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Appendix 2

PRESENTATION OF SCIENTIFIC ACHIEVEMENTS

1. First name and surname: **Jarosław Gawdzik**

2. Diplomas and degrees obtained:

a) 21 Sept. **1990** – *MSc. Eng.* – Cracow University of Technology

Title of the MA thesis: Numerical method of catalyst deactivation computation (in Polish) *Supervisor: Associated Prof. Wanda Kramarz, PhD, Eng.*

b) 24 Oct. **2001** – *Doctor of technical sciences*, Faculty of Civil Engineering, Kielce University of Technology.

Title of the doctoral dissertation: Investigations into oil derivative migration in the porous medium in relation to groundwater hazard

Supervisor: Dr habil. Maria Żygadło, the University Prof., Eng.

3. History of employment in research institutions:

a/ 1 Nov. 1990 to 30 Sept. **1991** – *Assistant at the Unit of Technical Chemistry, Kielce University of Technology.*

b/ 14 Feb. 1993 to 31 Dec. **2001** - *Assistant at the Department of Water and Sewage Technologies, Kielce University of Technology.*

c/ since 1 Jan. **2002** – *Assistant Professor at the Department of Environmental Engineering and Protection, Kielce University of Technology.*

4. Research work

a/ the modelling of contaminant migration processes:

After obtaining doctor's degree, I continued research into the migration of oil derivatives in a porous medium. In environmental engineering, it is important to find out how the transport processes of petroleum products occur. This knowledge is applied to technologies of waste disposal at landfills (the migration of leachate containing oil derivatives into the ground), issues related to derivative migration from typical areas of contamination (filling stations, petroleum product storage facilities, military testing grounds), and to situations in which those substances enter the ground as a result of road or railway accidents. The migration of oil-derived contaminants may occur in different states of matter, namely it can proceed in gaseous, liquid and solid form, or it can take place in the form of phase combination. In the zone of aeration (unsaturated), some oil derivatives undergo adsorption on the rock material, others infiltrate inside often reaching the groundwater table. The investigations aimed at developing a diffusive model of hydrocarbon propagation (initial-boundary value problem) in the sand-hydrocarbons system, and at the model experimental validation:

$$\frac{\partial C_i}{\partial t} = D_i \frac{\partial^2 C_i}{\partial z^2} - \mu_i C_i \qquad (1)$$

- $C_i(z, 0) = 0$ for $0 < z \leq S$
- $C_i(0, t) = C_{0i} \cdot exp(-\mu_i \cdot t)$ for $t \geq 0$
- $\frac{\partial C_i}{\partial z} = 0$ for $t > 0$ and $z = S$

where:

μ_i – constant velocity of decrease in hydrocarbon concentrations, $[s^{-1}]$
C_i – content of the "ith" hydrocarbon in the matrix, $[kg \cdot m^{-3}]$
C_{0i} – initial content of the "ith" hydrocarbon in the matrix, $[kg \cdot m^{-3}]$
D_i – substitute coefficient of diffusion of component "ith" $[m^2 \cdot s^{-1}]$
S – maximum ground penetration by hydrocarbons, [m]
t – time, [s]
z – independent variable of hydrocarbon migration in the vertical direction, [m]

The boundary value problem (1) was used to describe the transport of oil-derived hydrocarbons in the aeration zone. The model was validated at the research stand under the conditions simulating the natural ground medium.

I am a co-author of three studies, published by periodicals in JCR database, which originated in the research that resulted from continuing the topic of my doctoral thesis:

1. Żygadło M., Gawdzik J.: **Modelling the transport of petroleum products by soil filter method**, Polish Journal of Environmental Studies, vol. 19, No, 4, pp. 841-847, 2010.
2. Żygadło M., Gawdzik J.: **Modelling transport of hydrocarbons in soil-water environment,** Ecological Chemistry and Engineering S, vol. 17 No. 3, pp. 331-343, 2010.
3. Gawdzik B., Gawdzik J.: **Impact of pollution with oil derivatives on the natural environment and methods of their removal**, Ecological Chemistry and Engineering S, vol. 18 No. 3, pp. 345-357, 2011.

b/ heavy metal mobility in sewage sludge as indicated by speciation analysis:

Determining heavy metal migration in sewage sludge seems of primary importance when the sludge is used in agriculture. Sewage sludge from sewage treatment plants has both soil-forming and fertilising properties. It contains organic substances, nitrogen, phosphorus, magnesium, calcium and potassium forms that are available to plants. The constraints on sewage sludge use as an organic fertiliser result mainly from inappropriate microbiological composition and high heavy metal content. Problem of sewage sludge is related to the scale of its production. In 2012, 3191 municipal sewage treatment plants generated approx. 520 Gg dry mass. Heavy metals in sludge originate in sewage subjected to treatment processes. In sewage, heavy metals are found as suspensions or in dissolved forms. Sewage treatment processes, including the simultaneous phosphorus precipitation, and also chemical precipitation with lime, result in heavy metal adsorption and co-precipitation in the deposited sludge. That leads to their removal from the sewage. Additionally, mass bioaccumulation by microorganisms in the aeration tank and the sludge digestion process (the formation of immobile heavy metal sulphides) facilitate the transfer of heavy metals from sewage to sludge. The changes described above result in the formation of a variety of chemical forms of heavy metals accumulated in the sewage sludge. Only metal mobile forms migrate from sewage to the soil environment.

The major factors that affect the heavy metal bioavailability to plants include the following: the total metal content in the soil, kind of metal, the pH of the soil, the content of organic matter and clay fraction. Bioaccumulation of heavy metals in plants growing on soils contaminated with heavy metals depends on the plant kind and the content of metal mobile fractions in the soil. In the soil analysis, multi-step extraction of heavy metals should be used [1-2]. Legal regulations binding in Poland impose a limit on the maximum content of heavy metals in the municipal sewage sludge applied to soils (J. of Laws No. 137, item 924 of 13 July 2010). The regulations refer to the cumulative content of lead, cadmium, mercury, nickel, zinc copper and chromium after the mineralization in aqua regia (or concentrated acids), determined using the AAS method [3]. The law does require speciation of heavy metals contained in the sewage sludge. Recent analytical techniques, however, make it possible to assess the actual hazard posed by the soil exposition to sewage sludge containing heavy metals when their direct transfer to the soil involves only their mobile forms.

In the investigations, I used raw, and aerobically and anaerobically digested sewage sludge from sewage treatment plants located in central Poland, which are characterised by diversified content of microcontaminants. The sludge under consideration was subjected to speciation analysis. Basically, the speciation analysis with the Kersten and Förstner method involves chemical extraction of heavy metals contained in the sewage sludge. As a result of the process, extracts containing metals in the mobile, organic, oxidized, reduced and immobile forms are obtained. The diagram of the complete Kersten and Förstner procedure is shown in Table 1. Owing to the use of the speciation analysis, it is possible to accurately determine the concentrations of mobile forms of heavy metals. That is done with respect to the total heavy metal content, determined with the reference method for sewage sludge investigations (J. of Laws No. 137, item 924 of 13 July 2010)

Inter-laboratory investigations were conducted that aimed at comparing different sequential extraction procedures. It was found out that the four-step procedure developed by the European Community Bureau of Reference, called BCR for short, is the optimum means of identifying metal fractions in sewage sludge samples [4-5,7-16]:

- Step I: CH_3COOH extraction – to determine the content of metals that are accessible and bound to carbonates (FI - exchangeable fraction),
- Step II: $NH_2OH{\cdot}HCl$ extraction – to determine the content of metals bound to amorphous iron and manganese oxides (FII – reducible fraction),
- Step III: H_2O_2/CH_3COONH_4 extraction - to determine the content of metal-organic and sulphide fractions (FIII – oxidizable fraction).
- Step IV: mineralisation of the residual fraction in a mixture of concentrated acids (HCl, HF, HNO_3) - to determine the content of metals bound to silicates (FIV – residual fraction).

Table 1

Diagram of the sequential analysis for separating sludge samples [5,7]

Fraction/form of occurrence	**Kersten and Forstner - extended procedure (1986)**	**Tessier's procedure (1979)**	**EC/BCR procedure**
Exchangeable ions	1mol/L CH_3COONH_4	1mol/l $MgCl_2$	0.1mol/L CH_3COOH. Shake for 16h
Carbonate-bound metals	1mol/l CH_3COONa, pH=5 in/ CH_3COOH	1mol/l CH_3COONa, pH=5 in/ CH_3COOH	
Easily reducible fractions (e.g. Mn oxides)	0.01 mol/l $NH_2OH{\cdot}HCl$ w/ 0.01 mol/l HNO_3	0.04 mol/l $NH_2OH{\cdot}HCl$ + 25% CH_3COOH, 90°C	0.1mol/l $NH_2OH{\cdot}HCl$ conc. HNO_3 (pH =2) Shake for 16h
Moderately reducible fractions (e.g. Fe oxides)	0.1 mol/l oxalic buffer (pH=3)		
Sulphides/ organic fraction	30% H_2O_2 pH=2/ 0.02 mol/l HNO_3 extraction with 1mol/l CH_3COONH_4, 6% HNO_3	30% H_2O_2 pH=2/ 0.02 mol/l HNO_3 85°C, 2mol/l CH_3COONH_4 + 20% HNO_3	8.8 mol/l H_2O_2 (x2) 85°C; pH=2, 1 mol/l CH_3COONH_4 Shake for 16h
Residual fraction	hot, concentrated HNO_3	$HF/HClO_4$ or aqua regia	aqua regia

Metals that occur in water-soluble compounds and those bound to carbonates are thought to be the most mobile ones (Table 1). Metals bound to iron and manganese oxides are released into the environment much more slowly. Under particular conditions of pH and oxidation-reduction potential, the metals bound in FII can demonstrate significant bioavailability. Metals that form stable compounds with organic matter, or occur in the form of sulphides are considered potentially immobile. Metals bound to aluminosilicates are regarded as unavailable [13].
In the literature, many studies can be found that describe investigations into sequential extraction of heavy metals from soils, sewage sludge, river (sea) sediments and composts [7-20].
In order to conduct one series of sequential extraction experiments, I used four sludge samples of 0.5 g (sludge mass ~ 2 g altogether), then subjected to the BCR procedure. It is not recommended to employ larger test portions as that can lead to chemical interference.

I defined the **metal mobility** as a decimal of the content of heavy metal mobile compounds in the matrix.

$$WM = 100\% \frac{\sum_{i=1}^{2} m_i}{\sum_{i=1}^{4} m_i} = 100\%(F_1 + F_2) \qquad (2)$$

where:
m_i – metal mass in the i-th fraction
F_1 – relative metal content in the exchangeable fraction
F_2 – relative metal content in the reducible fraction

Metal stability index I_S provides information on the strength of metal bonds with mineral-organic soil components over the time that elapsed from the moment of contamination. It can take on the values in the range $1 \geq I_S > 0$. If a metal occurs in the easily soluble and exchangeable form, the value of I_S is close to zero, whereas when $I_S \approx 1$, the metal predominantly occurs in stable, mainly residual forms [11]. Intermediate values indicate the metal occurrence in both mobile and stable forms. The index I_S is expressed by the formula [11]:

$$IS = \sum_{i=1}^{k} \frac{i^2 \cdot F_i}{k^2} \qquad (3)$$

where:
i – denotes a subsequent step of the sequential extraction j,
k – maximum number of extractions (in the BCR procedure k=4),
F_i – relative metal content in the ith chemical form

At the initial stage of investigations, prior to the start of fractionation, I dried the samples to constant mass at the temperature of 105°C. The literature does not show a uniform approach to this important issue. In my opinion, it is reasonable not to modify the matrix thermally. I observed the above effect when trying to assess the effect of microwave radiation on the mobility of heavy metals. The variation in the mobility of heavy metals (Fig.1) is random in character and cannot be attributed to the effect of microwave radiation dosage [17].

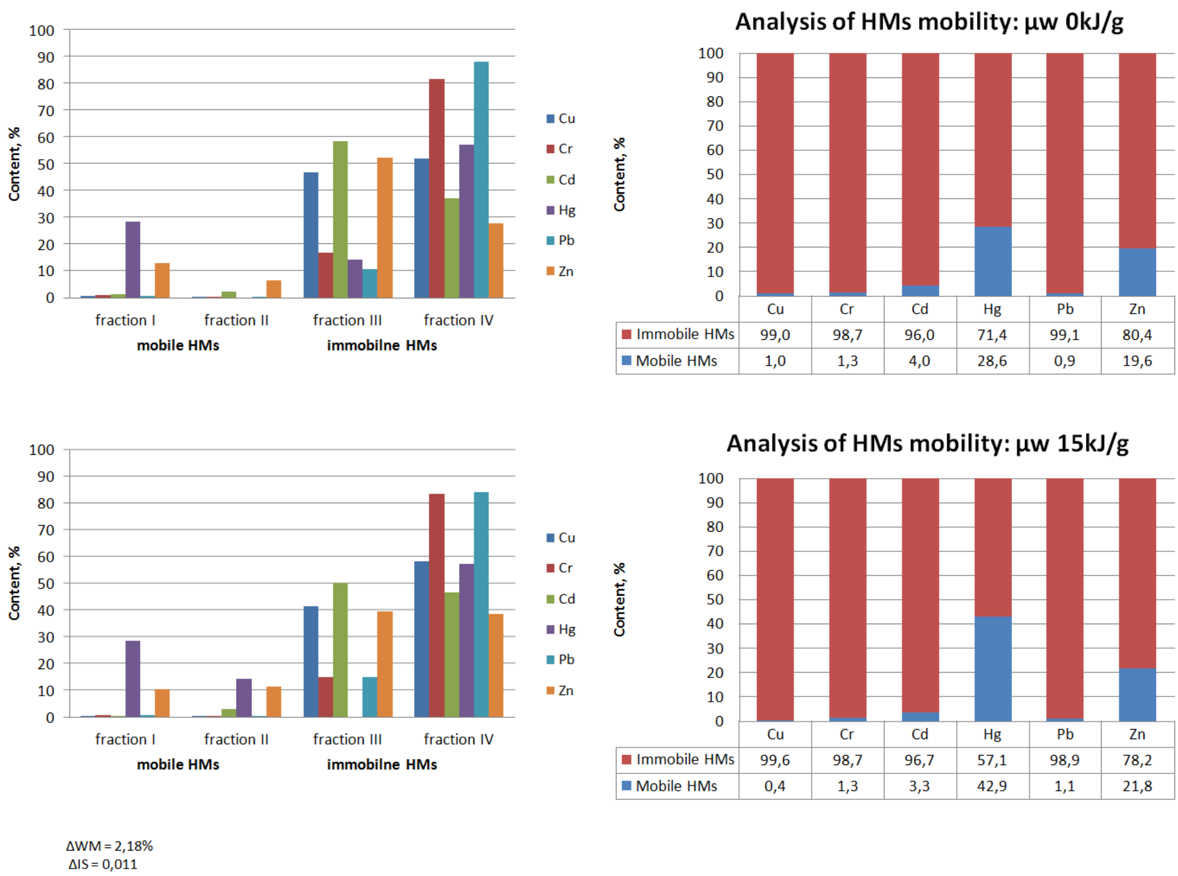
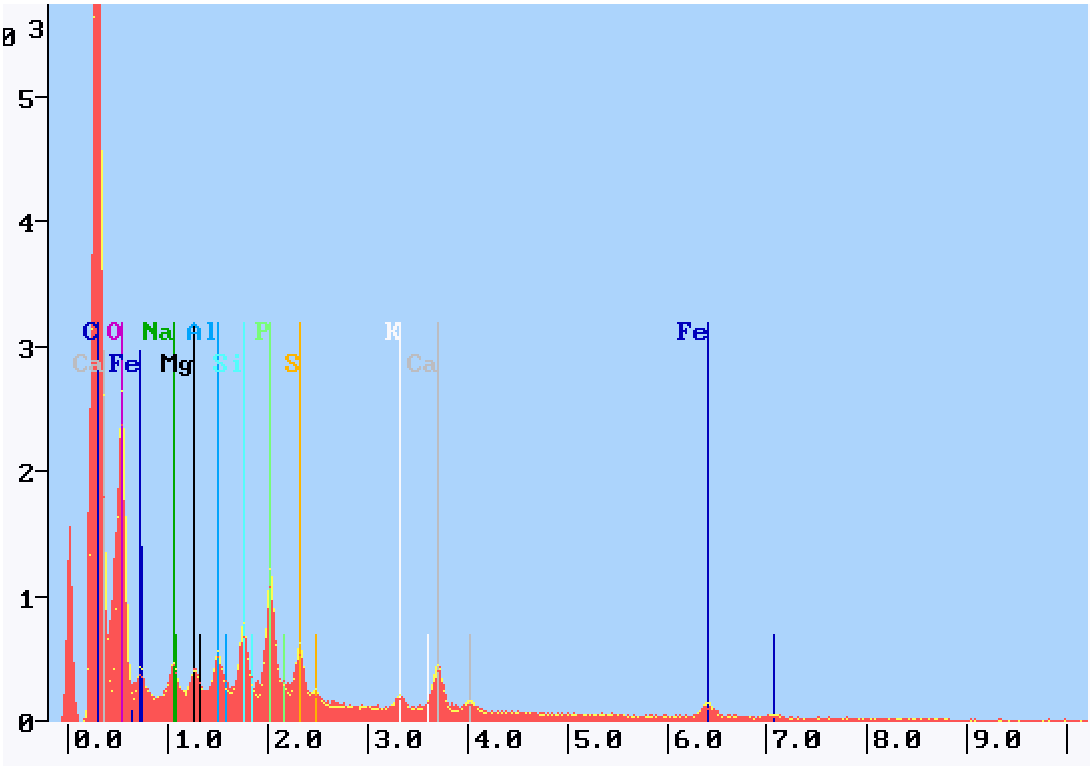


Fig. 1. The effect of microwave radiation (2450 MHz) on heavy metal mobility in sewage sludge collected from the sewage treatment plant in Sitkówka-Nowiny

I determined the content of heavy metals in individual forms with Flame Atomic Absorption Spectrometry *(*FAAS*)* using a PerkinElmer 3100 spectrometer. The results of investigations were subjected to the statistical analysis to eliminate gross errors. For that sake, I employed Dixon and Grubbs tests.

The occurrence of interception matrices for metal fraction FI ÷ FIV is assumed a priori. However, I confirmed their presence using the roentgen microanalysis. In the exemplary sewage sludge from the sewage treatment plant in Daleszyce (the Świętokrzyskie province) heavy metal compounds with the organic matter, iron oxides, sulphides and aluminosilicates are found (Fig.2).



Energy [keV]

Fig. 2. X-Ray microanalyses spectrum of the sewage sludge sample from the sewage treatment plant in Daleszyce

My greatest scientific achievement is the publication of the monograph entitled “Mobility of selected heavy metals in sewage sludge”. The study was published in July 2013 by the Kielce University of Technology Publishing House. The reviewers of the dissertation were Prof. Michał BODZEK, Dr habil. Eng. and Prof. Maria WACŁAWEK, Dr habil. Eng. In the study I presented the results of investigations into the mobility of heavy metals at 23 sewage treatment plants located in central Poland (Table 2).

Table 2

Sewage sludge collected from selected sewage treatment plants located in central Poland

Sample notation	Location	Type of sewage treatment plant	PE	Sludge treat-ment method	Sludge use
O1	Gnojno	Mechanical-biological	850	Aerobic sludge digestion	Remediation of soilless ground
O2	Pacanów	Mechanical-biological, EvU-Perl technology	1400	Aerobic sludge digestion	Reclamation of land for agricultural purposes
O3	Barcza	Mechanical-biological, EvU-Perl technology	1444	Aerobic sludge digestion	Insulation layers at the landfill
O4	Kostomłoty-Laskowa	Mechanical-biological, SBR technology	3333	Press dewatering	Insulation layers at the landfill
O5	Bartków	Mechanical-biological	3496	Dewatering	Insulation layers at the landfill
O6	Sobków	Mechanical-biological, SBR technology	3725	Drymet system	Insulation layers at the landfill
O7	Daleszyce	Mechanical-biological, SBR technology	5000	Aerobic sludge digestion	Remediation of soilless ground
O8	Strawczyn	Mechanical-biological	6770	Aerobic sludge digestion	Remediation of soilless ground
O9	Małogoszcz-Zakurcze	Mechanical-biological	8000	Aerobic sludge digestion	Thermal disposal
O10	Cedzyna	Mechanical-biological, EvU-Perl technology	9466	Aerobic sludge digestion	Insulation layers at the landfill
O11	Mniów	Mechanical-biological, COMA-TEC technology	9550	Aerobic sludge digestion	Insulation layers at the landfill
O12	Ożarów	Mechanical-biological	9660	Belt press dewatering	Insulation layers at the landfill
O13	Opatów	Mechanical-biological	15240	Digestion in open digester	Reclamation of land for agricultural purposes
O14	Kornica	Mechanical-biological	21594	Imhoff digestion	Insulation layers at the landfill
O15	Busko-Siesławice	Mechanical-biological, PUB technology	26444	Aerobic sludge digestion	Land reclamation
O16	Sandomierz	Mechanical-biological	29550	Aerobic sludge digestion	Crops not intended for human consumption or feed production
O17	Włoszczowa	Mechanical-biological, UCT technology	38522	Dewatering and disinfection	Land reclamation
O18	Pińczów	Mechanical-biological, hybrid technology	45000	Imhoff digestion	Land reclamation

Table 2 continued

Sample notation	Location	Type of sewage treatment plant	PE	Sludge treatment method	Sludge use
O19	Jędrzejów	Mechanical-biological, PUB technology	48272	Liming	Crops not intended for human consumption or feed production
O20	Skarżysko-Kamienna	Mechanical-biological, hybrid technology	59500	Digestion in the covered digester	Insulation layers at the landfill
O21	Ostrowiec Św.	Mechanical-biological	87150	Digestion in the digestion tank	Reclamation of land for agricultural purposes
O22	Starachowice	Mechanical-biological	95000	Digestion in the digestion tank	Crops not intended for human consumption or feed production
O23	Sitkówka-Nowiny	Mechanical-biological, PUB technology	172569	Digestion in the covered digester	Thermal disposal

In study [18], I demonstrated that for selected facilities O1÷O23, the percentage content of individual fractions of heavy metals was dependent on the sludge pH. Although the migration of heavy metals delivered to the soil with sewage sludge is small, yet it may increase in sandy soils with low pH.

The comparative analysis of heavy metal content in the sewage sludge collected from 23 municipal sewage treatment plant located in central Poland shows that only in three cases the content values of the examined heavy metals in the sewage sludge intended for agricultural use exceeded the permissible values. That referred to the Zn content in the sewage sludge from the sewage treatment plants O7, O20 and O22, and also Cr content in the sewage sludge from the sewage treatment plant O20. The source of chromium in the sewage sludge from the sewage treatment plant O20 is most likely the metallurgical industries sewage. As regards sewage treatment plants O7 and O22, it should be emphasised that the contents of heavy metals did not exceed the limit values, binding in Poland, for the sludge purposed for land use.

The mean percentage content of examined heavy metals in the sewage sludge from facilities O1÷O23 can be sorted by decreasing values:

- for Cu: FIII (64.5%) > FIV (27.1%) > FII (4.9%) > FI (3.5%)
- for Cr: FIV (50.7%) > FIII (35.6%) > FI (7.6%) > FII (6.1%)
- for Cd: FIV (43.2%) > FIII (28.7%) > FI (14.2%) > FII (13.9%)
- for Ni: FIV (49.0%) > FIII (22.6%) > FII (15.1%) > FI (13.3%)
- for Pb: FIV (74.5%) > FIII (12.1%) > FII (6.8%) > FI (6.6%)
- for Zn: FIV (37.1%) > FIII (33.9%) > FII (15.6%) > FI (13.4%)

On the basis of the analysis of heavy metal mobility in the sewage sludge from selected sewage treatment plants located in central Poland, it can be concluded that heavy metals occur in the sludge mainly bound to aluminosilicates. In those forms, they do not pose an environmental hazard because of their strong immobilisation. For five of the examined metals, the mean degree of immobilisation in the residual fraction ranges from 37.1 to 74.5%. In this fraction, lead shows the highest content. Similarly, the content of chromium and nickel is also high. Only the mean content of copper in the residual fraction is lower and amounts to 27.1%. Copper occurs mainly in the oxidizable fraction FIII.

In study [19], I confirmed statistically significant dependence of the mean heavy metal mobility in sewage sludge on the design capacity of the sewage treatment plant PE. Under conditions prevailing in Poland, a majority of sewage treatment plants is underloaded. The issue of hydraulic underloading of the sewage treatment plant results from the fact that too great amount of sewage was assumed, at the design stage, to be inflowing at the facility. The results of investigations into the relation between the mean heavy metal mobility and the actual capacity of the sewage treatment plant were published in study [18].

I demonstrated that sewage treatment plants of relatively high capacity produce sewage sludge, in which heavy metals occur primarily in immobile compounds that are not bearing much significance from the toxicological standpoint (Fig.3). Heavy metals form stable compounds in the sewage sludge (Fig.4).

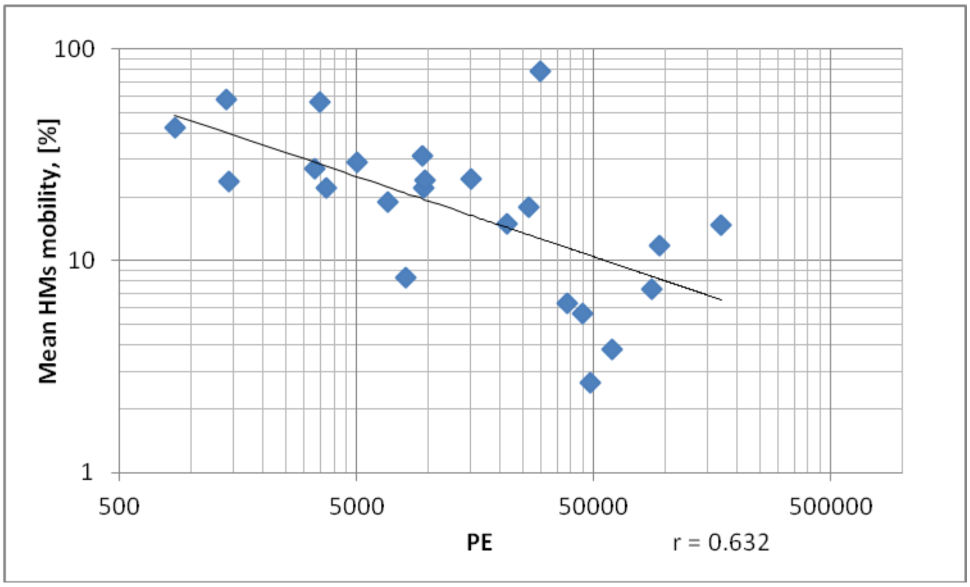


Fig. 3. The correlation between the mean heavy metal mobility and the sewage treatment plant capacity O1–O23

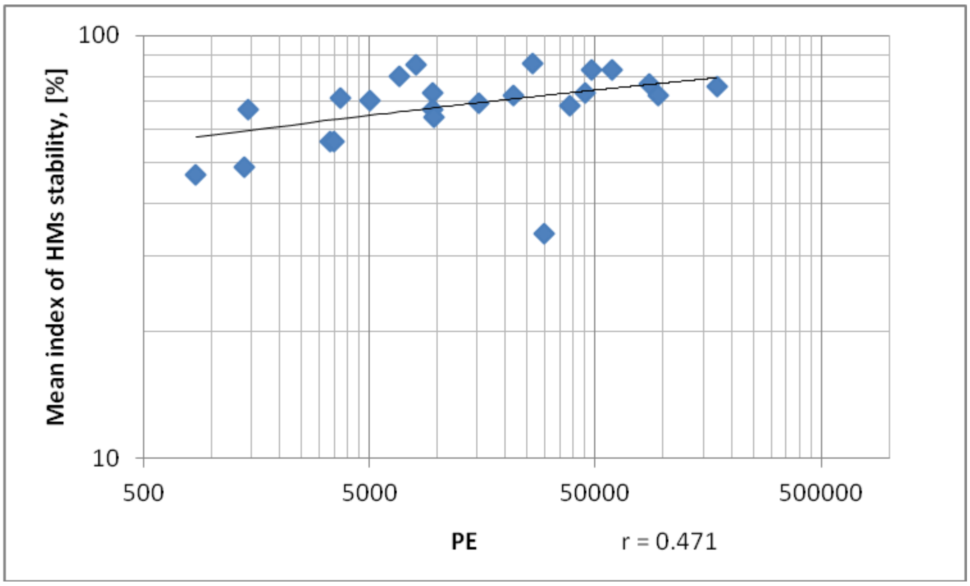


Fig. 4. The correlation between the mean index of heavy metal stability and the sewage treatment plant capacity O1–O23

Fig.5. Mobility of heavy metals in the sewage sludge on the example of the sewage treatment plant O13 and the metal content in accordance with the legislation in force and planned alterations [3,6,16]

For almost all facilities, heavy metal content in the sewage sludge did not exceed the limit values for sewage sludge intended for agricultural use. That is confirmed by exemplary results of speciation analysis for the sewage sludge from the sewage treatment plant in Opatów (Fig.5).

Sewage sludge liming is a recommended method for temporary immobilisation of heavy metals. Although liming tends to reduce the nutrient content of sludge, it is still used as the best form of prevention of heavy metal absorption by plants [12]. On the example of sewage sludge collected at the facility in Kostomłoty-Laskowa, I showed that it is possible that the reverse phenomenon can occur. At already pH=11.9, the mean mobility of heavy metals increased by approx. 0.48%. It turned out that increase in the sludge pH from 6.5 to 11.9 produced a decrease in the stability index of heavy metals in the sewage sludge. Detailed analysis of the experimental results confirmed that the observed effect resulted from a substantial increase in copper mobility in the sewage sludge from O4 (Fig.6).

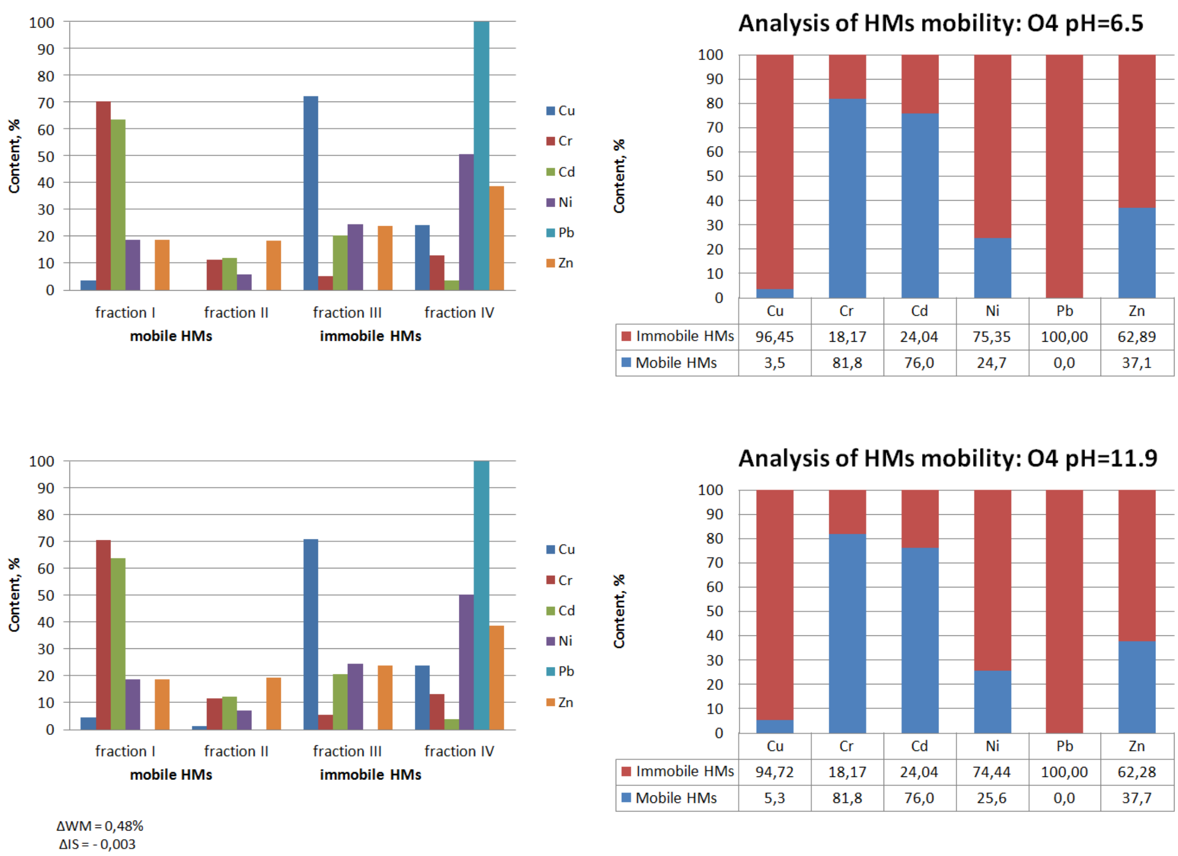


Fig. 6. Effect of sewage sludge alkalisation on heavy metal mobility (pH=11.9)

On of the fundamental questions I tried to answer in study [18] concerns the durability of the immobilization of heavy metals in the sewage sludge. The problem is of key importance because sewage sludge, before it is managed, often remains at the sewage treatment plant for a lengthy period of time. The issue arises whether the immobilization of heavy metals is durable, i.e. whether it is certain that the transfer of metals to mobile forms due to physical and chemical factors like electromagnetic radiation or temperature will not occur. To answer the question posed above, I conducted an experiment in which the sewage sludge samples from the sewage treatment plants O20 and O23 was subjected to ultraviolet radiation with wavelengths $\lambda \approx 250 \div 265$ nm, at the intensity of 710 $\mu W/cm^2$. At the same time, I examined the effect of temperature variation (253K÷293K) on the mobility of heavy metals. Prior to sequential extraction, sewage sludge samples were alternately irradiated and frozen out for a period of 22 days. Simultaneously, the reference sample was kept at dry-air conditions at the temperature 293K for 22 days. The results of investigations are shown in Fig. 7.

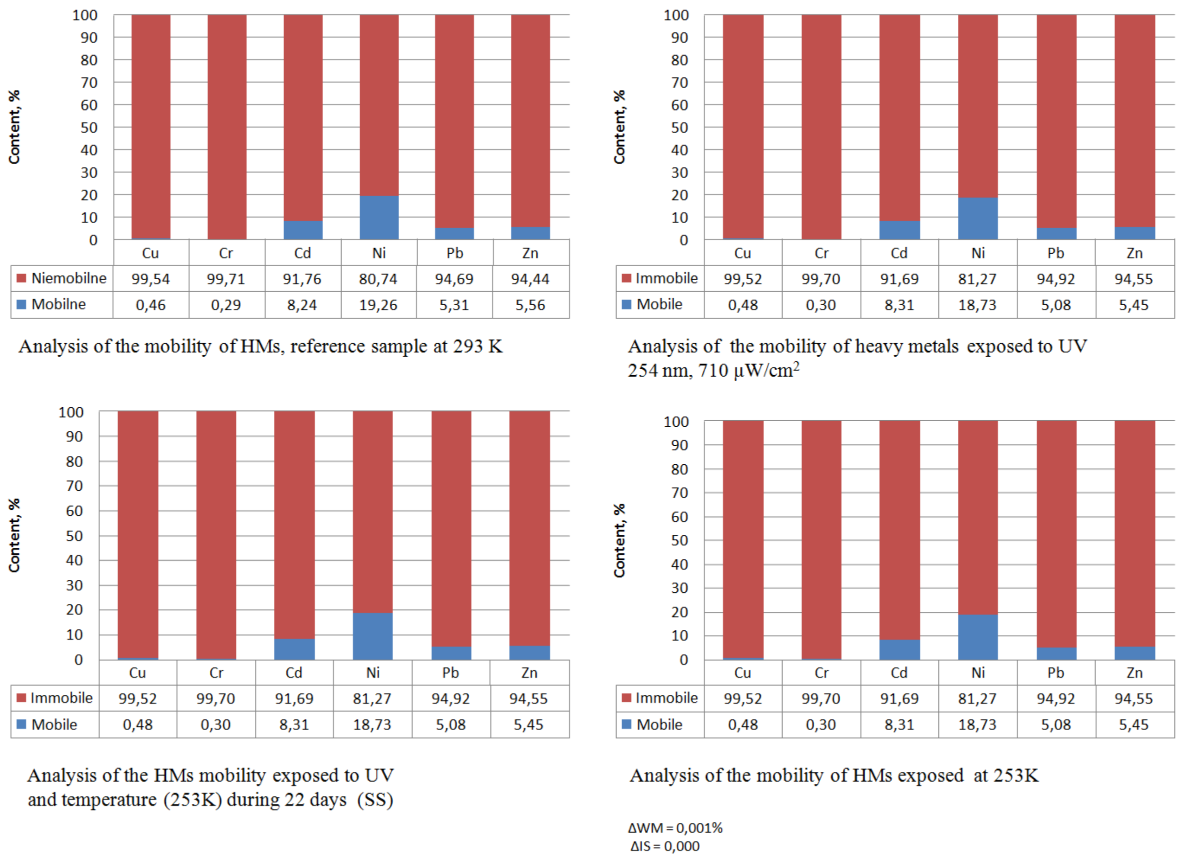


Fig. 7. Effect of sewage sludge weathering on heavy metal mobility

I observed that weathering processes do not significantly affect the mobility of heavy metals. Sewage sludge exposure to environmental factors does not alter the stability of heavy metal compounds (ΔIS=0).

From the toxicological standpoint, an important issue is to find out how the method of treatment of sewage sludge in the digestion tank affects the mobility of heavy metals. I put forward a research hypothesis that anaerobic stabilization of sewage sludge will change the form of heavy metals in sludge in a quantitatively and statistically significant manner. Sewage sludge from the facilities in Skarżysko-Kamienna and Sitkówka-Nowiny was subjected to investigations following the BCR procedure. As shown in Fig. 8, anaerobic sewage sludge digestion in the digestion tank results in the temporary immobilisation of heavy metals in the oxidizable fraction (fraction III in accordance with BCR) at the expense of the mobile fraction (I+II).

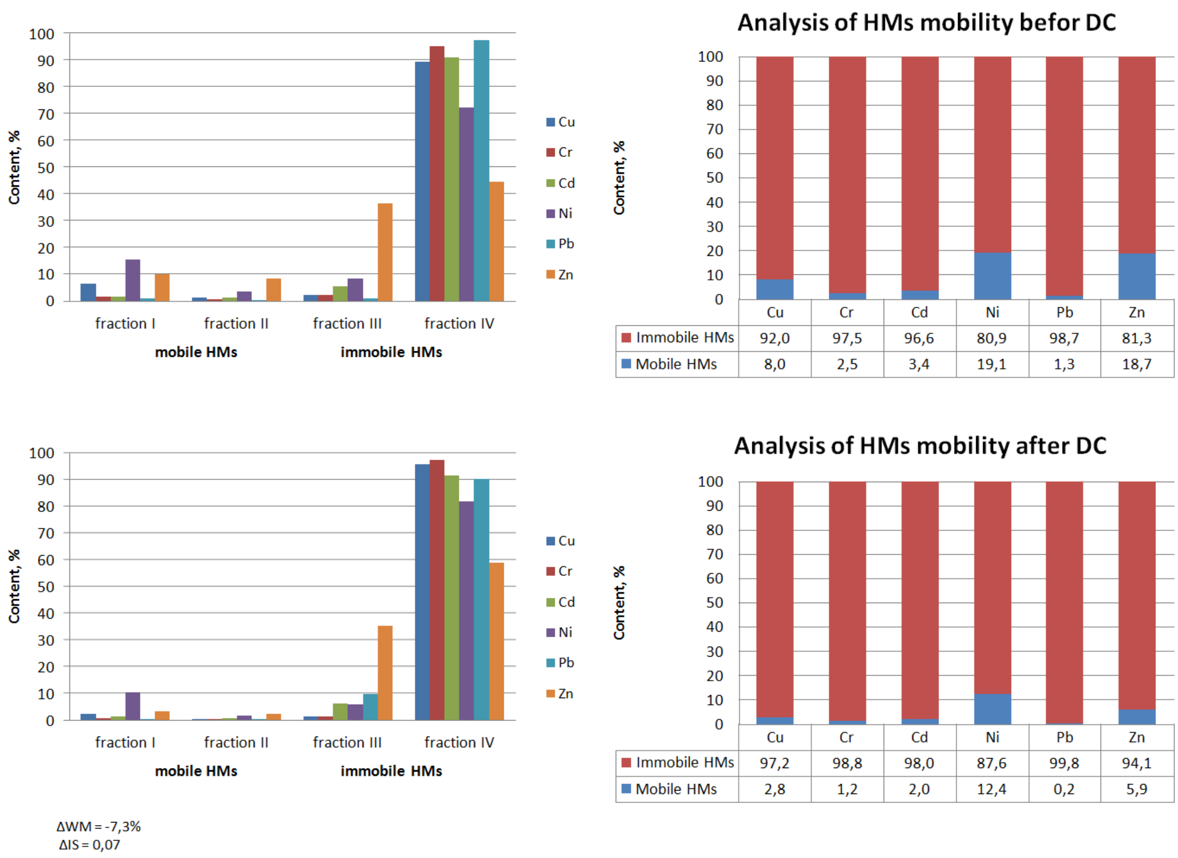


Fig. 8. Effect of mesophilic digestion of sewage sludge on heavy metal mobility

I also demonstrated that metals bound to aluminosilicates, and their crystalline structures, are immobile, thus of minor importance as regards toxicity.

The experimental results I obtained, make it possible to understand why the mobility of heavy metals in sewage sludge from sewage treatment plants with properly operating mesophilic digestion is low.

In the final stage of my investigations into heavy metal mobility, I determined to what extent sewage sludge incineration affects the immobilisation of heavy metals contained in the sewage sludge from the municipal sewage treatment plant in Skarżysko-Kamienna. The choice of the facility was not accidental because sewage sludge produced there (Fig.9) was characterised by a high content of Zn and Cr.

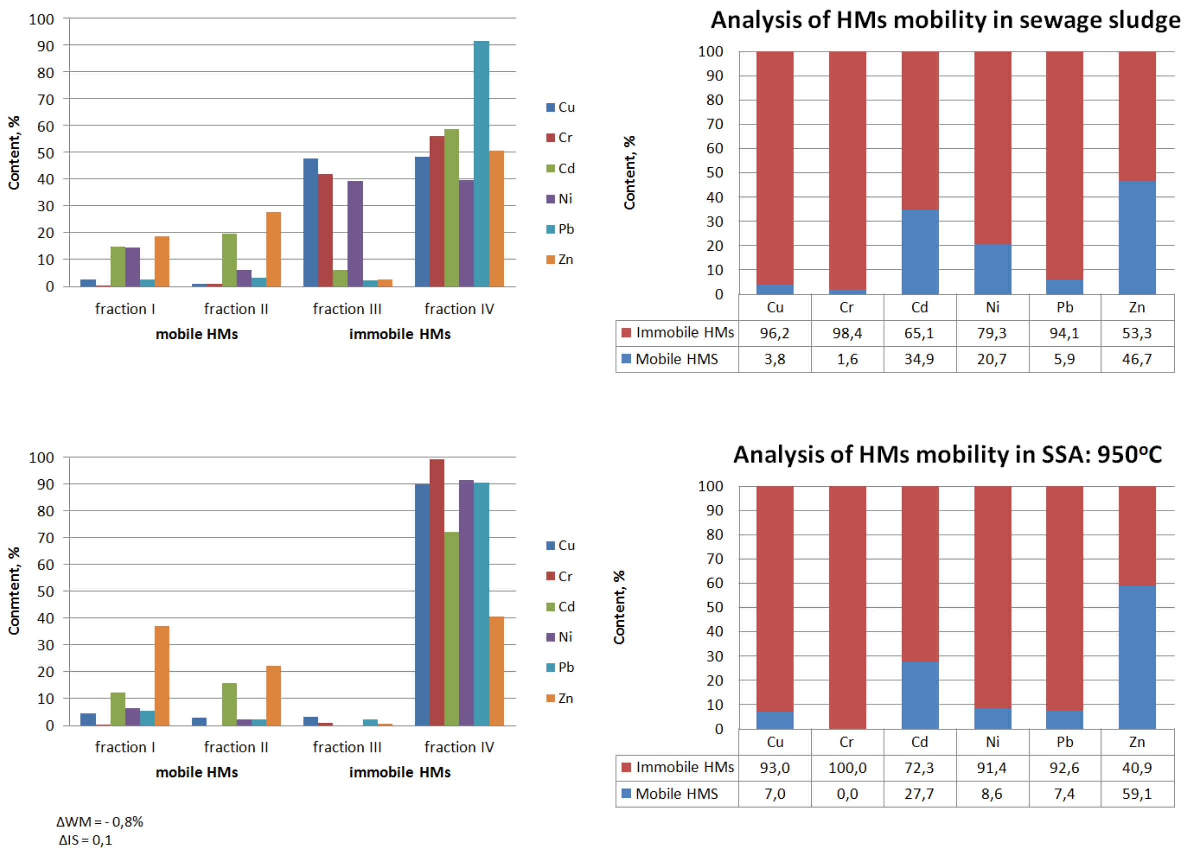


Fig. 9. Effect of sewage sludge incineration on heavy metal mobility

Heavy metal behaviour in incineration is affected not only by the temperature of thermal treatment, but also by metal volatility. Cadmium and zinc are classified as volatile metals, chromium, copper, nickel are non-volatile metals, and lead is moderately volatile. In the ashes of concern, I found the accumulation of metals mainly in fraction IV, which is unavailable to plants [20]. That resulted in a substantial increase in the stability index (ΔIS=0.1), and a noticeable decrease in the mean mobility of heavy metals (ΔWM=-0.8%). I demonstrated that within the range of sewage sludge incineration temperatures, the mobility of copper and zinc originating from ashes grew with an increase in the incineration temperature. The temperature of sewage sludge thermal treatment of 850 ÷ 900^{o}C, used in the incineration installations, makes it possible to prevent an increase in the mobility of copper and zinc. However, a local increase in temperature in the installation, to above 900^{o}C, may produce an adverse effect on the properties of the ash (Fig.9).

4.4. Main achievements of the habilitation dissertation

- I was the first to demonstrate that the mean content of mobile forms of heavy metals decreases with increasing PE.
- I proved that sewage sludge exposure to environmental factors is not accompanied by a significant increase in heavy metal mobility.
- I demonstrated the sewage sludge under consideration poses a lower environmental hazard than that predicted by the legislation in force. The content of mobile fractions of heavy metals in sewage sludge is usually low.
- I demonstrated that sewage sludge incineration increases the average value of the stability index of heavy metals in the matrix.
- I demonstrated that changes planned to be made in the limit values for heavy metal content in the municipal sewage sludge intended for land, should account for the forms of heavy metal occurrence.

4.5. Cited references

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18. Gawdzik J. Mobility of heavy metals in sewage sludge (in Polish). Monographs, Studies, Dissertations, M44, Kielce University of Technology, PL ISSN 1897-2691, Kielce 2013
19. Gawdzik J., Gawdzik B.: Mobility of heavy metals in municipal sewage sludge from different throughput sewage treatment plant. Pol.J.Environ.Stud. vol. 21, No. 6, pp. 1603-1611, 2012.
20. Latosińska J., Gawdzik J.: Effect of incineration temperature on the mobility of heavy metals in sewage sludge ash. Environment Protection Engineering vol. 38, No. 3, pp. 31-44, 2012

4.6. List of studies related to the subject matter of the monograph

1. Bezak-Mazur E. Dąbek L., Gawdzik J.: **Influence of Mineralization and Analysis Technique on the Results of Determination of Iron and Nickel in Industrial Wastes**, Polish Journal of Environmental Studies 10(1), pp. 63-66, 2001. JCR

Impact Factor	The contribution of the candidate
1.111 for a given calendar year: **0.000**	**20%** conducting research by AAS, statistical analysis of test results.

2. Gawdzik J.: **Speciation of heavy metals in sewage sludge on the example of a selected municipal sewage treatment plant** (in Polish), Ochrona Środowiska Vol. 32, No. 4, pp. 15-19, 2010. JCR

Impact Factor	The contribution of the candidate
0.958 for a given calendar year: **0.641**	**100%**

3. Gawdzik J., Gawdzik B.: **Mobility of heavy metals in municipal sewage sludge from different throughput sewage treatment plant.** Pol.J.Environ.Stud. vol.21, No.6, pp. 1603-1611, 2012. JCR

Impact Factor	The contribution of the candidate
1.111 for a given calendar year: **0.462**	**50%** designing the concept of publication, performing research by BCR/AAS, statistical analysis of test results

4. Latosińska J., Gawdzik J.: **Effect of incineration temperature on the mobility of heavy metals in sewage sludge ash.** Environment Protection Engineering vol. 38, No. 3, pp. 31-44, 2012. JCR

Impact Factor	The contribution of the candidate
0.412 for a given calendar year: **0.423**	**40%** designing research, performing research by AAS BCR/AAS, statistical analysis of test results

5. Gawdzik J., Latosińska J.: **Speciation of heavy metals in municipal sewage sludge from different capacity sewage treatment plants**, CRC Press, Boca Raton, New York, pp. 285-290, 2010.

Impact Factor	The contribution of the candidate
0.000 for a given calendar year: **0.000**	**50%** designing the concept of publication, performing research by BCR/AAS, statistical analysis of test results

<u>the second quarter 2014 will be published:</u> [1]

6. Gawdzik J., Długosz J., Urbaniak M: **General characteristics of the quantity and quality of sewage sludge from selected wastewater treatment plants in the świętokrzyskie province, Environment Protection Engineering**. JCR

Impact Factor	The contribution of the candidate
- for a given calendar year: -	**35%** designing the concept of publication, performing research by AAS statistical analysis of test results

Date 9th Dec. 2013 Signature:

[1] confirmed by the Publisher