In this case, it may be necessary previous purification of the water. It is important not to store gray water without purification. This is due to the fact that this water is usually warm and polluted with organic substances. Picture 5 shows the structure of water consumption in the household. The largest share in the structure of consumption is personal hygiene - about 35%. Not much smaller share concerns flushing toilets - 33%. Other objects, such as food, watering, washing and dishwashing consume about 32%. Blackwater, which must be discharged into the sewer, represent only one-third of the water consumed, while the rest may be reused after the primary cleaning [21].

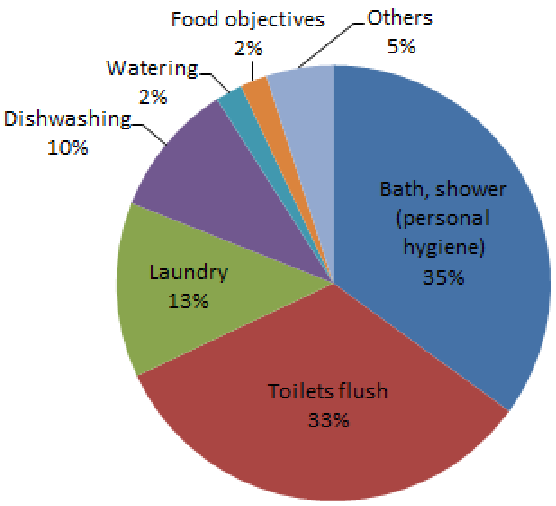


Figure 5. The structure of water consumption in the household

Source: [21]

Gray water recycling systems are becoming increasingly popular in countries such as Canada, USA, Australia, Japan, the Middle East, Israel, and Oman, as well as in the European Union. Examples of gray water re-use are [21]:

- hotels in Majorca, where gray water is primary treatment and used for flushing the toilet. In the hotels are used sedimentation, filtration and disinfection methods. Thus, making useful gray water, save 23% of water used in the hotel. Another system used in hotels is also a gray water pretreatment system based on filtration by sand and chlorine disinfection.

- in the homes of students at the University of Loughborough in the UK,
- entire universities buildings eg. Kalmar in Sweden,
- Agricultural University of Oslo in Norway,
- in the Republic of India in state of Madhya Pradesh - to 2006 in schools built 416 water purification systems,
- in less developed countries, eg. in Malaysia - since 2003, designing an integrated greywater recycling system for the entire city of Kuching in Sarawak province,
- in the Scandinavian countries, eg. in Toarp in Sweden - was a full-scale experimental ecological village,
- eg. Oman, Israel - at the moment re-uses 60% of wastewater, and plans to increase this amount to 90%.

Picture 6 illustrates an exemplary water recovery system wash basins. Water used in the wash basin is stored in a tank and used later to flush the toilet. It is an integrated system that combines a toilet and a wash basin to reducing clean water consumption.

Figure 6. Examples of recovery water from wash basins to flush toilets

Source: [21]

The gray water is much easier for the treatment of wastewater due to its small impurity. Although completely untreated gray water may cause a risk to health, because it contains the same types of bacteria as waste, but in much smaller quantities. Grey water contains microorganisms adequately to the source to its origin, hence the gray water from a single-family home should be treated differently than water with a multi-family building. The residents in single-family building are constantly subjected to the action of bacteria roommates. Grey water from multi-family building exposes people who have contact with her to bacteria and microorganisms derived from a wider range of people, thus increasing the risk of disease transmission between residents [21].

If you will construct a separate sewer system for gray water, separate from toilets ,than gray water can be processed directly in the home or garden. It should be use immediately, and if you want to collect it, it is allowed only after cleaning. Recycled grey water should never fit for human consumption. On the other hand, multi- filtration and its processing by microorganisms that absorb nutrients and refresh it makes it possible for washing or flushing traditional toilets. Relatively clean gray water can be led direct into the garden or constructed wetland. There works plants and their roots. The gray water contains nutrients and sometimes pathogens. It has also higher temperature. That is why it shouldn't be stored, but spread directly through the garden [21].

Picture 7 shows an example of dual water-plumbing system with re-use of gray water.

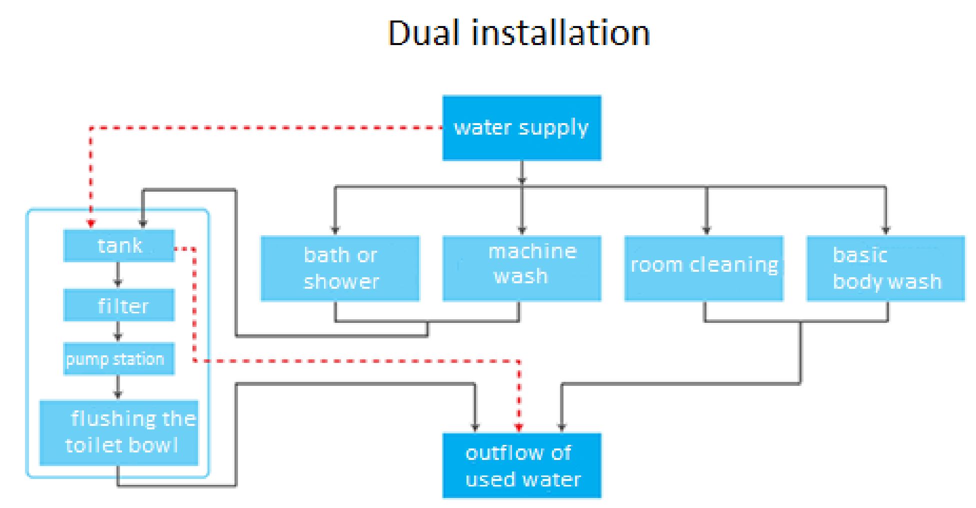


Figure 7. Installation example in which to flush the toilet at least in part used is the wastewater from bath, showers and washing machines

Source: [21]

In this system, the water from the water supply is used for all activities in the apartment, but only part of it is directly discharged into the sewage system. The water from the bath or shower, as well as water from the washing machine is stored in the tank. After filtration gray water is pumped to flush the toilet and then goes to the sewer. This installation can work well only partially use gray water, because after the exhaustion of the tank can be refilled from the water supply (upper red arrow), and in the case of excess gray water can be transferred directly to the sewer (lower red arrow).

The simplest system for gray water recovery is directing it to the garden. Legislation allows such solution and it is different in every country. The most common guidelines for its use are:

- not to keep the raw water above 24 hours,
- make sure that does not create ponds,
- filtration in the garden through subsurface irrigation system,
- no spraying her by distributor.

The gray water recovery system can be designed for the newly built home and perform in an existing building. Gray water from the shower or bath is a very good source of water for the garden. The content of dissolved soap acts on the plant as a moisturizing agent. Discharging water into the garden with laundry, you should pay attention to that the detergents have possibly low levels of phosphate and salt, as well as to their pH is as possible close to neutral. It is also important that when it the use of strong chemicals to water direct her down to the sewer, and not to the garden, because if we don't do, the aggressive chemicals can damage the plants.

Like other technologies, as well as installations for the use of gray water has advantages and disadvantages. The undeniable advantages of the use of gray water can include:

- reduce the consumption of drinking water from the water supply,
- reduce the impact on the environment due to the reduced amount of wastewater,
- possibility fertilize the soil using material from eg. composting toilets,
- restoration of groundwater levels while reducing groundwater download,
- recovery of fertilizing ingredients, which in the traditional system would be directed to the treatment plant,
- reducing costs with constantly rising prices of water.

The disadvantages of this system we include:

- increased concentration of wastewater, and thus more difficult to clean them in a wastewater treatment plant,
- an increase in the cost of wastewater treatment
- difficulties in the treatment and possibility discharge wastewater to the receiver not cleaned properly.

6. Use of rainwater

The annual rainfall in Poland is from 500 to 600 mm in central areas and at coastal and foothill areas may reach 1100 to 1200 mm. Rain is highly volatile, ranging from small wetting the surface, to large heavy fall causing alarm states and flooding on the receivers. In Poland, there is an average from 120 to 150 rainy days wherein the most of rains are magnitude of less than 5 l / s · ha [22].

Until recently, the rain water was treated as conventionally clean water. Currently, rain water is discharged by closed channels and is considered as wastewater. The composition of rainwater is shaped by [22, 23]:

- washed out of the air and settled aerosols,
- flushed from the catchment area of contamination,
- raw materials, semi-finished products or industrial waste located in industrial areas,
- municipal and industrial wastewater discharged into storm sewer and from sewer sludge.

The best suited rainwater for use in households is water from the first phase of atmospheric fall and those that flow down from the roofs. The composition of rainwater in the first phase is shaped by impurities in the atmosphere. Pollution in the atmosphere comes mostly from power plant emissions, local furnaces and local industry. Into rainwater enter compounds such as carbon monoxide, sulfur dioxide, nitrogen oxide, hydrocarbons compounds and dust [22].

Rainwater does not raises objections of health and it is suitable for washing and cleaning, flushing toilets and watering the green. In the case of a complete rainwater management, or use it at home, should be projected additional rainwater distribution system in building. Its combination with potable water system is banned. The pressure tank should be integrated part of the system. In case of drought or poor rainfall automatic control system provides backup supply from drinking water. Automatics also controls the water level in the tank and protects the pump from running dry. Rainwater used in the home becomes a municipal wastewater and can be discharged to sewer. The object is connected to the sewer system. In order to reduce the cost of discharge of wastewater, in the rainwater installation should be installed a water meter.

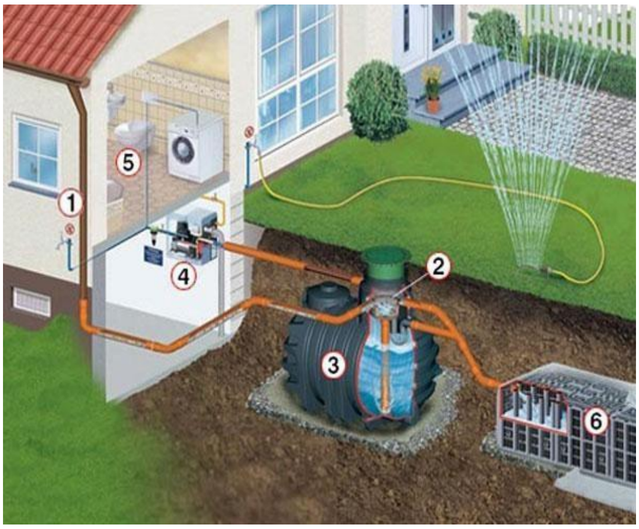


Figure 8. An example of a use rainwater in the garden

Source: http://www.powode.pl/01wazne_inf/wi01.htm

Rainwater can also be used only for watering plants. In that case, we can use a very simple and inexpensive supply-pump system (pump placed in the tank) and standard garden hoses. It is also possible to connect directly rainwater from tank to the automatic system of watering the garden. If you plan to use less rainwater or on already organized property and you want to avoid earthwork, we can use a very esthetic ground tanks for rainwater. Captured and transported by gutters, rainwater by downpipes must be cleaned through the filter system (position 2 on picture 8). Then it goes to a tank where may be stored in an appropriate amount in the event of a long period of drought.

To use the collected water, control - pumping system (position 3 on picture 8) sucks water and after the possible additional filtering, delivers it to access points (washing machine, toilet, etc.).

In the case of prolonged drought drinking water is led in into the tank, or by "by - pass" system supplies to reception. Conversely, when rainfall is excessive and the water does not fit in the tank, through a siphon system is directed transfer into storm sewer or in its most advanced version to filtration into ground (position 4 on picture 8).

The advantages of the use of rainwater is:

- reduce the consumption of tap water by up to 50%,
- reduce the amount of water discharged to the sewer, so you can reduce the diameter of the channel, which help to reduce the cost of future investment in sewerage infrastructure,
- no need to use softening agents, rainwater is relatively soft,
- softness of rainwater reduces the consumption of detergents when washing this water and also does not appear in the washing boiler scale,

- rainwater is more favorable for sensitive skin, pets and plants watered it,
- reduces the problem of discharge the rainwater from the catchment area,
- has a better composition than the water from the surface tank and is suitable for agricultural work and industrial for the purposes of cleaning and auxiliary,
- possible reductions in fees for wastewater discharge to sewer.

The disadvantages of the use of rainwater is:

- content of weak acids in water (mainly carbonic) gives the rainwater the corrosive nature and the discharge and use system must be anti-corrosion,
- not suitable for human consumption,
- requires filtration and the precipitation - sludge must be regularly removed from the filter and the bottom of the tank,
- unstable composition depending of air pollution,
- water which had contact with any type of roof is suitable for use, roofs with bituminous coverage may discolour water, metal roofing can be emitted into water too much metal, water from roof with asbestos-cement cover completely unsuitable for use.

7. Conclusions

1. The amount of safe water suitable for human consumption useful in households and industry is relatively small and should seek to the protection and rational use without harming for consumers.
2. Recovering water from sewage, gray water and rainwater can be led to installation to reduce the usage of groundwater and surface water, .
3. The facilities to water recover from wastewater showed in studied examples can partially satisfy the demand for water in the cities. They contribute to the renewal of groundwater resources.
4. The concept of water recovery from wastewater may raise objections, opposition or protests by inhabitants. It must be ensured the public environmental education as the example of Singapore.
5. The use of gray water in many countries has tradition for a long time. It is convenient to flush toilets or clean with gray water.
6. Rainwater is suitable for use. Climate zone in the Europe, promotes profitability of rainwater re-use systems and allows to reduce the amount of conventional water used in the household.

References

1. Wescoat J.L.Jr.: *Water Resources and Sustainable Water Management* [in:] International Encyclopedia of the Social & Behavioral Sciences (Second Edition), 2015, Pages 437-442.
2. European Water Charter.
3. United Nations General Assembly Resolution of 22 December 1992.
4. Heidrich Z.: *Wodociągi.* Wydawnictwo Szkolne i Pedagogiczne, Warszawa 1999.
5. http://stat.gov.pl
6. World Health Organization; http://www.who.int/en/
7. Shiklomanov I.A.: *World Water Resources: Modern Assessment and Outlook for the 21st Century. Summary of World Water Resources at the Beginning of the 21st Century, prepared in the framework of the IHP UNESCO*. Federal Service of Russia for Hydrometeorology & Environment Monitoring, State Hydrological Institute, St. Petersburg; http://webworld.unesco.org/water/ihp/db/shiklomanov/summary/html/summary.html
8. Kowalczyk P.: *Konflikty o wodę*. Wydawnictwo KURPISZ S.A., Przeźmierowo 2007.
9. Kowalczyk P.: *Wodne dylematy urbanizacji*. Wydawnictwo Poznańskiego Towarzystwa Przyjaciół Nauk, Poznań 2011.
10. http://www.sheffy6marketing.com/index.php?page=namibia
11. Du Pisani P.L.: *Surviving in an arid land: Direct reclamation of potable water at Windhoek's Goreangab Reclamation Plant*; https://ag.arizona.edu/OALS/ALN/aln56/dupisani.html
12. http://www.desalination.com/wdr/47/14/windhoek-dpr-update
13. Texas Water Development Board: *History of water reuse in Texas;* https://www.twdb.texas.gov/innovativewater/reuse/projects/reuseadvance/doc/component_a_final.pdf
14. Van der Bruggen B.: *The Global Water Recycling Situation* [in:] Sustainable Water for the Future: Water Recycling versus Desalination Volume 2; page 41-62; 2010.
15. http://www.pub.gov.sg
16. Love P.: *Water resources: meeting future demand;* [in:] Foresight 1999 1:3, page 275-278.
17. WaterCorporation: *Water recycling and water efficiency,* May 2013; http://watercorporation.com.au

18. https://www.watereuse.org
19. Dixon A., Butler D., Fewkes A.: *Water saving potential of domestic water reuse systems using greywater and rainwater in combination* [in:] Water Science and Technology Volume 39, Issue 5, 1999, Pages 25–32.
20. PN-EN 12056-1:2002 Systemy kanalizacji grawitacyjnej wewnątrz budynków - Część 1: Postanowienia ogólne i wymagania.
21. Rucińska T.: *Woda szara*; http://trucinska.zut.edu.pl/fileadmin/Szara_woda_1.pdf
22. Górska K., Górski J.: *Skład wód opadowych i możliwość ich oczyszczania*, [in:] Janusz Łomotowski [red.]: Wody opadowe a zjawiska ekstremalne, Wydawnictwo Seidel-Przywecki, 2011.
23. Królikowska J., Królikowski A.: *Wody opadowe. Odprowadzanie, zagospodarowanie, podczyszczanie i wykorzystanie*, Wydawnictwo Seidel-Przywecki, 2012.

mgr. inż. Dominika Matulewicz[1], dr hab. inż. Iwona Skoczko[2]
Politechnika Białostocka, Katedra Technologii w Inżynierii i Ochronie Środowiska
ul. Wiejska 45A, 15-351 Białystok
[1]e-mail: d.matulewicz@doktoranci.pb.edu.pl, [2]e-mail: i.skoczko@pb.edu.pl

Heavy Metal content in the leachate water from the landfill in Czerwony Bór

Key words: *landfill, leachate, heavy metals, lead, underground water*

Abstract: The largest contaminants of the ecosystem are chemical elements which, when present in higher concentrations, can cause a phenomenon of so-called chemical stress, and also in a situation where the reactions of ions chemical compounds occur may become active and harmful. Heavy metal contamination is one of most troublesome, because as far as contaminated water regenerates relatively quickly through self-purification, these elements are absorbed in the ground where they can be stabilized only by means of well-defined physicochemical conditions ,and the change thereof may cause a reactivation of the elements into water soluble forms, which leads to secondary contamination of aquatic ecosystems. This paper presents the characteristics of waste treatment and disposal facility in Czerwony Bór in terms of its impact on ecosystem's groundwater. The paper focses on one of the factors which is the lead concetration.

1. Introduction

Using the data of Główny Urząd Statystyczny it can be concluded that Poland's resource management policy is unreasonable. At present we produce about 120 million Mg of industrial waste annually, where about 75% is subject to recovery, 21.7% is disposed of, and 2% being temporary stored. Additionally, about 12 million Mg of municipal waste is created which is stored in about 74%, 9.7% biologically neutralized mainly in manure piles and 0.52% is subjected to heat treatment. One should remember that, unfortunately, still 1,650 million Mg are wastes accumulated in the environment.

Widely used colloquialism "garbage dump" is a colloquial wording describing the rendering pand waste disposal plants, which are quite burdensome for the environment. The problems associated with this issue is not just a unsightly appearance, unpleasant odor or amount of space that is that they occupy. One of the main problems is the content of harmful substances in the leachate generated at these facilities, which can contaminate soil, surface and groundwater.

The composition of leachate is a parameter that best illustrates us to what has been deposited in the landfill, and therefore what may have entered the environment. Among the dangers contained in this liquid we can find heavy metals in three forms, such as metal ions, metal hydroxides and complex compounds dioxins and furans. The wastewater from the municipal waste landfills are characterized by a quality and quantity diversity. This is conditioned by factors such as the size of the landfill, the amount and type of waste stored, environmental conditions (mainly rainfall), the age of the facility and technologies used that affect the degree of the compaction of waste.

2. Chemical elements present in leachate water of landfill

The largest contaminants of the ecosystem are chemical elements which, when present in higher concentrations, can cause a phenomenon of so-called chemical stress, and also in a situation where the reactions of ions chemical compounds occur may become active and harmful [1] which then may result in a chemical imbalance in the environment and living organisms in these areas. The contents of the effluents from landfills are significant quantities of chlorides, sulfates, nitrogen compounds, phosphates, fluorides, calcium, magnesium, sodium, potassium and iron. The prime indicator of human activity in the environmental changes is its heavy metal contamination [2]. Heavy metals are those that have a density greater than 6 g/cm^3. Universally this term is used in reference to a set of elements such as chromium, cadmium, copper, nickel, mercury and lead. The natural amount of these elements is not harmful to a human being and the content of some of them (zinc, copper, cobalt) is even essential for the proper functioning of the human, plant or animal organisms. Heavy metal contamination occurs in the case where they are present in amounts above the normal range [3]. Heavy metal contamination is one of most troublesome, because as far as contaminated after regenerates relatively quickly through self-purification ,these elements are absorbed in the round where they can be stabilized only by means of welled fined physicochemical conditions and the change thereof may cause a reactivation of the elements into water soluble forms, which leads to secondary contamination of aquatic ecosystems. Heavy metals have the ability to build up in different parts of plants and human bodies, and the consequences of the pejorative effects of these compounds are not immediately apparent and can cause permanent and progressive damage to living organisms [4].

This study focuses on the impact of one of the heavy metals, which is lead. Described below in more detail is its influence on the environment and health of living organisms.

2.1. Impact of lead on the environment and health of living organisms

Lead occurring in a double and tetravalent form together with all its chemical compounds, especially when talking about organic compounds are potent poison. The compounds of divalent lead are very stable in both solid and liquid form, that is not the case with tetravalent lead compounds that generally are strong oxidizing agents. One of the examples of the organic compound is tetraethyl lead, which was once used as a antiknock substance added to gasoline. Addition of this compound to gasoline, which is burned during transport resulted in its excretion in the oxide form to the sides of roads, resulting in contamination of surrounding areas [5].

Obvious sources of environmental lead pollution are dust and gases formed during volcanic eruptions and forest fires, of which conflagration only activates lead that was already present in the environment. According to Steiger (1984) these sources are the cause of 1800 t of the metal entering the soil annually. In contrast, anthropological activities, such as mines, industries, steel mills, agriculture (phosphate fertilizers, pesticides), as well as automotive are responsible for about 440 thousand. tones per year [6].

Number of different forms of this heavy metal in the soil environment is a practical indicator which enables assessment of how much of the lead is derived from natural sources, and what part is the product of human activities. Lead compounds are mainly emitted to the atmosphere, due to this fact mainly exposed to contamination are the aboveground parts of plants. From the ground lead it is assimilated to a lesser extent, due to the roots, which hinder the absorption of its compounds. As mentioned above, the most vulnerable to contamination are the upper parts of the plants growing along the roads. According to Grün (1985) in unwashed green forage beet leaf 25-33 mg of lead were detected per kilogram of dry weight within distance of 5 m from sources of pollution. Phytotoxic content of the described heavy metal ranges from 15 to 60 mg of lead per kg of dry mass and contamination of the vegetation occurs when the value exceeds 100 mg PB / kg DM [7]. Despite the interest in the issue of fuel and the introduction of unleaded version of gasoline vegetation growing along busy routes still shows elevated levels of lead. In the area surrounding Olkusza meadow hay that comes from these areas cannot be consumed by animals, because of elevated lead values;. This is due to the proximity of lead, cadmium and zinc ores. Also in the vicinity of these ores (Olkusza, Katowice) significantly higher values of lead in the hair of cattle were detected than it was in the vicinity of Bialystok. You can partially protect cattle against accumulation of lead in their bodies by adding protective formulations to the feed. It should be also noted that the lack of iron or its insufficient amount in the body can also cause problems, such as anemia and inhibit the growth of young animals [5].

2.2. Phenomena and physicochemical parameters of rocks which act on the movement of contaminants from landfills into soil-water of the ecosystem.

The radius of the impact of landfills and its intensity on soil and water environment depends among other things on the filtration and sorption properties of rocks, but also from the permeability of the aquifers, hydrogeological circumstances and the number and characteristics of the analyzed object leachates[8]. As a matter of consideration,, the contamination may be present as the three phase center dissolved in porous solution, bound to a surface of the solid phase and in gas phase. The phenomenon of distribution of wastes in the aquatic and ground environment is a complex process, which consists of a number of physicochemical factors responsible for transport of compounds and bacteriological processes. The main processes responsible for the movement of contaminants are phenomena such as convection, sorption and desorption, molecular diffusion and the degradation of organic substances [9].

Convection is an important transport mechanism of contaminants. It can be described as a mass moving through filtration stream with an average speed of waters through the pressure present in the medium.

The fact that the soil is the three-phase medium all kinds of reaction between rocks and contaminants are made easier, that's why sorption and desorption, occurring at the meeting point between contaminants with the water and soil. are significant elements in the migration of wastes. Soluble substances mostly penetrate into the pores of the soil where they are absorbed. Inorganic compounds accumulate on the surface of soil particles, and organic materials often are bound by the reacting with material organic matter occurring in the rock [10].

As for the molecular diffusion, it is the phenomenon where migration of contamination follow the direction of the concentration gradient.

The last mentioned phenomenon responsible for the transport of contaminants was the degradation of organic matter. The essence of this process are decomposition and biodegradation of organic pollutants by chemical and biological transformations, such as the addition, reduction, hydrolysis, oxidation and complexing. The result of these phenomena may be the emergence of new polluting substances and compounds. Since for example biodegradation process running under anaerobic conditions results in the formation of carbon dioxide and water, but in addition also to the formation of molecular nitrogen in gaseous form, hydrogen sulphide and methane [9].

The radius of migrating contaminants from objects dealing with the disposal of solid waste is conditioned by a type of pollutant, with which we are dealing. Bacteriological contamination, which range includes about 100 m from the landfill, exhibit the smallest spread. However, if we take into consideration chemical pollution in ionic form this distance becomes considerably larger, up to several kilometers [10].

3. Description and location of the waste processing and disposal plant in Czerwony Bór

He landfill is located in the town of Red Bor in the municipality of Zambrów, on the forest complex, which is adjacent to the villages Krajewo- Budziły and Łętowo. The area devoted to facility is 10.73 hectares, of which 2.55 hectares has been accomplished in the years 96'-97 'twentieth century. as a garbage dump, which operates to this day [15]. With the use of the Internet portal geoportal.gov location of the treatment facility and waste disposal in the aforementioned village is shown below marked by arrow[16] (Fig.1) plus approximation photo of a lanfill (Fig. 2).

Figure 1. Location of waste processing and disposal plant in Czerwony Bor

Source: Own study based on [16]

Figure 2. Waste processing and disposal plant in Czerwony Bor

Source: [16]

Facility built in Czerwony Bór is planned to service the region which includes 26 municipalities (including 21 municipalities of Podlaskie province and 5 of the Mazowieckie province) inhabited by over 164 thousand. residents.

The procedure for receiving of waste include qualitative lustration of supplied wastes which is carried out by an authorized employee, a quantitative auditing (determination of the weight of the waste) with the weighbridge and directing accepted waste depending on their composition to the sorting of waste, for composting (Fig. 3), to the dismantling of bulky waste(including household appliances / electronics), to designated waste storage sites, directly at the newly built accommodation, directly exploited at the moment accommodation deposition of waste containing asbestos[15].

Figure 3. Composting plants of waste processing and disposal plant in Czerwony Bór

Source: [15]

Waste sorting technology relies on fragmentation through a sieve(27000 mg/year) and the sorting line (14000 mg/year) (Fig. 4) . From what line of segregation is secondary treatment of raw materials originating from the big-container collection, organizing waste from sieves with fraction of over 80 mm, or dry fraction of two container collection.

Figure 4. Sorting line of waste processing and disposal plant in Czerwony Bór

Source: [15]

4. Research Methodology

Places allowing groundwater monitoring are most commonly piezometers, dug and drilled wells and sources. When examining the impact of the storage and disposal of waste plants on groundwater is is determined that minimum number of openings are three, at least one must be located on the path of inflow of groundwater in the area surrounding landfill, and at least two are responsible for monitoring the groundwater flowing from the plant[13]. Regulation of the Minister of the Environment of 9 December 2002, on the scope, time, manner and conditions of landfill monitoring describes a very poor range of control of groundwater. The only requirement is testing of two parameters in the samples taken, such as pH and electrolytic conductivity (PEW) and the overall measurements of the groundwater level. In the case of plants that receive municipal septic further analysis is required including physicochemical parameters as total organic carbon (TOC), the concentration of heavy metals (chromium, zinc, cadmium, copper, lead, mercury) and total polycyclic aromatic hydrocarbons (PAHs).Determination of the likely impact of a facility for treatment and segregation of wastes on groundwater through such a narrow field of research is very limited. In the case of demonstration of elevated values of electrolytic conductivity and total organic carbon it can be concluded that the investigated landfill adversely affects the environment of groundwater, but without a broader physicochemical analysis it is impossible to prove a particular source of contamination[13]. Additionally taken into account Regulation of the Minister of Environment of 11 February 2004 on the classification for presenting the status of surface water and groundwater, method of conducting of monitoring and how to interpret the results and presentation of state of water, which were used to determine the degree of exceeding the maximum allowable concentrations of tested components in which division of groundwater by water quality in classes I to V was adopted [14].

Bearing in mind the abovementioned problem this study focuses on the analysis of ground water taken from four points of measurement and control and demonstration of differences in the concentrations of the tested parameter (in this case the concentration of lead) depending on the place of collection and landfill operation.

4.1 Points of measurement and control

Ground water samples were collected from four of measurement and control located on the premises of waste treatment and disposal plant in Czerwony Bór in December 2014. Two monitoring locations were piezometers and two drilled wells located at the basins operated and closed down. Below shows the map with locations of measurement and control points marked by arrow (Fig. 5).

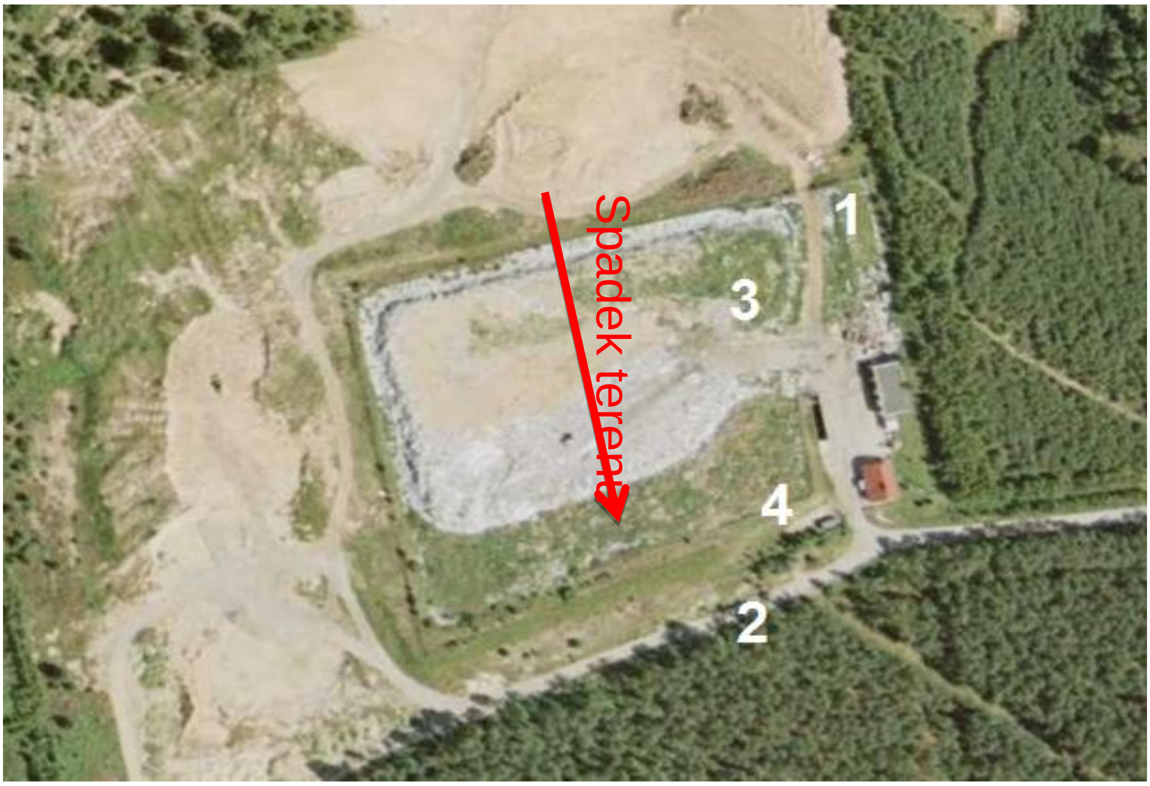


Figure 5. Location of measurement and control point at landfill in Czerwony Bór

Source: Own study based on [16]

In the above figure (Fig. 5) four places of groundwater collection exposed to close contact with pollutants typical for a landfill are marked. First piezometer, which is in the northeast corner of the site is marked as 1.

In the second test site underground water was collected from piezomete located just outside the gate of a plant in a nearby forest. Spatial conditions of landfill which is land inequality indicates that in the first piezometer mainly ground water coming from the surrounding areas was examined, while the second' s location was meant for monitoring of groundwater flowing out of the landfill. In the third point location of drilled well is marked just by an active basin, which daily receives litter (containing asbestos) from twenty-six different municipalities. While the fourth position indicates the location of well drilled at the disused basin, which was excluded from service and subjected to reclamation in August 2012.

4.2 Atomic absorption spectrometry

Atomic absorption spectrometry (AAS) is a method based on the phenomenon of absorption of electromagnetic radiation by free atoms. The existence of such kind of absorption was discovered in the early nineteenth century, through the observation of in the spectrum of sunlight darker lines later called Fraunhofer lines [11].

The atomic Spectrometry is based on analysis of atomic spectra using a quantitative relationship occurring between electron transitions. The amount of energy, or radiation at a predetermined frequency or by explicit wavelength that is absorbed by the atom is emitted during returning to the basic state. Judging by this we know that the atom has the ability to absorb electromagnetic radiation of only such a wave magnitude at which its emissions is possible and is representative of the element. Described above phenomenon is the basis of qualitative research carried out by the means of atomic absorption spectrometry. With this method, due to its selectivity, it is possible to detect different elements in the sample independently of each other. Transitions of electrons between different energy levels are assigned to different frequencies of radiation collection of which is typical for a particular element atomic spectrum otherwise known as linear spectrum. Only one of the many absorption lines should be selected for the analysis [12].

In the methods of atomic absorption spectrometry analysis thermal plasma spectrum. Is usually tested. thermal plasma is a medium which is heated to a temperature above 1000K in the gaseous state, containing free atoms and ions in diverse states of excitation. Free electrons, radicals, molecular ions, and molecules. Such plasma can be obtained through the use of flames of different burners, electric arcs and sparks and hot graphite cuvettes [11].

The metallic elements generally takes the form of organic or inorganic compounds, so to stage the absorption phenomena one should change its form atomic state, that is vapor state, which is capable of absorbing radiation. Given the sensitivity and selectivity of this method it is very important that the vast majority of atoms were in the basic state. When using low temperature plasma (from 1000K to 4000K), a majority of the elements is in this state, regardless of whether the element is excited easily or with difficulty [11].

The essence of measurements made by the ASA is that the resonant line of the analyte of a given intensity is sent from the points of radiation to the atomizer, wherein the absorption on free atoms occur. Portion of the radiation (resonance line) which was not absorbed by the free atoms reaches the detector through the monochromator, which measures its intensity. Then a comparison between intensity that reached the detector with intensities of analysed element is made, which gives the absorbance proportional to the concentration of analyte [12].

For the purposes of analyzing the concentration of lead in samples taken from the Facility of Processing and Waste Disposal in the Czerwony Bór samples were first acidified with nitric acid (V) (HNO_3) the pH of lower or equal to 2 , this was done by addition of concentrated, the abovementioned acid in a ratio of 0.5 ml per 100 ml of sample. From the previously acidified samples 20 cm3 with added 6cm3 of nitric acid (V) was taken to analysis. The samples were then subjected to mineralization at mineralisation block. In order to completely oxidize organic forms about 15 cm 3 of 30% hydrogen peroxide. Was added to sample. Upon completion of mineralization, mineralizers were diluted by adding distilled water to a volume of 50 cm3, and further subjected to indication of concentrations of heavy metals including lead in the analyzed samples on ASA100 device located in the Department of Engineering and Technology in Environmental Protection at the Technical University of Bialystok. The test method used a flame and a thermoelectric ionization depending on the target concentrations of the respective elements.

5. Tests results

In this study we focused on the amount of lead concentrations in the underground water taken from the area of landfill in Czerwony Bór in December 2014. For this purpose measuring and control samples were collected from four monitoring sites two piesometers and seven drilled wells. Laboratory was conducted next, aiming to identify the magnitude of the lead concentration in the leachate from the examined object. The following table (Tab. 1) and figure 6 presents the results of this survey.

Table 1. The concentration of lead in the water leachate collected from landfill in Czerwony Bór

Measurement and control point	**Lead concentration (µg/dm^3)**
Piezometr 1 (pkt. 1)	9,72
Piezometr 2 (pkt. 2)	11,55
Well near open basin (pkt. 3)	18,34
Well near closed down basin (pkt. 4)	14,91

Source: Own study

Figure 6. Lead concentration at measurement and control points at Czerwony Bór landfill

Source: Own study based on table 1 and [16]

Based on the above Table 1 and Fig.6 it has been observed that the highest concentration of lead, that was 18.34 mg/dm^3 was present at fourth measurement and control point, which is located at landfills operated basin, while the lowest value of the analyzed concentration of the element equal to 9.72 mg/dm^3 was found in water taken from the first piezometer , located in the northeastern section of the landfill. In the second control point lead concentration amounted to 11.55 mg/dm^3, it was the second lowest. In the water taken from wells drilled by the out-of-use basin reported lead content equals to 14.91 mg/dm^3.

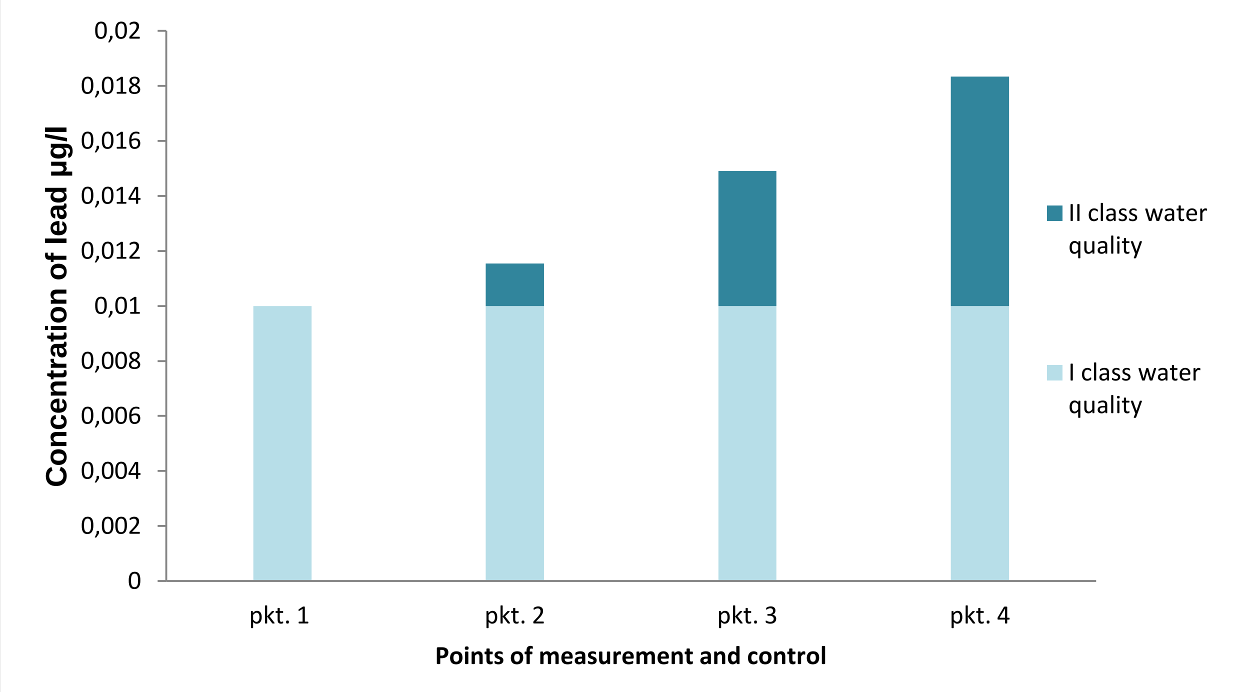


Figure 7. Lead concentration at control points in landfill in Czerwony Bórtaking into account the Regulation of the Minister of Environment dated 11 February 2004

Source: Own study based on table 1. and [14]

Based on Fig. 7 and the Ordinance of the Minister of Environment of 11 February 2004 we plotted graph of the relationship of lead concentration to the measurement-control points taking into account the limit values for water quality classes contained in the abovementioned Ordinance. It was observed that only the first control point concentration (9.72 mg/l) of the test element corresponds to the value of class I water quality be in lower than 0,01 mgPb/l. In other points the values corresponding to Class I groundwater quality have been exceeded. Assigning analyzed in points. second (11.55 mg/l), third (14.91 µg/l) and fourth (18.34 mg/l) for Class II water quality, which limits the concentration of lead to 0.05 mg /l.

6. Interpretation of research results

Assessment of the status of groundwater in the landfill area in Czarny Bor, located in the municipality of Zambrów was determined based on the results of monitoring conducted in Facility’s surrounding area in December 2014. It was carried out using the Ordinance of the Minister of Environment of 11 February 2004 concerning the classification for presenting status of surface and groundwater, methods of conducting of monitoring and how to interpret the results and present state of the waters, that were used to determine the degree of exceeding the maximum allowable concentrations of the test ingredients [14]. Analysis of the results of monitoring carried out in the investigated facility showed that the range of the tested parameters is relatively narrow and therefore was limited to the determination of the parameters specified in the Ordinance of the Minister of Environment of 9 December 2002, on the scope, timing and conditions of landfill monitoring[13]. According to the guidelines of quoted above Ordinance [13], basic monitoring of groundwater in the landfill area should include a determination of parameters such as pH, electrolytic conductivity, total organic carbon content, the content of heavy metals (Cu, Zn, Pb, Cd, Cr (VI) Hg) and the total polycyclic aromatic hydrocarbons. In this study we focus on one element mentioned in the aforementioned Ordinance [13], namely, the magnitude of the lead concentration. The analysis was performed in a laboratory located in the Department of Engineering Technology and Environmental Protection at the Technical University of Bialystok using atomic absorption spectrometry by flame and the thermoelectric ionization on device ASA100.

The results indicate a slight contamination of groundwater with lead, in almost every control point, excluding the first values slightly exceed the levels described in the Ordinance of the Minister of Environment dated 11 February 2004 [14], in which groundwater falling under to class I water quality the limit value is 0.01 mgPb/l by respectively 1.55 mg /l second, about 4.9 mg/l third and 8.34 mg/ l for fourth control point, . To compare the results, the analysis of lead concentrations in groundwater collected in two piezometers made in 1996 for the landfill located in Tarnów- Krzyż, values of the analyzed component were 0.005 mg/l and 0.062 mg/l. classifying groundwater taken from one piesometer to class I water quality while in the second point the contamination was much higher corresponding to V class water quality [10,14]. When it comes to the Gromnik landfill in studies performed in 2002, groundwater was collected from drilled well, analysed sample was contaminated by 0,081 mgPb/l which then classified the water to class V of water quality. While on the same landfill in 2005 and 2006 significant decrease in the concentration of lead was observed. In those years the waters were examined at the two sites through piezometers and values were determined to be less than 0,001 mgPb/l in both points in 2005 and the value of 0.003 mgPb/l (piezometer 1) and 0,004 mgPb/l (piezometer 2) in 2006, which classifies the leachate from the landfill during those years as first class water quality according to the aforementioned Regulation [10,14]. At the Biała Niżna landfill the monitoring was conducted in the period from 1997 to 2005. An analysis of the lead content carried out a year after the start of operation of the landfill indicate that it’s amount was less than 0.1 mgPb/l (V class water quality), in the years 2004 to 2005, in the amount of less than 0.01 mgPb / l (water quality class I).Compared with the results of the analyzes carried out in 1997, when lead was present in amounts of 0.25 mg / l (class V) there was a significant reduction of its content[10,14].

Referring to the Regulation of the Minister of the Environment of 9 December 2002, bon the scope, time, manner and conditions of landfill monitoring, it is concluded that the landfill meets the requirements for the number and location of monitoring sites. Because the minimum number of openings is three, at least one must be located in the way of inflow of groundwater from the vicinity of landfill, and at least two are responsible for monitoring the groundwater flowing out from the object [13]. Considering the location of measurement points, and lay of the land it can be said that groundwater coming to the landfill containins about 9.72 μgPb/l (pkt. 1), and flow out with the value of 11.55 μgPb/l. It is concluded that the Waste storage and disposal facility in Czerwony Bór slightly, but still adversely affects the groundwater ecosystem.

7. Conclusions

1. Taking into account lead concentration Waste treatment and disposal Facility in Czerwony Bór has a slight negative impact on groundwater contamination in surrounding area.
2. In almost every control point, excluding the first values slightly exceed the levels described in the Ordinance of the Minister of Environment dated 11 February 2004 [14], in which groundwater falling under Class I water quality the limit value is 0.01 mgPb/l by respectively 1.55 mg / l second, about 4.91 mg / l third and 8.34 mg / l for fourth control point.
3. Referring to the Regulation of the Minister of the Environment of 9 December 2002, on the scope, time, manner and conditions of landfill monitoring, it concluded that the landfill meets the requirements of adequate quantity and location of monitoring sites.

References

1. Kabata-Pendias A., Mukherjee A. *Trace elements from soil to human*. 2007.
2. Alloway B.J., Ayres D.C., *Chemical principles of evnironmental pollution*. 1997.
3. Kabata – Pendias A., Pendias H., *Biochemia pierwiastków śladowych*. PWN. Warszawa 1993.
4. 4. Budek L., Wardas M., Kasprzyk A., *Rozprzestrzenianie się metali ciężkich w środowisku wód powierzchniowych wokół wysypiska odpadów komunalnych w Baryczy* 2000.

5. Karol Węglarzy *Metale ciężkie zródła zanieczyszczeń i wpływ na środowisko* Instytut Zeotechniki PIB 2007.
6. Steiger K. Blei in Boden. W: *Mengen und Spurenelemente*. Wyd.: Anke M., Groppel B., Gürtler H., Grün M., Lombeck I., Schneider H.J., Friedrich- Schiller-Universität Jena, pp. 175-192. 1984.
7. Steiger K. Blei in Boden *Spurenelemente*. Wyd.: Anke M., Groppel B., Gürtler H., Grün M., Lombeck I., Schneider H-J., Friedrich-Schiller-Universität Jena 1984.
8. Kulig A., *Metody pomiarowo – obliczeniowe w ocenach oddziaływania na środowisko obiektów gospodarki komunalnej*. Oficyna Wydawnicza Politechniki Wrocławskiej. Wrocław 2004.
9. Małecki J. *Wyznaczanie parametrów migracji zanieczyszczeń w środku porowym dla potrzeb badań hydrogeologicznych i ochrony środowiska.* Poradnik metodyczny. Ministerstwo środowiska 2006.
10. Katarzyna Sobik *badanie wpływu składowisk odpadów na środowisko gruntowo- wodne na przykładzie wybranych obiektów zlokalizowanych w obrębie zlewni Dunajca.* Akademia Górniczo- Hutnicza, Kraków 2007.
11. Walenty Szczepaniak: *Metody instrumentalne w analizie chemicznej*. Warszawa: PWN, 2002.
12. Bernhard Welz, Michael Sperlin. *Atomic Absorption Spectrometry*. Wiley-VCH, 1999.
13. Rozporządzeniu Ministra Środowiska z dnia 9 grudnia 2002 roku. *W sprawie zakresu, czasu oraz warunków prowadzenia monitoringu składowisk odpadów.*
14. Rozporządzenia Ministra Środowiska z dnia 11 lutego 2004 roku. *W sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz sposobu interpretacji wyników i prezentacji stanu wód, które wykorzystano do określenia stopnia przekroczenia maksymalnych dopuszczalnych stężeń badanych składników.*
15. www.pgkzambrow.pl
16. www.mapy.geoportal.gov.pl