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The quality of rainwater collected from roofs in the aspect of the possibility of their economic use

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Abstract. The large variability in rainwater quality both in time and location as well as the relatively small number of tests make the preliminary assessment of economic exploitation of these waters difficult. Determining the relation between the conditions and location of rainwater collection and rainwater quality would help to indicate the range of options for rainwater use as well as parameters that require improvement.

The aim of the presented article is to establish chosen physical, chemical and microbiological parameters of rainwater and, based on the results obtained, to determine the possibilities for a safe use of these waters in households. The research had been carried out for two years. Samples of chosen rainfalls were collected from spring to autumn from the following roofing materials: concrete roof tiles, ceramic roof tiles, zinc coated metal sheets and epoxy coated. The physical, chemical and microbiological quality assessment has been conducted basing on the following parameters: reaction, turbidity, electrical conductivity, concentration of biogenic compounds, concentration of chosen elements, number of *Escherichia coli* as well as number *faecal streptococci*.

A significant bacterial contamination, a decreased pH and an increased turbidity of rainwaters were identified, depending on the parameters of the roofing washed by rainfalls and the intensity and frequency of precipitation.

1. Introduction

Currently, approximately 36% of the world's population face a water crisis. In many areas, it is not possible to satisfy the increasing demand for this resource, due to a restricted access to freshwater supplies. It is believed that countries with water resources below 2 000 $m^3 \cdot M^{-1}$ may face difficulties addressing the needs of their population, while countries with resources below 1 000 $m^3 \cdot M^{-1}$ are considered as areas with a severe water deficit.

In Poland, the biggest problem of water management is a major variability of atmospheric precipitations as well as extreme hydrologic phenomena, particularly apparent in large agglomerations and in rural areas (Pierzgalski et al. 2012, Kundziewicz et al. 2010).

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The analysis of the domestic water consumption structure shows that approximately 50% of potable water can be substituted by rainwater, while in public buildings this value is almost 65% (Ludwińska and Paduchowska, 2017). Rainwater harvesting and storage systems have been implemented in several countries. Water collected in this way is a valuable source of freshwater, which can reduce the demand for tap water and which can be used during periods of drought (Słyś, 2013). Rainwater harvesting technologies are used worldwide to support drinking water supplies (Zhang et al., 2009, Jones and Hunt, 2010), rainwater management and flood risk reduction by reducing the volume of water flows in storm drainage systems (Słyś and Stec, 2012). These technologies constitute also one of the elements of an efficient and environmentally sound functioning of buildings (Basinger et al., 2010). In areas with dispersed housing and high costs of building classic water supply system, the RWHS (Rainwater Harvested System) was found to be an affordable and sustainable alternative (Khan et al., 2017, Kimani et al., 2015) of drinking water supply.

In households, rainwater can be used i.e. for sanitary facilities flushing, laundry, cleaning, watering lawns and crops as well as for washing cars. In areas particularly exposed at the risk of water deficit, rainwater is also taking into consideration as water intended for consumption, i.e. in Kenya and Bangladesh (Evans et al., 2006). Thus, the knowledge of the quality of harvested water is crucial for the protection of public health.

While it is generally believed that rainwater is relatively clean, the test results obtained prove it physical, chemical and microbiological pollution (Zdeb et al., 2016, Gwenzi et al., 2015). The quality of the harvested rainwater is characterized by a significant variability both in time and space. The composition of rainwater is dependent on many factors such as i.e.: atmospheric pollution (including the presence of dusts, pollen, bioaerosol), type of catchment, land use (industrial areas, roads and highways), local microclimate and the type of the run-off surfaces (various roof pitches and various roofing materials). In urban areas, the rainwater contamination reaches highest levels, which is mainly linked to the emissions by power plants, local boiler plants and industry (Fiedler et al., 2017, Despins et al., 2009).

Water quality is a very important factor as regards possible options of utilization for economy, although not only highest quality water meeting the standards for consumption and hygienic applications is required for such utilization. Rainwater can be a carrier of surface water pollution and soil. Research on their quality may partly explain the impact of rainfall, for example on the condition of water in water reservoirs (Koszelnik, 2007).

The aim of this article is to examine the physical, chemical and microbiological quality of rainwaters harvested in suburban areas and the assessment of utilization possibilities of this water for different economic purposes, including also potable water supplies in crisis conditions.

2. Location of the study area

The research was carried out in 2015-2016 on a non-industrialized area located in the immediate vicinity of the city of Rzeszów, which is located in the south-eastern part of Poland (Fig. 1).

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Fig. 1. Location of Rzeszów against the background of Europe

The area within a radius of 3 km from the sampling site is characterized by low emission of dust pollution due to the lack of industrial and organic plants, excluding the summer period, when their formation is associated with mowing grass. The nearest transport route is a county road with a limited traffic intensity (LR), 0.3 km away from the sampling site, and a national road (NR), 5.5 km away southerly direction. The area where sampling was conducted, where overgrown with low shrubs and grasses, and the nearest trees and agricultural fields were located approximately 1 km to the west of the housings. To the north-west of the sampling site, there is a water treatment plant (2.5 km) and the CHP plant Załęże (approx. 5 km). Westerly and south-westerly winds prevailed (Fig. 2).

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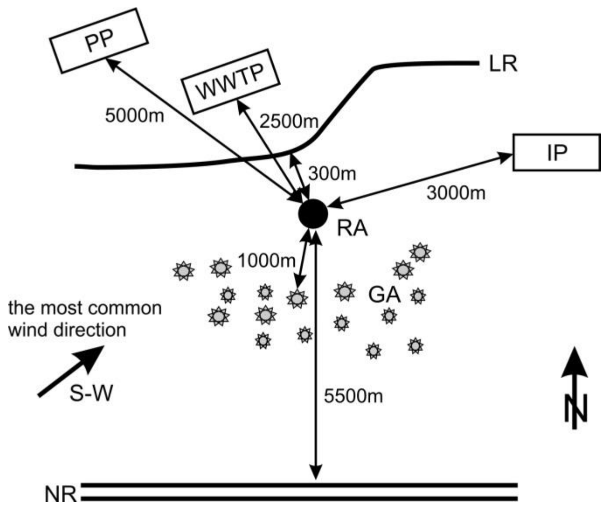

Fig. 2. Characteristics of the research area

3. Research methodology

Water samples were collected in the following seasons: spring (March-May), summer (June-August) and autumn (September-November), excluding winter, when temperatures below 0 ° C and there are no technical opportunities for rainwater. Rainwater quality tests were carried out for samples taken from outlet pipes that lead them out of the roofs. The impact of roofing materials on water quality was analyzed. The following materials were analyzed in the study: I) concrete roof tiles (Co), II) ceramic roof tiles (Ce), III) zinc coated metal sheets (Gs) and IV) epoxide coated (E). The control was a rainwater sample which did not come into contact with any roof surface and was collected directly from atmospheric precipitation (P).
Samples were collected during selected rain episodes according to rain fall intensity and after rejecting the so called first run-off. The first run-off time was established for intensive and moderate rain falls and for heavy or moderate torrential rain. A determining factor was the possibility to measure rain fall intensity with available tools. Sampling was carried out at particular points of time after the start of the rainfall and quality control marks were made (Table 1.).

Table 1. Changes in the quality of rainwater during precipitation - determining the time of the first runoff.

Duration of rain [min]	Number of bacteria [cfu / ml]				Turbidity [NTU]	
	mesophilic		psychrofile			
	rainwater directly from atmospheric precipitation	rainwater from a roof covered with concrete tiles	rainwater directly from atmospheric precipitation	rainwater from a roof covered with concrete tiles	rainwater directly from atmospheric precipitation	rainwater from a roof covered with concrete tiles
1	105	101	1206	1600	7	>10
2	89	50	997	1267	4	5

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3	75	55	512	1210	4	3
4	10	78	610	1300	5	3
5	69	26	486	1200	4	2
10	55	20	212	840	3	2
20	60	25	155	613	3	2
30	80	30	178	500	3	2

On this basis, the time necessary for the first run-off of roof surfaces and the moment for sampling during rainfall were set. The measurement was made for rainwater collected directly from atmospheric precipitation and from a concrete tile roofing. Basing on the results obtained, it had been established, that samples would be taken as of the 10th minute of rain with a defined intensity.

The selected physical, chemical and microbiological rainwater parameters were determined according to applicable surface water and groundwater research procedures and standards (Table 2.).

Table 2. Scope and methodology for the determination of physicochemical and microbiological properties for the examined rainwater.

Parameter	Method /standard
pH	Electrometric method; EN ISO 10523: 2012
Conductivity	Electrometric method; EN 27888: 1999
turbidity	Nephelometric method; EN ISO 7027: 2003
ammonium ion, nitrite nitrogen, nitrate nitrogen, phosphates	Ion chromatography method, EN ISO 10304-1: 2009
General Organic Carbon (OWO)	analyzer TOC Sievers 5310 C; EN 1484: 1999
heavy metals: copper, lead, chromium, nickel, zinc; trace elements: arsenic, titanium, bromine, strontium	X-ray spectrometry method; procedures for equipment PICOFOX
the number of *Escherichia coli* bacteria	The membrane filter method; EN ISO 9308-1:2004
the number of fecal streptococci	The membrane filter method; EN ISO 7889-2:2004

4. Results and discussion

3.1 Test cycles characteristics

Test were carried out for rainwater harvested in the years 2015 and 2016. Each test cycle was described with the number of rain episodes, total monthly rainfall, duration of intervals between rainfalls and average air temperatures (Table 3.).

Table 3. Characteristics of research cycles

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Characteristic	year 2015	year 2016
Number of rain events	31	48
The number of rain events analyzed	11	23
Total precipitation from research months [mm]	254	413
Average air temperature in spring [° C]	12,3	12,2
Average air temperature in the summer [° C]	24	19,5
Average air temperature in autumn [° C]	10,5	15,1
The longest break between precipitation [days]	40	27
Months with rainfall over 40mm	III	IV, V, VII, IX, XI

In 2015, there was a significantly smaller number of rain events, longer rainless periods and higher air temperatures than in 2016.

Annually rainfall in 2016 was nearly twice as high as in 2015. The characteristics of test seasons refer to the area where rainwater samples were taken. In 2016, a monthly precipitation exceeding 40 mm was recorded in April, May, July, September, October and November, while in 2015 only in March.

3.2 Physical and chemical rainwater quality

Parameters most commonly used for the description of rainwater quality are the pH and turbidity. The lowest pH values were recorded for rainwater collected directly from atmospheric precipitations (Fig. 1).

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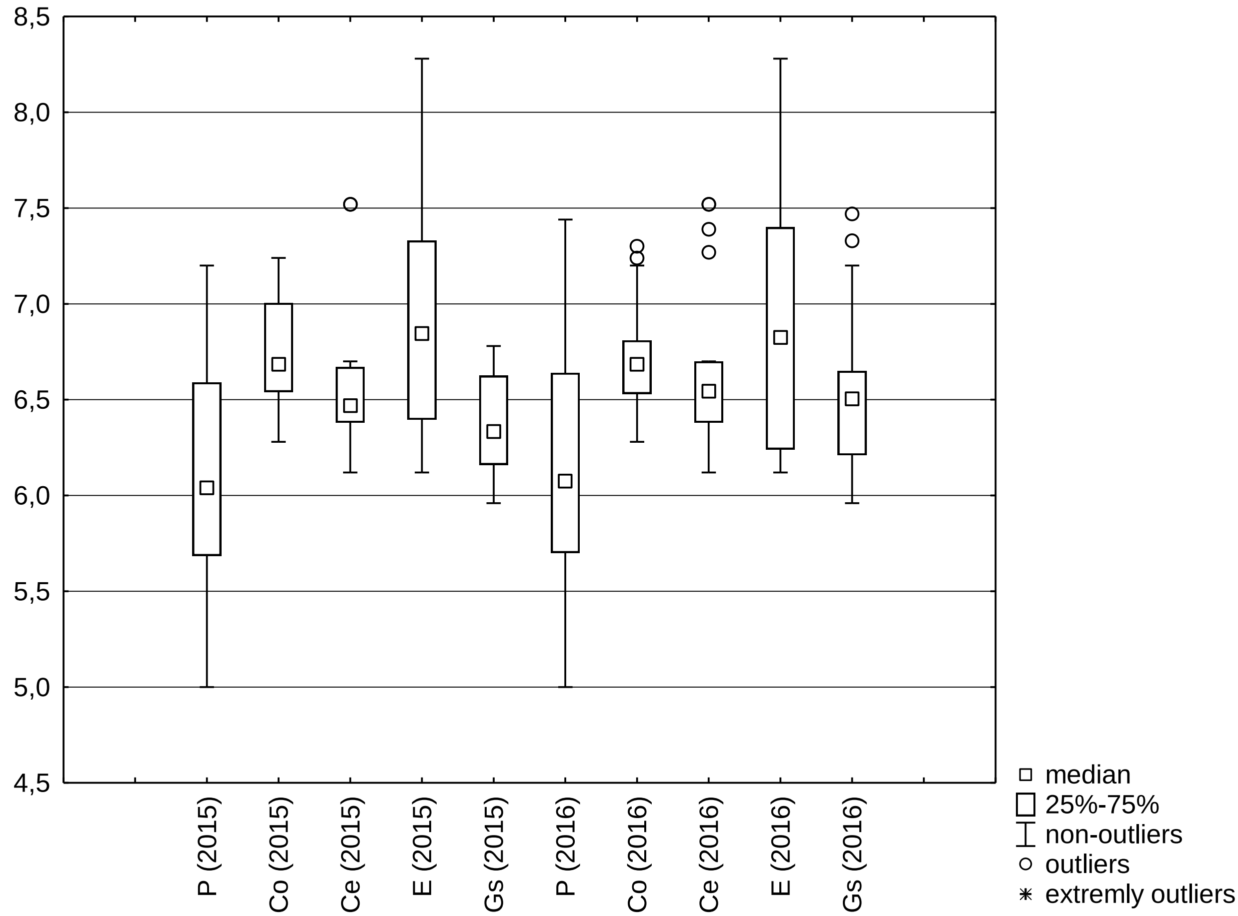

Figure 3. pH of the tested rain water

Among rainwaters collected from different roofing materials the lowest pH was noted for rainwater collected from a zinc coated metal sheet.

In rainwater collected directly from atmospheric precipitations lower pH values were noted than in the roof-harvested rainwater. Rain water deposited due to the air pollution - sulfur compounds and NO_x had acidic character. However, in a further step after the trailing surfaces of the roof, degree of neutralization gradually changes. Rain water deposited due to the air pollution - sulfur compounds and NO_x had acidic character.

In turn, characterized by the highest turbidity water collected from the surface coated with epoxy resin - max. 14 NTU, and the lowest turbidity was found in rainwater collected from the zinc coated metal sheet – medians 1.5 and 2.0 NTU (Fig. 4).

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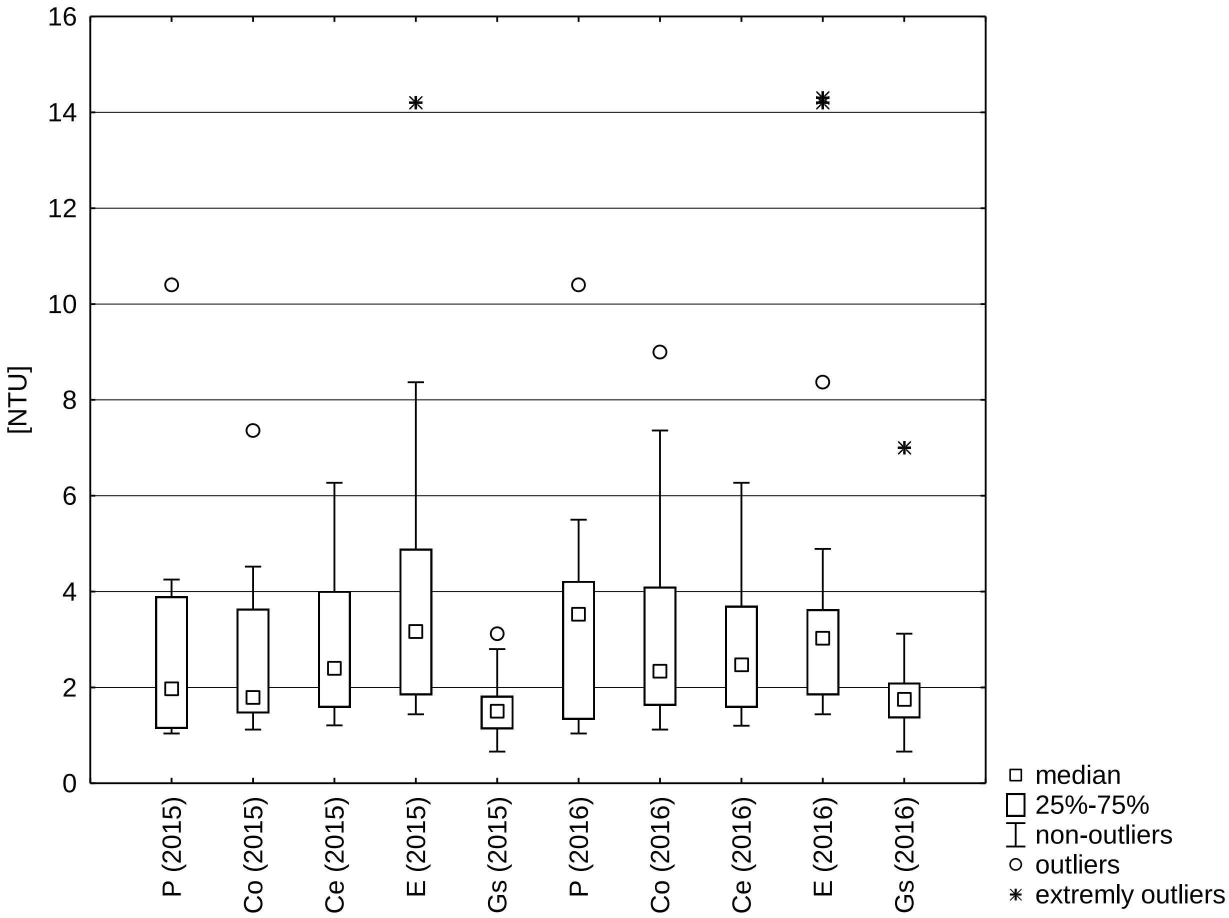
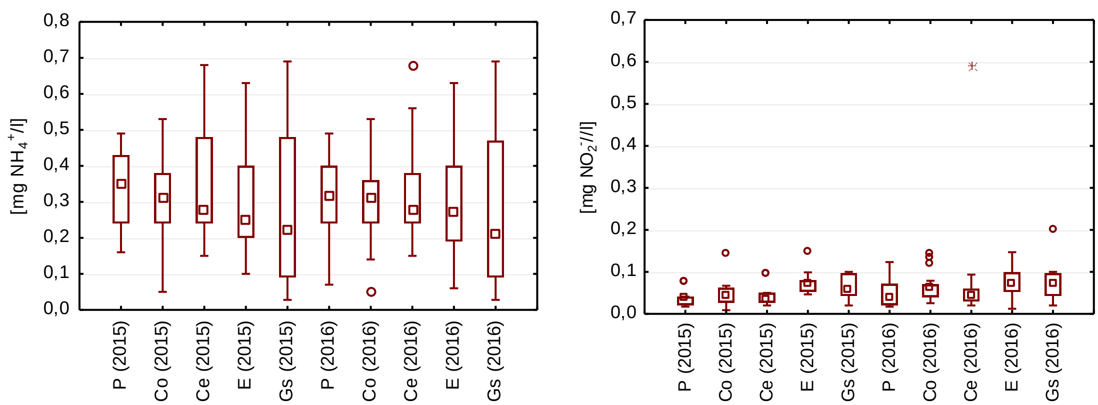


Figure 4. Turbidity of rainwater tested

In the case of water harvested directly from air, the turbidity reached 4 NTU in 2015 and 2 NTU in 2016.

The amounts of nitrogen compounds for all examined rainwater samples were at a similar level (Fig. 5.)



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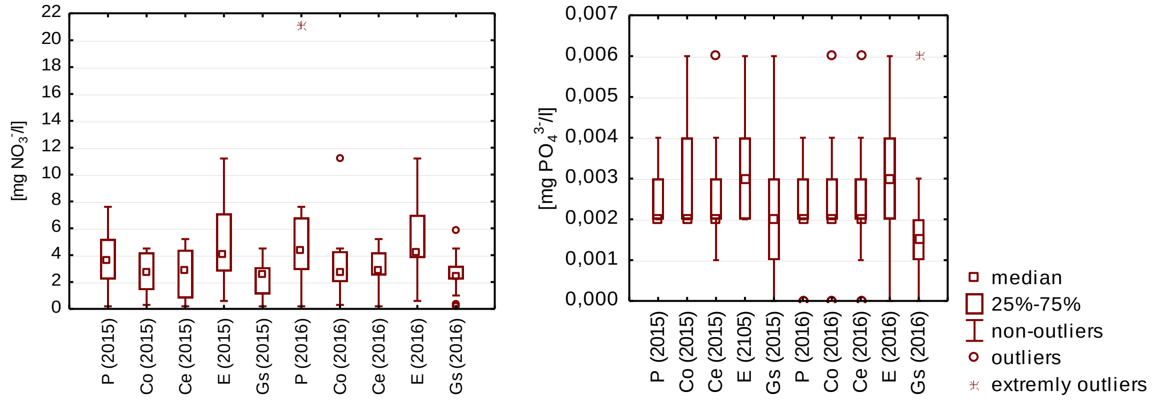

Figure 5. Statistical data for the content of nutrients in the analyzed rainwater

Middle values of ammoniacal nitrogen concentrations were found to be in the range 0,20–0,35 mg NH_4^+/l. Extreme values obtained for rainwater collected from galvanized steel and the rainwater collected directly from precipitation.

The highest concentrations of nitrite (III) were determined in rainwater taken from the surface covered with epoxy resin and amounted to 4 mgNO_2/l, and the lowest in rainwater flowing from the washing ceramic, concrete and galvanized sheet, for which it reached the value of 2 mgNO_2/l.

The lowest amounts of phosphates were found in rainwater collected from zinc coated metal sheet, and the highest in rainwater from the surface covered with epoxide coated.

Total organic carbon (TOC) is a parameter describing the level of water pollution by organic matter. The highest middle TOC values were identified for the rainwater from the surface covered with epoxide coated – 5 mg C/l (Fig. 6.).

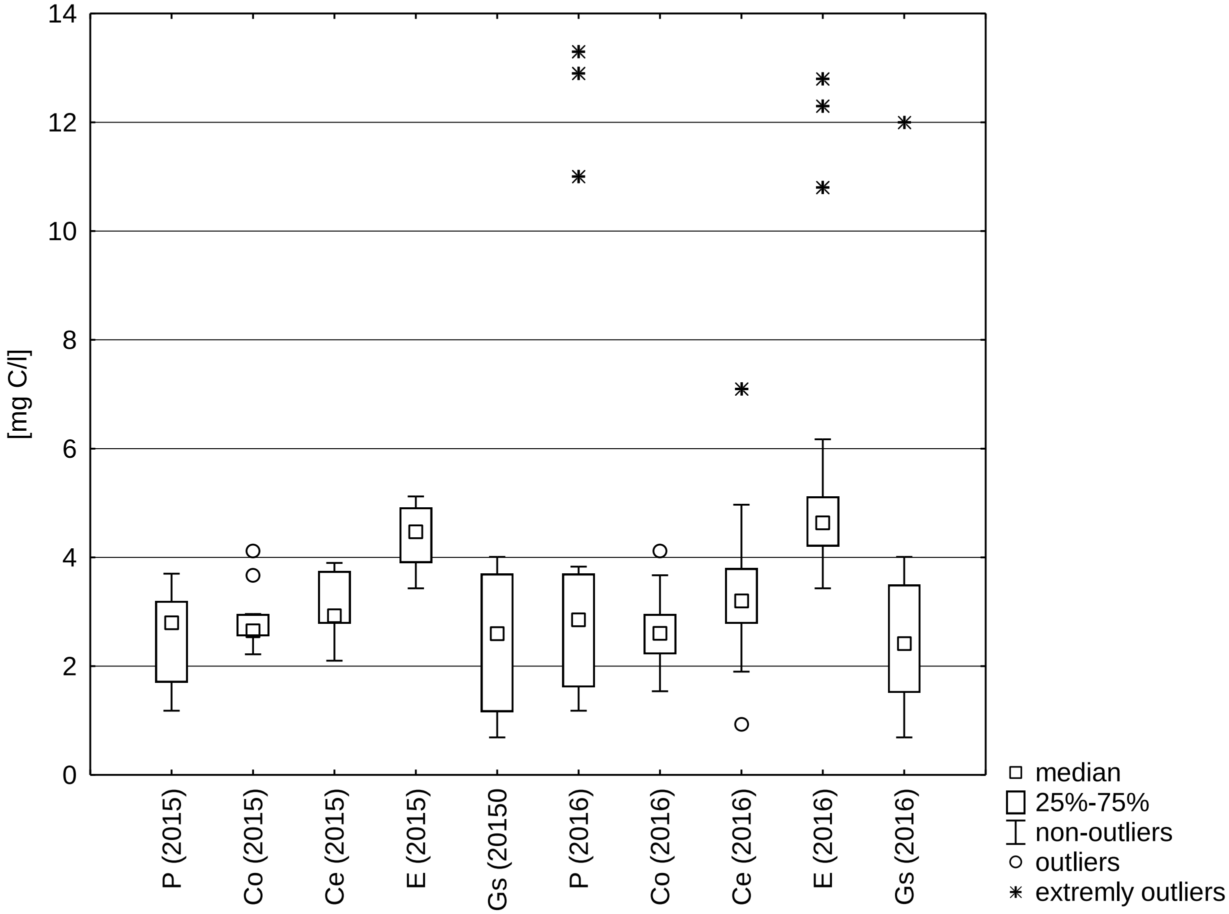

Fig. 6. Statistical data for total organic carbon content in the analyzed rain water

3.3 Heavy metals in rainwater

The results of the analysis focussing on heavy metal ions in both test cycles are displayed in Fig. 5 and 6. Each tested water sample appeared to contain trace amounts of nickel, chromium, lead and arsenic at concentrations slightly above 1 µg/l, ions of copper, manganese, bromine and strontium at levels around 10 µg/l and of iron, zinc, titanium and silver in amounts often exceeding 100 µg/l.

Electrical conductivity of rainwater collected from different roofing and directly from the air fluctuated between 1 and 26 µS/cm, and the middle values were from 1 to 4 µS/cm (Fig. 7 and 8.).

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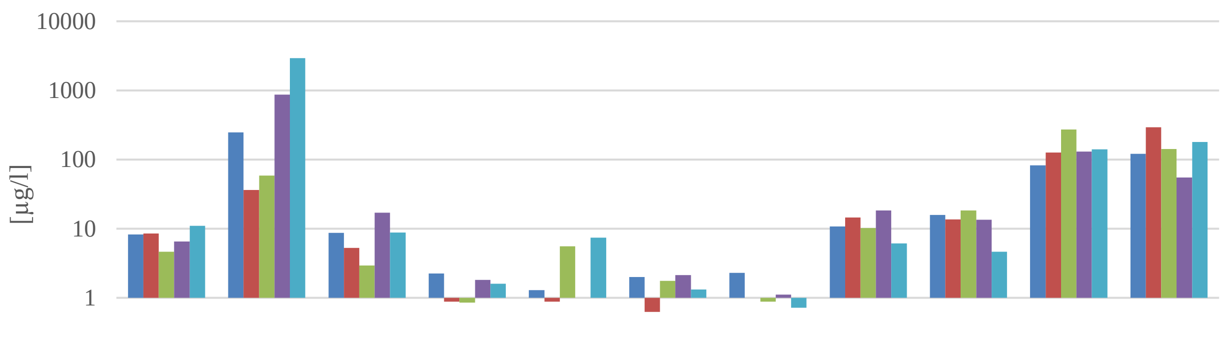
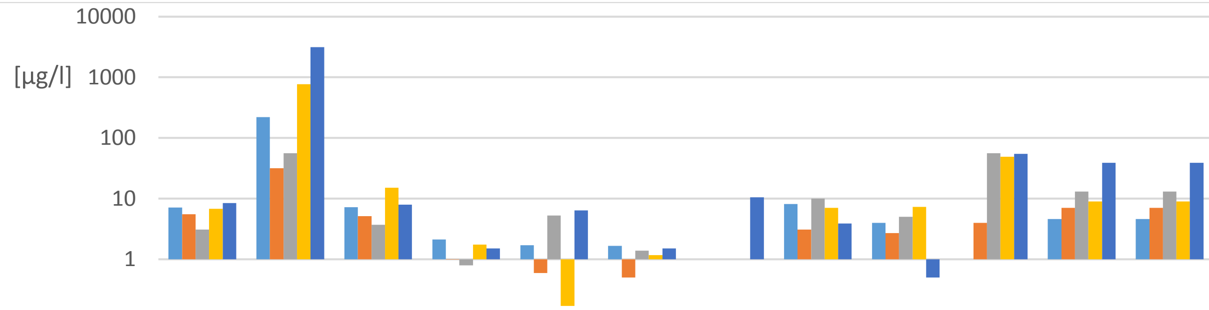


	copper	zinc	manganese	nickel	chrome	lead	arsenic	bromine	strontium	titanium	silver
P	8,22	246,27	8,74	2,25	1,29	2	2,29	10,75	15,86	82,84	120,53
Co	8,57	36,3	5,28	0,88	0,88	0,63	1	14,46	13,7	126,32	291,79
Ce	4,65	58,42	2,94	0,85	5,59	1,76	0,88	10,21	18,43	272,36	142,49
E	6,52	866,32	17,07	1,82	0	2,14	1,12	18,29	13,54	129,87	55,19
Gs	10,98	2934,52	8,77	1,61	7,42	1,32	0,72	6,15	4,63	141,02	180,49

Fig. 7. Median concentration of ions in rainwater in 2015



	copper	zinc	manganese	nickel	chrome	lead	arsenic	bromine	strontium	titanium	silver	srebro
P	7,16	221,77	7,2	2,13	1,7	1,66	1	8,15	4	1	4,6	4,6
B	5,52	31,6	5,13	0,99	0,59	0,5	1	3,1	2,7	4	7	7
C	3,1	55,9	3,7	0,79	5,27	1,39	1	10	4,99	56	13	13
T	6,78	772,17	15,12	1,75	0,17	1,17	1	7	7,32	49	9	9
O	8,44	3164,55	7,97	1,51	6,42	1,5	10,5	3,9	0,5	55	39	39

Fig. 8. Median concentration of ions in rainwater in 2016

The lowest electrical conductivity values were recorded for water collected from the guttering of a roof covered with zinc coated metal sheets (like in the control sample collected directly from atmospheric precipitations). It was not clearly indicated, for which type of rainwater this parameter had highest values.

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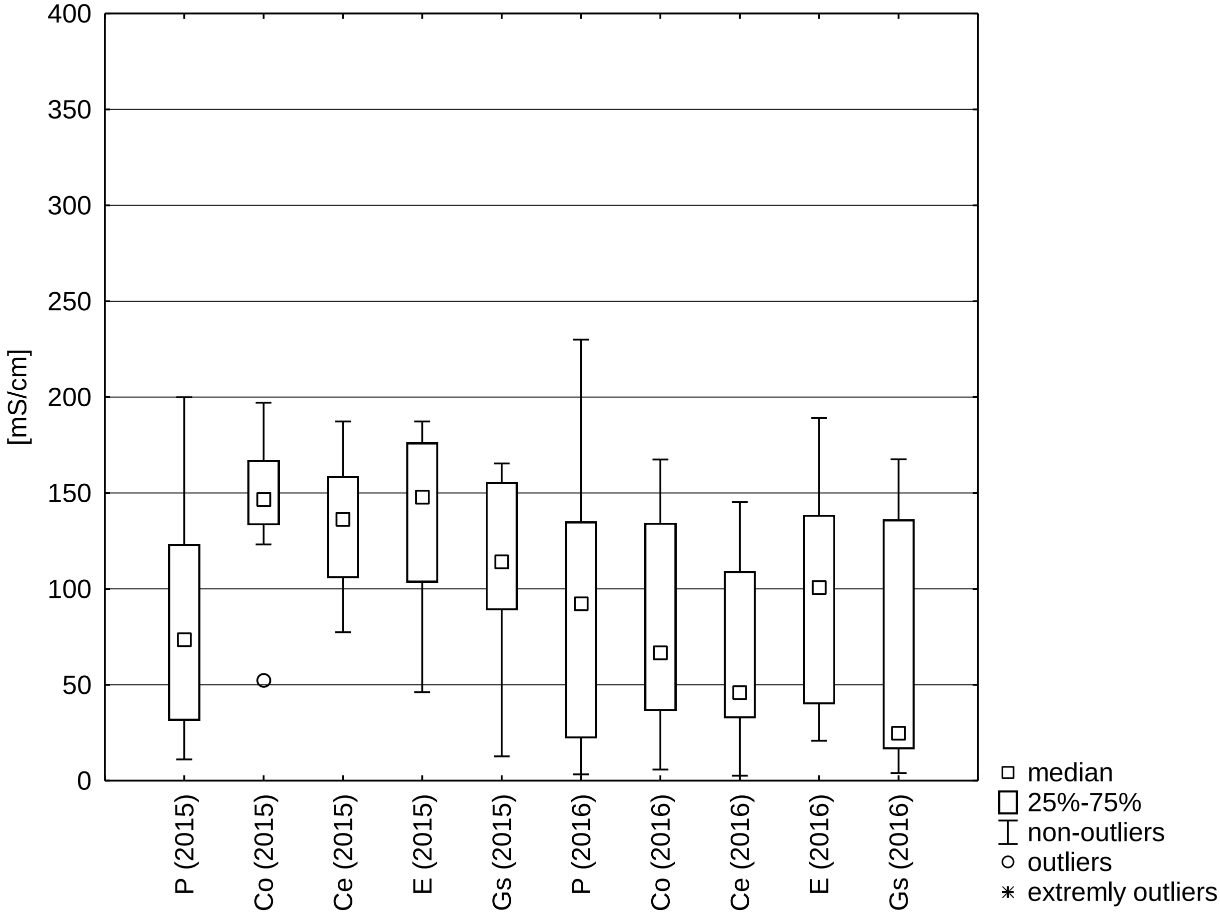

Figure 9. Statistical data for the specific conductivity in the analysed rainwater

3.4 Microbiological quality of rainwater

Sanitary quality aspects of water are normally defined by two factors – the number of *Escherichia coli* and the number of faecal enterococci.

E. coli bacteria were found in each rainwater tested (Fig. 10.).

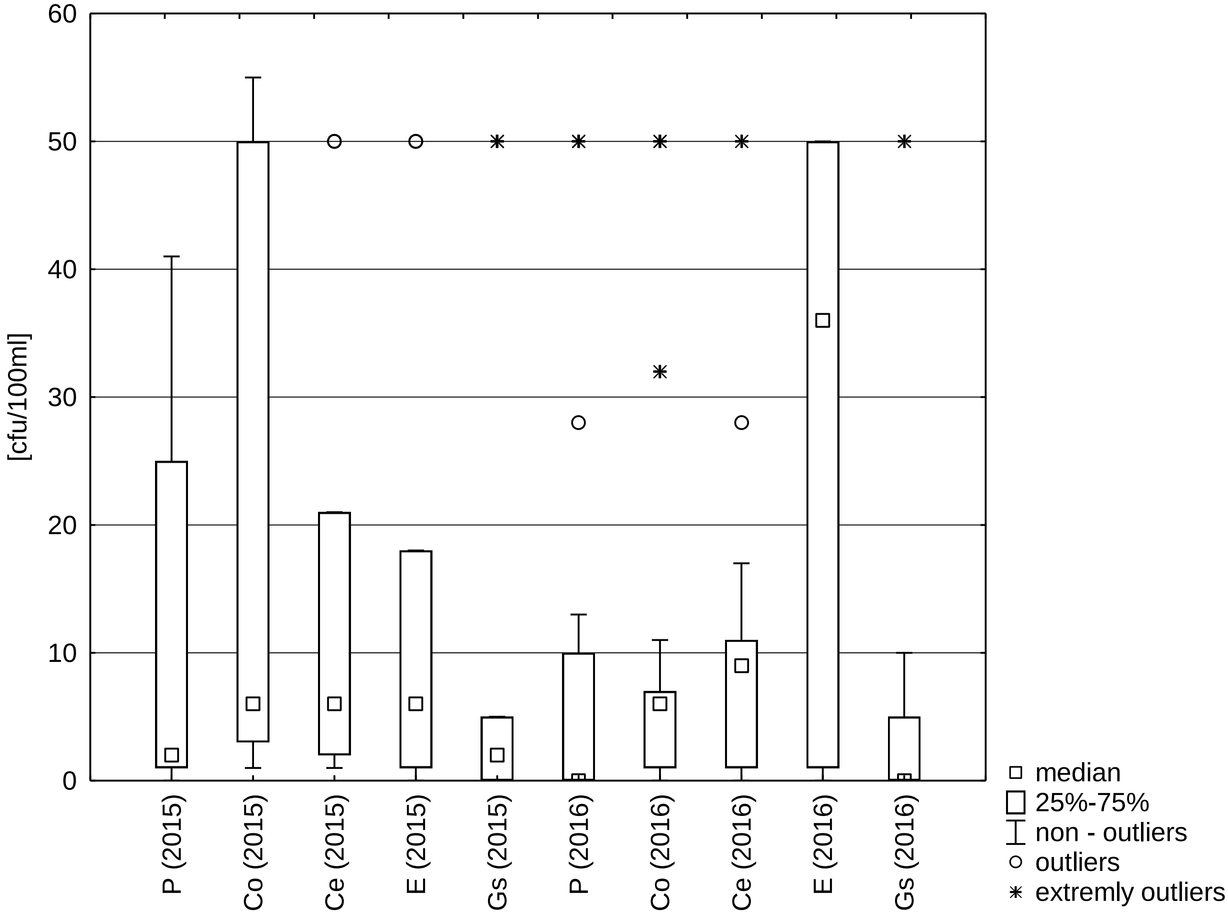

Figure 10. Statistical data for the number of *Escherichia coli* bacteria present in rainwater

E. coli were most numerous in rainwater collected from concrete tile roofing for the test seasons from 2015 and in terrace-collected rainwater in 2016. The lowest number of *E. coli*

(excluding the lowest and highest outliers) were marked for the rainwater collected from zinc coated metal sheet roofing – less than 5 cfu/100ml. In this rainwater, the number of bacteria was similar in both test cycles. However, the number of faecal streptococci in rainwater collected directly from atmospheric precipitations and from concrete and ceramic tile roofs and zinc coated metal sheet roof was lower in 2016 than in 2015. The values were similar in both test cycles only for the rainwater from the epoxide covered surface (Fig. 11.).

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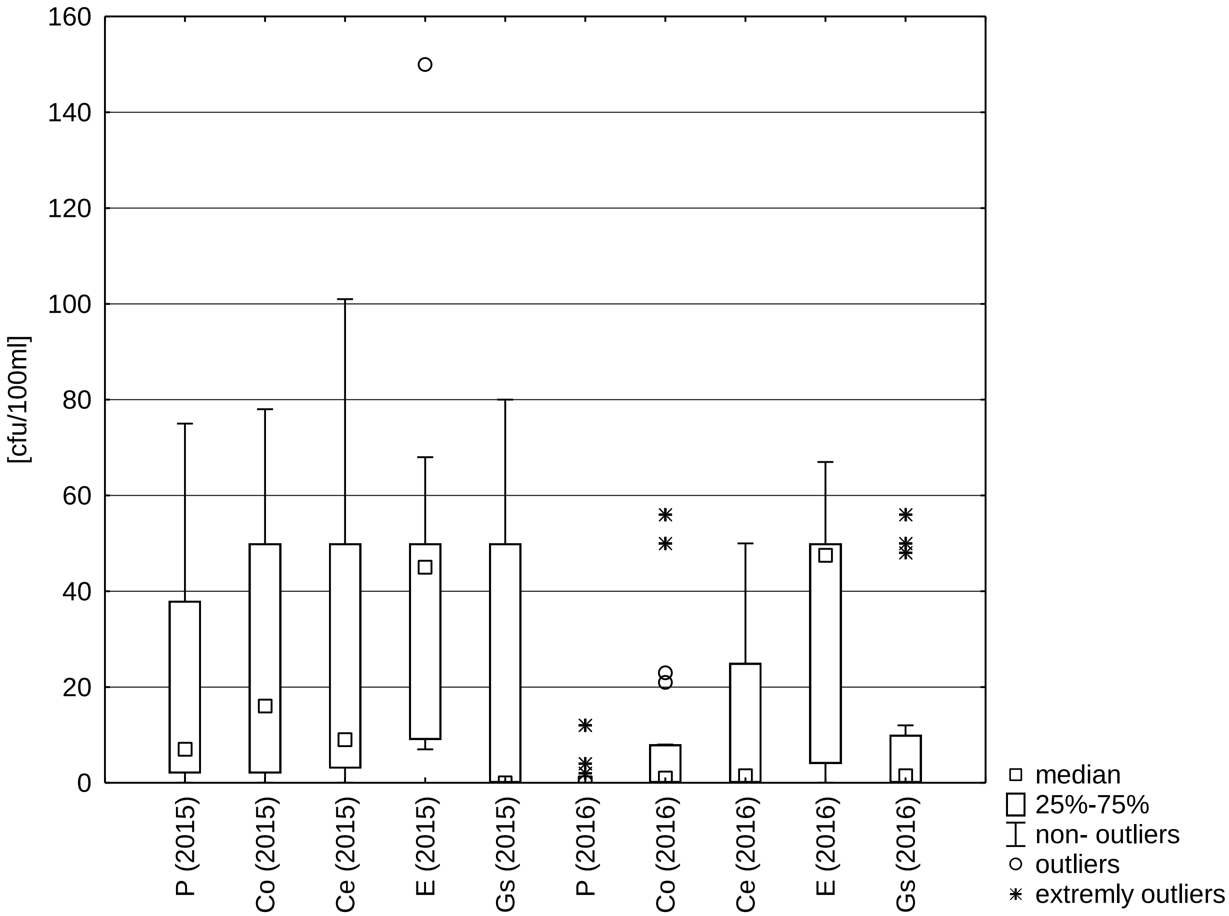

Figure 11. Statistical data for the number of Enterococci present in rainwater

The highest median values of faecal streptococci were established for rainwater collected from the surface covered with epoxide coated terrace – approx. 50 cfu/100ml.

4. Discussion

All results obtained describing the quality of rainwater collected from both roof surfaces and directly from atmospheric precipitation took into account the so-called time of the first runoff. Literature data indicate differences in the quality of rainwater collected from the beginning of the rainfall and the one after the designated time of the first runoff. Nosrati shows even four times higher concentrations of phosphates, sulphates and nitrates in waters collected from bituminous roof without taking into account the first runoff in relation to the water collected after a certain time from the beginning of the fall (Nosari, 2017).

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The presented rainwater turbidity tests prove that this parameter is dependent on the roughness of the roof covering material. The rainwater turbidity increases with the roughness of the roof surface. Leong et al. demonstrate reverse dependencies, indicating the rainwater dirt holding capacity in rough surfaces. For glass, metal and ceramic surfaces the following maximum turbidity values were established: 92.9 NTU, 57.1 NTU, 10.1 NTU (Leong et al., 2017). Naddeo et al. report significantly higher turbidity values for rainwater collected directly from air: 25.88 NTU in comparison to the obtained result of 4 NTU. This may result from a higher number of suspended dust particles as well as from the fact that the tests were conducted in an urban area (Naddeo et al., 2011). Rainwater turbidity can be also a result of revivable bacteria (Ding et al., 2017).

The determination of the concentration of nitrogen compounds proves to be particularly important with regard to microbiological tests and the assessment of the conditions of survival and growth of bacteria in water. The source of nutrients in rainwater from atmospheric precipitations can be plants pollens, fungal spores, bacterial cells and spores as well as other substances from i.e. agricultural crops, which pollute roof surfaces by dry deposition. In addition, nutrients may also come from natural sources such as bird droppings, bryophytes and lichens polluting roof run-offs (Ducan et al., 1995). In the analyzed rainwater, regardless of the type of roofing material, the value of nitrogen compounds oscillated around the value of 0.2-0.4 mg NH_4^+ /l. Research on the content of nitrogen compounds in rainwater in urbanized areas showed significantly lower concentrations of NH4 + ions and amounted to an average of 0.02 mg / dm3 (Lee et al., 2011).

The highest nitrate concentrations were recorded for rainwater collected from concrete and ceramic tiles roofing. Similar nitrate concentrations to those determined for rainwater collected from concrete tiles roofing were found in strongly urbanized areas (Lee et al., 2012).

In turn, the concentration of phosphates in the analyzed rainwater samples oscillated around the value of 0.02 mg PO_4^{3-} /l. Duncan et al. (1995) in his research observed in the rainwater from the urban zone concentration of 0.01-0.10 mg PO_4^{3-} / l. Other authors emphasize the significant impact of surface roughness on the content of biogenic substances including (Lai et al., 2018). This observation coincides with the obtained test results. The differences in levels of phosphates and nitrogen compounds that occurred between water samples collected from different roof may be primarily due to the structure of these surfaces and the possibility of washing out dry deposition pollutants.

It should also be noted that the inclination of the roof surface can have a significant impact on the quality of rainwater. The conducted research indicates that the values of turbidity, nitrates, phosphates or TOC are the highest in rainwater harvested from the roof with a minimum inclination angle (covered with epoxy resin). This is confirmed by studies carried out much earlier on the quality of rainwater collected, among others from roofs covered with shingles, green roofs and so-called cold roofs with smooth coatings to prevent overheating. The results for parameters such as turbidity or total organic carbon content were almost twice as high in waters collected from smooth roof surfaces with a small inclination angle compared to waters collected from roofs with rough surfaces with a higher slope angle (Mendez, 2011).

In the research cycle carried out in 2016, the concentrations of elements detected in the water collected directly from air as well as from different roof surfaces, occurred to be lower than in the test cycle 2015. This may result from a higher total rainfall in 2016. As it results from the analyzes of literature The presence of heavy metals was recorded in virtually all types rainwater:

from natural (Türküm et al., 2008), strongly urbanized (Bai et al., 2014; Xu et al., 2015), and rural areas (Gikas et al., 2012), in both stored rainwater (Despins et al., 2009) and the so called first run-off (Lee et al., 2012; Georgios et al., 2012). The source of heavy metals present in rainwater are the surfaces washed by rainwater, where these pollutants accumulate by dry deposition. The solubility of non-ferrous metals, such as i.e. lead, may vary according to the rainwater pH (Chester et al., 1997). Metals such as Cd, V, Cu and Zn demonstrate a higher solubility than Ni, Cr and Pb, both in wet and dry deposits (Morselli et al., 2003; Gunawardena et al., 2013). This is confirmed by the concentrations achieved by these elements in the analysed rainwater types.

Water collected from a roof covered with zinc coated metal sheets is distinguished by higher zinc content (3164,55 μg Zn/l) than other samples (less than 1000 μg Zn/l). This dependency on roofing material was also found by other researchers (Lee et al., 2010; Mendez et al., 2011; Yaziz et al., 1989; Vialle et al., 2011).

Electrical conductivity is an indicator of any positive or negative ions present in the water. It may indicate pollution by i.e. heavy metal ions. In the analysed waters, the electrical conductivity was around 1-4μS/cm (median). Zhang et al. obtained similar results for waters collected from roofs covered with roof tiles and sheets, and a significantly higher conductivity was determined for run offs from the so-called green roof (Zhang et al., 2014). The general mineralization of rainwaters in natural conditions may be only several milligrams of the substance dissolved per litre of water, however, in industrialized regions, the mineralization level is increased. The values obtained are relatively low in comparison to those recorded in industrialized zones – 614,8 μS/cm (Bai et al., 2014).

In each rainwater type test, including the rainwater collected directly from atmospheric precipitations, indicative bacteria levels from faecal contamination were detected. The presence of such bacteria was demonstrated by almost all analogue studies. Lee et al. determined a lower amount of E. coli in rainwater collected from concrete tiles roof (2 cfu/100ml), ceramic (1 cfu/100 ml) and zinc coated metal sheets (0 cfu/100 ml). It is interesting to note, that in extensive green roof water leachate an average amount of only 1 cfu/100 ml was identified. It is believed that the substrate for plant growth may create, in a certain sense, deposit and conditions for the creation of biofilm, which makes washing out microorganisms from roof surfaces more difficult (Lee et al., 2012).

In rainwater samples collected without rejecting the so-called first run-off, the number of E. coli can be significantly higher – 5500 cfu/100 ml (Dobrowolsky et al., 2014), and even 7670 cfu/100 ml (Leong et al., 2017). This is also confirmed by the research mentioned previously done by Lee et al., where the bacteria numbers from the first run-off in waters collected from different surfaces were as follows: concrete roof tiles – 18 cfu/100 ml, ceramic roof tiles – 8 cfu/100 ml, zinc coated metal sheets – 4 cfu/100 ml (Lee et al., 2012).

Escherichia coli, faecal *streptococci* are almost always detected in roof-harvested rainwater. Comparing the middle values of enterococci, it can be noted that their numbers were lower in 2016 than in 2015. The reason may be the number of rain episodes in individual research cycles, and thus the frequency of leaching microbiological pollutants from roof surfaces. Only for a roof with a minimum inclination, the results were comparable in both research cycles.

E. coli and faecal *streptococci* are micro-organisms present at high levels in faeces of both humans and animals. The presence of these bacteria in roof-harvested rainwater can be explained by the deposition of faeces on these roofs by birds and small mammals (Śmigielska, 2010). A potential source of contamination by faecal micro-organisms can be also soil particles carried by wind from agricultural fields fertilized with organic substances or the bio-aerosols from free-standing, unsheltered reactors of biological wastewater treatment plants – especially because sampling points of tested waters are located south from the above-mentioned potential sources of micro-organisms, while south-west winds were predominant. Some studies which appear to confirm this hypothesis show that bacteria contained in droplets of water carried by wind can travel even up to 1 km retaining their viability (Korzeniewska et al., 2008, Ekstrom S. et al., 2010, Ahern et al., 2007, Cho and Chwang, 2011, Polymenakou 2012).

Among the examined waters, the best microbiological quality was characterized by the one taken from the roof covered with galvanized sheet. This is related to the biocidal properties of zinc and the relatively smooth surface of the sheet. Mendez et al. indicate that adequate roofing can be an effective measure to prevent the growth of microorganisms. In the experimental studies, various roof coverings were used, and galvanized steel proved to be the cover with the greatest disinfection properties. This may have resulted from an increase in temperature on the roof surface (Mendez et al., 2011). The relationship between the roughness of the roof material and the amount of microorganisms was confirmed by the majority of rainwater researchers (Leong et al., 2017, Dobrowsky et al., 2014).

At the same time, it is noted that depending on rainfall frequency and roofing material, the quality of roof-harvested rainwater can deteriorate or improve as compared to rainwater collected directly from atmospheric precipitations. This means that these waters cannot be used as a source of drinking water or for hygienic purposes, without prior treatment, which in certain situations can be expensive and requires advanced processes.

The presence of indicative faecal bacteria contamination precludes this water being considered as safe for watering crops the fruit of which can be consumed without being cleaned (such as strawberries or raspberries). A safe utilization of this water can be only for laundry or dishwashing, provided that appropriate temperature is applied (above 60 ^{o}C), as well as for typical cleaning activities in households such as washing driveways, car washing or lawn watering.

5. Conclusions

Comprehensive studies on the quality of rainwater discharged from roofs made of various materials allowed for the formulation of a number of general and specific applications.

• The quality of rainwater significantly depends on the material from which the roof surface is made. Rainwater collected from a roof covered with zinc coated metal sheets displayed the lowest pH (approx. pH= 6.0) and the lowest turbidity as compared to water collected from other roof surfaces included in the research (concrete roof tiles, ceramic roof tiles, epoxide coated). The most polluted were the water collected from the surface covered with epoxy resin, which confirms the fact that surfaces with high roughness and a small angle of roof inclination tend to accumulate on their surface pollution, deteriorating the quality of rainwater. This is confirmed by the results of turbidity tests, biogenic substances or the number of bacteria.

• Observed that rough roofing materials provide favourable conditions for deposition of airborne pollutants which subsequently can be washed out by rainfalls. At the same time, it has been noted that in the event of less intensive precipitations micro-organisms and chemical pollutants can be deposited in the pores of roofing materials, which results in a relatively good rainwater quality. This can be observed in waters collected from concrete and ceramic tile roofs – these water types show a better micro-biological, physical and chemical quality than the water collected directly from atmospheric precipitations.

• Smooth surfaces, eg sheet metal, very quickly rinse in the first moments of rainfall, both physicochemical and microbiological rainwater quality is very good. Smooth surfaces, eg sheet metal, very quickly rinse in the first moments of rainfall, both physicochemical and microbiological rainwater quality is very good.

• In rainwater collected directly from atmospheric precipitations lower pH values were recorded than in roof-collected rainwater. The contact of rainwater with ceramic or concrete surface (ceramic roof tiles or concrete roof tiles) had a positive impact on its pH (pH values increased).

• Micro-biological pollution of roof-harvested rainwater do not allow for its safe utilization as potable water or as water intended to come into contact with food, nor for hygienic purposes. The pH needs to be corrected and the turbidity and faecal bacteria need to be removed.

• The analysed rainwater types can be used as resources where lower water quality is sufficient, i.e. for cleaning, car washing, laundry, toilet flushing, watering crops and lawns without any negative impact on plants or organisms living in the soil.

• The analysed rainwater types can be used as an alternative source of drinking water and for hygienic purposes in crisis conditions, only after having undergone a disinfection.

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