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Assessment of municipal waste accumulation at State University of Applied Sciences in Nowy Sącz

Abstract

The aim of the study was to assess the composition collected of municipal waste in selected three Institutes of State University of Applied Sciences in Nowy Sącz in 2017 and 2018, taking into account the morphological composition covering five fractions. Paper waste had the highest share of 24.28% in the structure of the analyzed municipal waste in the Institute of Economics. The highest average value among the analyzed waste fractions was for organic waste (0.117 kg), similarly the standard deviation confirming the greatest variability of the results. The poor correlation relationships were most often noticeable in the Engineering Institute (r = 0.30), between organic waste and metals. Based on the conducted research, it was considered justified to implement selective waste collection at the University in accordance with the waste management hierarchy.

Key words: morphological composition, municipal waste, segregation, statistics.

Ocena składu gromadzonych odpadów komunalnych w Państwowej Wyższej Szkole Zawodowej w Nowym Sączu

Streszczenie

Celem pracy była ocena składu gromadzonych odpadów komunalnych w wybranych trzech Instytutach Państwowej Wyższej Szkoły Zawodowej w Nowym Sączu w latach 2017 i 2018 z uwzględnieniem składu morfologicznego, obejmującego pięć frakcji. Największy udział, 24,28%, w strukturze badanych odpadów komunalnych przypadał na odpady papieru w Instytucie Ekonomicznym. Najwyższa wartość średnia spośród badanych frakcji odpadów przypadała na odpady organiczne (0,117 kg), podobnie odchylenie standardowe, potwierdzające największą zmienność wyników. Słabe związki korelacyjne wystąpiły pomiędzy odpadami organicznymi i metalami (r = 0,30). Na podstawie przeprowadzonych badań za wskazane uznano wdrożenie selektywnej zbiórki odpadów w uczelni, zgodnie z hierarchią postępowania z odpadami.

Słowa kluczowe: skład morfologiczny, odpady, segregacja, statystyka.

1. Introduction

Currently Municipal Solid Waste (MSP) is an unavoidable consequence of existence of society and operations of economic entities (Przydatek, 2020). For a society to be able to exist in an environmentally sustainable country it is required to introduce such methods of managing waste which will take into consideration waste recycling as well as environmentally-friendly neutralization and, primarily, minimization of the quantity of waste and its influence on environment protection (Tsoulfas, Pappisx, 2006). In order to minimize accumulation of waste and waste landfills the European Union has defined in its legislation the hierarchy of waste treatment according to which storing waste is a last resort measure (Pomberger et al., 2017). Member states, including Poland, are facing the ambitious challenge of reaching the municipal waste recycling level of 50%, including recycling of paper, metals, plastics and glass, in each year following the year 2024 (The Act, 2020). In order to achieve the expected results legislative and educational endeavors are made such as e.g. promoting selective waste collection.

An important role in recognizing efficiency of waste management is being played by waste management indicators which were utilized by Przydatek and Ciągło (2019). These are particularly important when determining quantity of produced waste.

Recently the universities began to play significant role in developing behavior patterns positively influencing society. Therefore the waste management at universities in the area of Poland requires analysis; the produced results can be used for expanding the knowledge regarding the discussed issue. In Romania such studies were performed by Popescu et al. (2016), and by Sánchez-Salinas et al. in Mexico (2015).

The goal of this paper is to develop assessment of the accumulated municipal waste on the basis of the morphological composition in the selected facilities of the State University of Applied Sciences in Nowy Sącz in years 2017-2018.

2. Methodology and materials

The performed studies of morphological composition of waste consisted of isolating fractions of the waste generated in the area of three selected Institutes (Economics, Physical Education and Engineering) from among six institutes in the State University of Applied Sciences in Nowy Sącz (Southern Lesser Poland region) (Figure 1). This waste is characterized by selected properties influencing effectiveness of its recycling. According to Rosik-Dulewska (2015) the basis for classification of waste consists of appropriate criteria, including the type of primary product verifying a given type of waste.

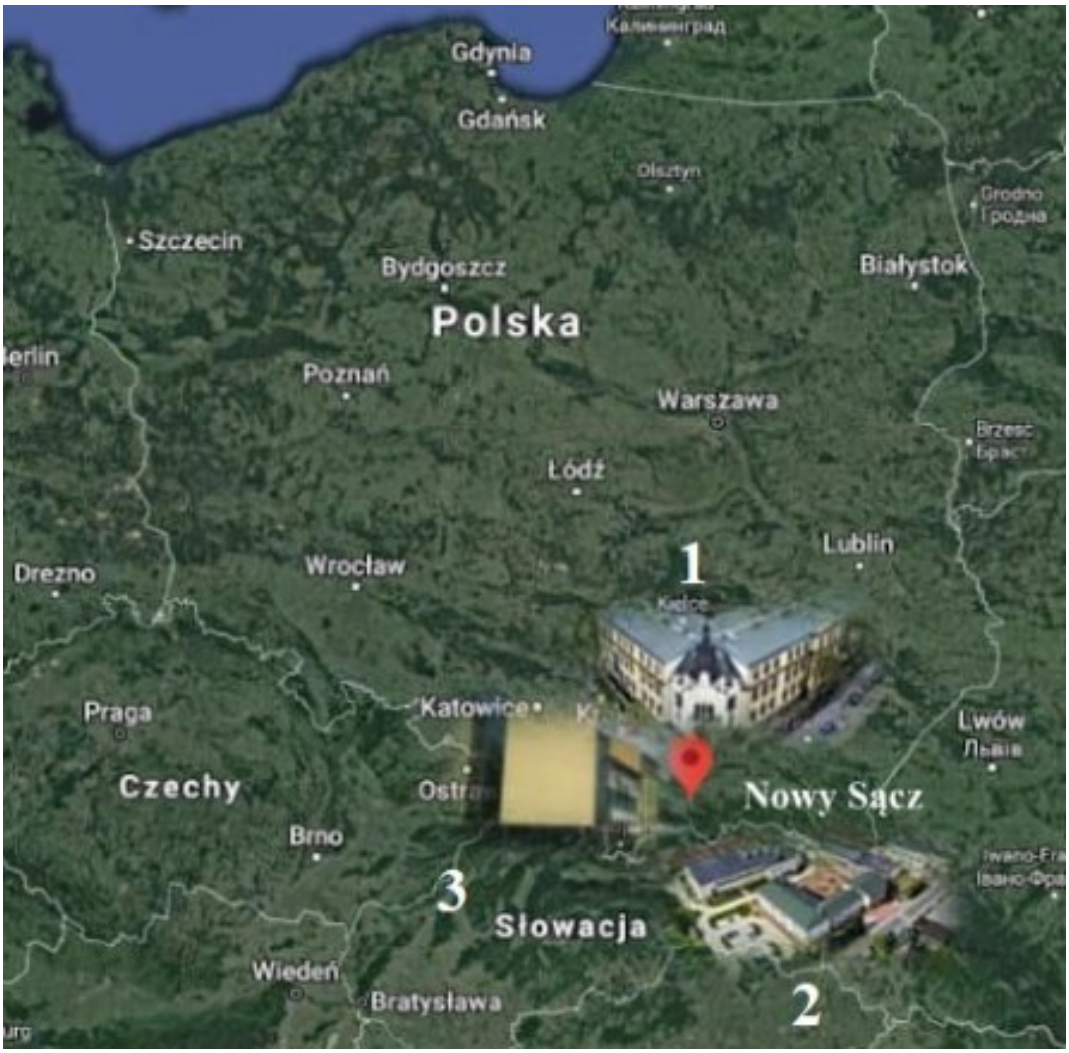

Figure 1. Location of State University of Applied Sciences in Nowy Sącz (southern Poland) (1) Institute of Economics (2) Institute of Physical Education (3) Institute of Engineering

Morphological composition of waste has been determined on the basis of the performed studies – composite sub-scores in three different periods, on the basis of the requirements stipulated by Malinowski and Woźniak (2010). The first series of studies took place between 16th and 20th of October 2017, the second series took place between 18th and 31st of December 2017. The third and final series of studies was performed between 19th and 23rd of February 2018. Morphological composition of waste was determined on the basis of the collected data. The following fractions of municipal waste were isolated within the framework of the study: paper, glass, metals, plastics and organic waste.

Hand-held scales with the maximum permissible load of 30 kg were used for determining morphological composition. The following formula was used for performing necessary calculations (OBREM, 2006):

$$X_n = \frac{m_n}{m} \times 100\% \quad (1)$$

where:

m_n – mass of individual fractions of waste [kg],
m – overall mass of waste from a given container [kg],
n – 1, 2, 3 symbols of individual fractions.

On the basis of the formula presented below the yearly volume of waste has been estimated:

$$V_{annual} = 12 * (n * \mathrm{p}) \quad (2)$$

where:

n – monthly volumetric accumulation indicator,
p – number of students.

Annual mass accumulation indicator of the produced waste was calculated on the basis of the following formula:

$$m = n * p \quad (3)$$

where:

n – annual mass accumulation indicator,
p – number of students.

Statistica 12 program was used for processing results of study and determining minimal, maximum and average values as well as standard deviations. Furthermore, a matrix of correlations has been generated. Two hundred twenty five individual results were registered for each of the variables during the study, 75 for each of the Institutes. Following identification of normality of distribution which appeared in the majority of the analyzed fractions of waste through Shapiro-Wilk method ($p<0.050$) we proceeded to study the correlation between the determined types of waste through using Pearsons correlation method. In order to analyze correlations indicating meaningful relations between the pieces of data we adopted the following scale of the strength of data interconnectivity (Stanisz, 1998):

- $r_{xy}=0$ – no correlation
- $0 < r_{xy} <$ – a trace correlation
- $0.1 \leq r_{xy} < 0.3$ – a weak correlation
- $0.3 \leq r_{xy} < 0.5$ – an average correlation
- $0.5 \leq r_{xy} < 0.7$ – a strong correlation
- $0.7 \leq r_{xy} < 0.9$ – a very strong correlation
- $0.9 \leq r_{xy} < 1.0$ – a nearly complete correlation.

Waste management

Building of the Institute of Engineering (IoE) has three floors on which lecturing halls, classes, laboratories, front office and lecturers' and tutors' offices are located (25 teaching staff in total).

The Institute of Economics (IoEco) is located in the building where five lecture halls, classes, three computer workrooms as well as an accounting workroom are located.

The Institute of Physical Education (IoPE) is a complex consisting of an educational building where workrooms (12) are located, incl. kinesiotherapy, cryotherapy, physiotherapy workrooms and a sports psychology workroom. Apart from the educational building the Institute consists of a sports hall, a gymnastics hall with a gym, a swimming pool and a football field (pwsz-ns.edu.pl).

Waste collection in the areas of IoE, IoEco and IoPE in years 2017-2018 was realized on the grounds of Act No. XIII/123/2015 of the Nowy Sącz City Council adopted on 23rd of June 2015 and the system of waste management in these facilities is based on collecting waste into mixed waste containers (vol. of 60 dm^3) which are then put into collective containers with volume of 1 100 dm^3 which are located outside the buildings.

The entity selected by City of Nowy Sącz through tender procedure collects waste from the listed State University of Applied Sciences facilities in accordance with the determined schedule.

Such actions are performed to ensure that the amount of waste is limited, waste is recycled and, ultimately, neutralized (Armijo et al., 2008; Smyth et al., 2010).

In terms of waste collection the area of Nowy Sącz has been divided into 40 zones in accordance with division into estates and, furthermore, on the basis of the individually determined, hard to access locations. Taking into consideration division into zones the Institute of Engineering is located in zone 31 which covers Przydworcowe estate, the Institute of Economics is located in zone 20 which includes the Old Town and the Institute of Physical Education is located in zone 33 covering Wólki estate (odpady.nowysacz.pl).

3. Analysis of the results of study

Morphological composition

The Institute of Engineering

The highest share, 24.08%, in the composition of the waste studied in the Institute of Engineering consists of waste paper. Organic waste enjoys a slightly smaller share, 21.76%; share of plastics is 21.50%. Glass and metals have a smaller share: 17.73% and 14.93% respectively (Figure 2).

The most frequently utilized volumetric waste accumulation indicator for such institutions as schools and universities is 2 $dm^3 \cdot studnet^{-1}$ over two weeks (Program, 2014). Therefore the indicator at the level of 5 dm^3 $pupil^{-1}$ $month^{-1}$ was adopted for the purpose of calculating the maximum annual volume and thus the result of 0.005 $m^3 \cdot student^{-1} \cdot$ month was calculated. In academic year 2017/2018 962 students studied in the Institute of Engineering.

$$V_{annual} = 12 * (0{,}005 * 962)$$
$$V_{annual} = 57{,}72\ m^3$$

According to the estimation approx. 58 m^3 of waste was generated in the IoE in the aforementioned years which translates into the amount of approx. 4.8 m^3 generated monthly. Adopting the annual mass indicator at the level of 6.6 $kg \cdot student^{-1}$ (Program, 2014) the estimated amount of waste generated in the Institute of Engineering is:

$$m = 6{,}6 * 962$$
$$m = 6349{,}2\ kg\ \text{year}^{-1}$$
$$m \approx 6{,}35\ Mg$$

In academic year 2017/2018 it was estimated that 6.35 Mg of waste was generated in total which translates into 0.53 Mg per month.

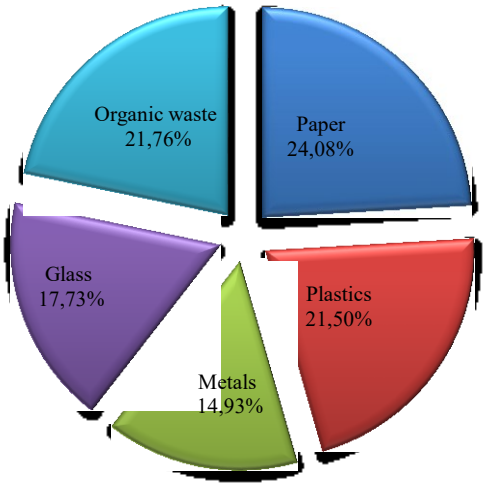

Figure 2. Morphological composition of waste in the Institute of Engineering of State University of Applied Sciences in Nowy Sącz

The Institute of Economics

In the Institute of Economics the highest share of waste, 24.28%, consists of paper waste. Share of plastics was lower by 3.25% and organic waste by 3.55%. Glass waste had the lowest share in the total amount of waste – 16.20% (Figure 3).

With 844 students in the IoEco in the academic year 2017/2018 the accumulation of waste has been estimated in terms of volume and mass:

$$V_{annual.} = 12 * (0{,}005 * 844)$$
$$V_{annual.} = 50{,}64\ m^3$$

In the analyzed academic year this Institute generated approx. 51 m^3 of waste, 4.22 m^3 per month. The estimated mass of waste generated in academic year 2017/2018 in IoEco was:

$$m = 6{,}6 * 844$$
$$m = 5570{,}4\ kg\ \text{year}^{-1}$$
$$m \approx 5{,}57\ Mg$$

In the aforementioned academic year approx. 5.57 Mg of waste was generated which translates into approx. 0.46 Mg per month.

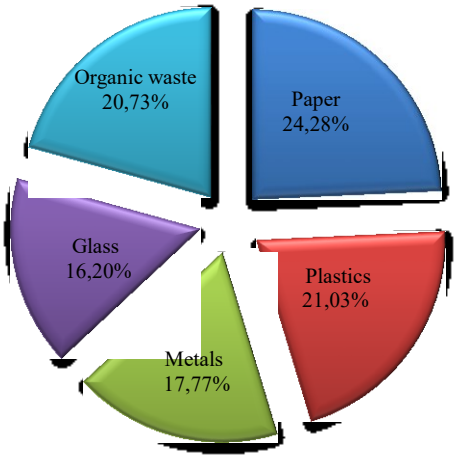

Figure 3. Morphological composition of waste in the Institute of Economics

The Institute of Physical Education

Similarly to previous Institutes the highest share of waste in the Institute of Physical Education consisted of waste paper – 23.44%. Plastics had a slightly lower share of 21.87% and the lowest share of waste consisted of glass (16.60%) and metals. During comparison of morphological composition of the waste generated in IoPE facilities to the remaining institutes a slight difference between fractions (not exceeding 2%) have been recorded (Figure 4).

In academic year 2017/2018 317 students were learning in the Institute of Physical Education. This number was used to estimate the volume of accumulated waste:

$$V_{annual} = 12 * (0{,}005 * 317)$$
$$V_{annual} = 19{,}02\ m^3$$

Approximately 19 m^3 of waste were generated in the analyzed academic year which amounted to 1.59 m^3 per month. Mass of the waste generated in this Institute in academic year 2017/2018 has been estimated on the basis of the following calculations:

$$m = 6{,}6 * 317$$
$$m = 2092{,}2kg\ \text{year}^{-1}$$
$$m \approx 2{,}09Mg$$

In the aforementioned period approx. 2.09 Mg of waste was generated which translates into 0.17 Mg per month.

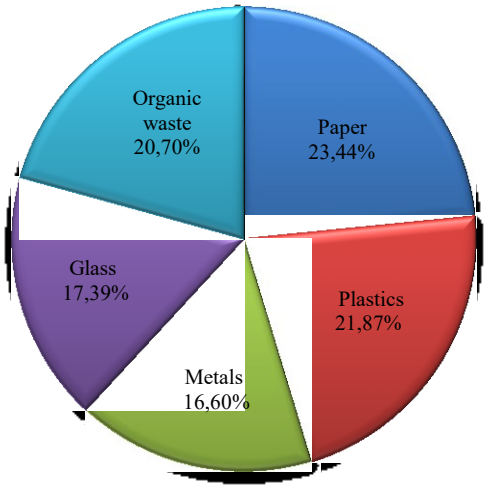

Figure 4. Morphological composition of waste in the Institute of Physical Education

Statistical analysis

The highest amount of organic, paper and plastics waste which was, respectively, 0.91 kg (22.12.2017), 0.92 kg (20.12.2017) and 0.90 kg (20.10.2017) has been recorded in the Institute of Economics. In turn, the highest amount of glass waste, – 0.93 kg (20.10.2017) – has been recorded during the studies performed in the Institute of Physical Education. In the Institute of Engineering the highest value for the accumulated waste, 0.91 kg (18.12.2017), has been recorded for metals. The greatest amount of waste consisting of the five distinguished fractions in terms of mass accumulated in the selected facilities of State University of Applied Sciences in Nowy Sącz was recorded in October and December of 2017, i.e. during the first and second series of studies (Figure 5).

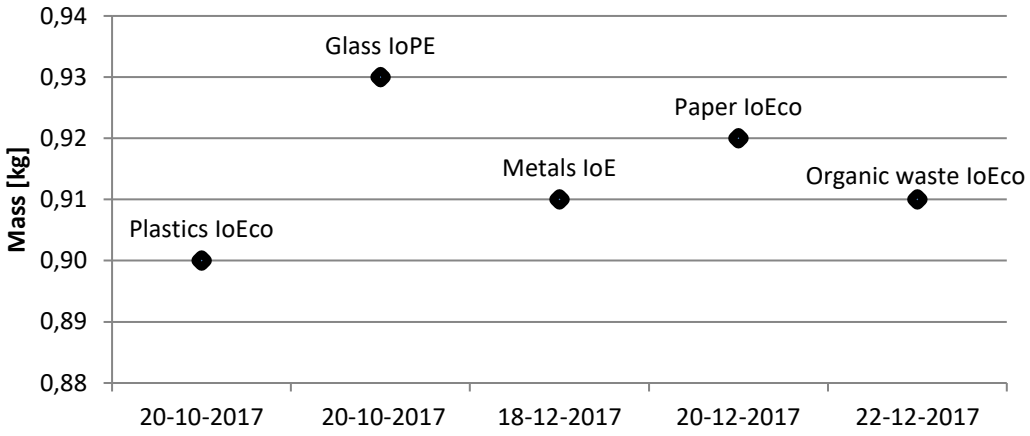

Figure 5. The highest values for the mass of collected waste in division into five fractions of waste

Table 1 presents the basic statistics for the results concerning the waste collected in individual Institutes in division to fractions.

Table 1
Basic statistical data for waste accumulation in selected Institutes

Fraction	Basic statistics				
	Number of attempts	Average [kg]	Minimal [kg]	Maximum [kg]	Standard deviation [kg]
Paper	225	0.116	0.00	0.92	0.077
Plastics	225	0.107	0.00	0.9	0.091
Metals	225	0.088	0.00	0.91	0.098
Glass	225	0.098	0.00	0.93	0,118
Organic waste	225	0.117	0.00	0.91	0.114

Organic waste displays the highest average mass from among the five examined fractions (0.117 kg) which was slightly higher (by 0.001 kg) than the average mass of paper waste. The value of standard deviation was similarly the highest (0.114 kg). Metal waste displayed the lowest average value in the Institutes – 0.088 kg. Average waste mass below 0.100 kg was displayed by glass and plastics. The latter type of waste was characterized by the lowest standard deviation – 0.091 kg.

In the case of the Institute of Engineering the highest average mass was recorded for the organic fraction – 0.132 kg. Also the standard deviation was characterized by the highest value (0.129 kg). In case of the IoE metals was the fraction with the lowest average – 0.090 kg. It should be noted that the highest value for metals, 0.91 kg, was recorded in the analyzed institute. The lowest standard deviation was recorded for plastics (0.060 Mg).

Table 2
Basic statistical data for the results of study performed in the Institute of Engineering

Fraction	Basic statistical data				
	Number of attempts	Average [kg]	Minimal [kg]	Maximum [kg]	Standard deviation [kg]
Paper	75	0.115	0.00	0.26	0.064
Plastics	75	0.101	0.00	0.31	0.060
Metals	75	0.090	0.00	0.91	0.126
Glass	75	0.114	0.00	0.70	0.147
Organic waste	75	0.132	0.00	0.60	0.129

In the IoEco the highest average mass of waste has been recorded for paper – 0.126 kg, and the lowest for glass – 0.088 kg. In the aforementioned Institute there were as much as three values which turned out to be the highest values recorded during the performed studies (paper, plastics and organic waste). The lowest average value, 0.50 kg, has been recorded for glass. In turn, the highest value of standard deviation, confirming significant variability of the results, has been recorded for organic waste (0.133 kg) (Table 3).

Table 3
Basic statistical data for the results of study performed in the Institute of Economics

Fraction	Basic statistical data				
	Number of attempts	Average [kg]	Minimal [kg]	Maximum [kg]	Standard deviation [kg]
Paper	75	0.126	0.02	0.92	0.106
Plastics	75	0.113	0.00	0.90	0.111
Metals	75	0.093	0.00	0.70	0.094
Glass	75	0.088	0.00	0.50	0.084
Organic waste	75	0.117	0.00	0.91	0.133

Table 4
Basic statistical data for the results of study performed in the Institute of Physical Education

Fraction	Basic statistical data				
	Number of attempts	Average [kg]	Minimal [kg]	Maximum [kg]	Standard deviation [kg]
Paper	75	0.108	0.00	0.24	0.047
Plastics	75	0.107	0.01	0.70	0.095
Metals	75	0.082	0.00	0.30	0.064
Glass	75	0.093	0.00	0.93	0.116
Organic waste	75	0.101	0.00	0.25	0.066

In the IoPE the highest average value has been recorded for paper 0.108 kg and the lowest for metals 0.082 kg. The highest value of standard deviation has been recorded for glass (0.116 kg). This type of waste was also characterized by the highest accumulation achieved during studies – 0.93 kg.

Table 5
Correlation matrix for the results regarding waste accumulated in the Institute of Technology

Fraction	Pearson's rank order correlation for waste in the IoE Marked coefficients of the correlation are meaningful, p <.05000				
	Paper	Plastics	Metals	Glass	Organic waste
Paper	1.00	0.29	0.13	-0.02	0.24
Plastics	0.29	1.00	0.25	-0.03	0.12
Metals	0.13	0.25	1.00	-0.07	0.30
IT glass	-0.02	-0.03	-0.07	1.00	0.05
Organic waste	0.24	0.12	0.30	0.05	1.00

In case of the IoE meaningful correlations appeared between paper and plastics fractions as well as between metals and plastics, organic waste, paper as well as metals and organic waste. The recorded values of correlation coefficients were the highest for paper and plastics ($r = 0.29$) and organic waste and metals ($r = 0.30$); these values did not exceed 0.3 and turned out to be weak.

Table 6
Correlation matrix for the results concerning the waste collected in the Institute of Economics

Fraction	Pearson's rank order correlation for waste in the IoEco Marked coefficients of the correlation are meaningful, p <.05000				
	Paper	Plastics	Metals	Glass	Organic waste
Paper	1.00	-0.22	-0.01	-0.08	0.19
Plastics	-0.22	1.00	0.27	0.03	-0.11
Metals	-0.01	0.27	1.00	0.07	0.03
Glass	-0.08	0.03	0.07	1.00	0.00
Organic waste	0.19	-0.11	0.03	0.00	1.00

In case of the Institute of Economics only a single meaningful correlation appeared – the correlation between plastics and metals (r = 0.27) which was counted among weak correlations (Figure 6).

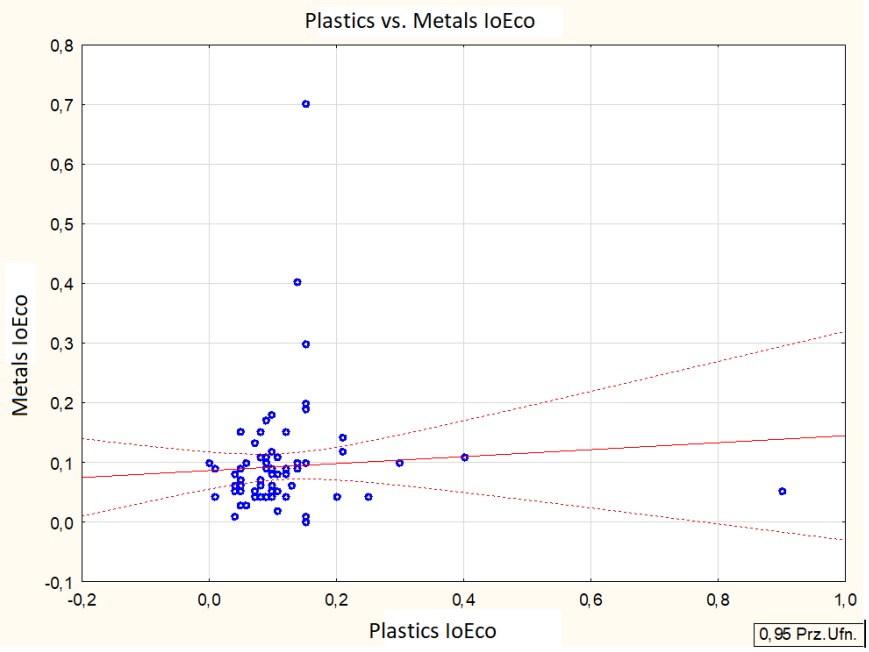

Figure 6. Correlation between plastics and metals fractions in the IoEco

The analysis of the data presented in Table 7 indicates that there are no meaningful correlations between waste fractions in the Institute of Physical Education.

Table 7
Correlation matrix for the results concerning the waste collected in the Institute of Physical Education

Fraction	Pearson's rank order correlation for waste in IoPE. Marked coefficients of the correlation are meaningful, p <.05000				
	Paper	Plastics	Metals	Glass	Organic waste
Paper	1.00	0.12	-0.10	0.09	-0.13
Plastics	0.12	1.00	0.07	0.21	-0.02
Metals	-0.10	0.07	1.00	-0.11	-0.12
Glass	0.09	0.21	-0.12	1.00	0.03
Organic waste	-0.13	-0.02	-0.12	0.03	1.00

4. Discussing the results

Existence of five fractions of waste: paper, plastics, metals, glass and organic waste, has been confirmed during study of the composition of the waste accumulating in three Institutes of State University of Applied Sciences in Nowy Sącz. The last type of waste is particularly significant owing to the opportunities related to utilizing it as a raw material for manufacturing compost, biogas or utilizing it as a source of alternative energy (Brzózan et al., 2011).

Paper enjoys the highest share in the composition of the municipal waste with the share of 24.28% recorded at the IoEco. Sánchez-Salinas et al. achieved similar results (2015). The share of organic waste among the waste accumulated at IoE, 21.76%, also remains significant. Salau et al. (2017) have also indicated a significant participation of organic waste and paper.

The highest share of plastics, 21.87%, has been recorded for the Institute of Physical Education. A significant share of this type of waste has been indicated by Przydatek et al. (2017) in the area of rural communes. The participation of glass and metals in the total mass of the accumulated waste was lower, below 18%.

In general, the Institute of Engineering is the facility with the highest number of students (960) and where the highest volume of waste has accumulated over periods of a year (58 m^3) and a month (4.8 m^3). The mass of the waste generated within a year and within a month was similarly the highest – 6.35 Mg and 0.53 Mg respectively. It is here where the mass of accumulated metals waste was the highest (0.91 kg).

In turn, at the Institute of Economics the highest values for the accumulated waste concerned the greatest number of types of waste (organic, paper, plastics) despite the number of students lower by 116 than at the Institute of Engineering. It may point towards the greater variability of the produced consumer waste. The highest average value from among the five studied fractions of waste coincided with organic waste (0.117 kg) and was slightly, by 0.001 kg, higher than the average for paper waste. The value of standard deviation was similarly the highest and confirmed the greatest variability of results. The highest average value for organic waste, 0.132 kg, has been recorded for the Institute of Engineering. In turn the standard deviation values were the highest for the IoE and the IoEco, a fact which may result from the higher number of students.

The highest mass of glass waste has been recorded in the Institute of Physical Education (0.93 kg) which indicates the greatest accumulation of glass containers which may be possibly related to the increased physical activity of students (Utama et al., 2018). Przydatek et al. (2018) have also indicated the greatest share of glass waste in the area of Nowy Sącz. According to Rosik-Dulewska (2015) this type of waste is one of the major issues of municipal waste management.

Statistics is helpful in analyzing waste accumulation (Kaca, Kaca, 2012). The observable meaningful values of correlation coefficient were recorded at the Institute of Engineering the most frequently. Such correlation have emerged between paper and plastics fractions ($r = 0.29$) as well as organic waste and metals ($r = 0.30$); these correlations were weak. With 844 students only a single correlation appeared – a weak correlation between plastics and metals ($r = 0.27$).

The five fractions covering metals, paper, glass, plastics and organic waste distinguished on the basis of the analysis of morphological composition indicate towards the opportunity for introduction of selective waste collection which enables recycling waste "at the source" – an action consistent with waste treatment hierarchy (Popescu et al., 2016; Biegańska, Ciuła, 2011).

5. Conclusions

The following conclusions can be drawn on the grounds of the analysis of accumulation of waste in the selected facilities of State University of Applied Sciences:

- The greatest share within the composition of the studied municipal waste consisted of paper waste the greatest amount of which has been recorded at the Institute of Economics (24.28%). The amount of organic waste at the Institute of Engineering is also significant (21.76%). As a result of the highest number of students (960) the highest volume and mass of waste (58 m^3, 6.35 Mg) has been recorded at the Institute of Engineering.

- The highest maximum value (0.93 kg) was recorded for glass waste at the Institute of Physical Education where the lowest amount of students attend whereas the highest number of maximum values regarding accumulated waste covering three types of waste (organic, paper, plastics) has been recorded for the Institute of Economics where a higher number of students learns.
- The highest average value and standard deviation value from among the five examined fractions of waste were recorded for organic waste (0.117 kg).
- Correlation relationships most frequently occurred at the Institute of Engineering and in particular covered paper/plastics relationship (r = 0.29) and organic waste/metals relationship (r = 0.30), both of which turned to be weak correlations.
- The opportunity for introduction of selective waste collection in the facilities consistent with the waste treatment hierarchy has been demonstrated on the grounds of the performed studies.

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Uchwała Nr XIII/123/2015 Rady Miasta Nowego Sącza z dnia 23 czerwca 2015 r., w sprawie szczegółowego sposobu i zakresu świadczenia usług w zakresie odbierania odpadów komunalnych od właścicieli nieruchomości i zagospodarowania tych odpadów w zamian za uiszczoną przez właściciela nieruchomości opłatę za gospodarowanie odpadami komunalnymi.

Ustawa z dnia 13 września 1996 r. o utrzymaniu czystości i porządku w gminach (JoL 2020 r., item. 1439).

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