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Sanitary condition of electrical hand dryers in toilets of shopping centres in Kraków

Stan sanitarno-higieniczny elektrycznych suszarek do rąk w toaletach centrów handlowych na terenie miasta Krakowa

Anna Lenart-Boroń [a, b, c, d, e], *Jordan Jarosiński* [b, c, d]

Department of Microbiology, Faculty of Agriculture and Economics, University of Agriculture in Kraków, Poland.
Head of the Department of Microbiology: Prof. PhD Eng. M.J. Chmiel; Rector of the University of Agriculture: Prof. W. Sady

[a] *concept and design*
[b] *planning of experimental methods*
[c] *conducting research*
[d] *analysis of results and conclusions*
[e] *writing the manuscript*

ABSTRACT

Introduction. Shopping habits have changed over the past several years and consumers choose shopping centres, where they can spend time and visit restaurants. People usually wash hands before meals, but toilets in shopping centres are visited by hundreds of users every day which makes their cleanliness questionable. Therefore, the aim of this study was to assess the sanitary condition of electrical hand dryers in toilets of the selected shopping centres in Kraków.

Material and methods. Air was sampled at the outlet of electrical hand dryers and surface swabs of hand dryers were taken in toilets of five shopping centres. Air sampling was conducted using the MAS-100 impactor. The number of mesophilic bacteria, fungi, actinomycetes, staphylococci and *Escherichia coli* was determined. The results of air analyses were compared with the limits provided by the Polish Standards on air quality.

Results. The number of microorganisms varied between the studied centres. In terms of mesophilic bacteria and fungi the air was unpolluted. The concentration of actinomycetes however significantly exceeded the limits set by the Polish Standards. Numerous *Escherichia coli* were found both in the air and in swabs in one of the centres. However the number of *E. coli* and staphylococci did not exceed the minimum infective dose.

Conclusions. The studies showed high concentrations of airborne actinomycetes and staphylococci. Also the presence of *E. coli* in the air and swabs allows the conclusion that legal regulations for concentrations of airborne microorganisms are necessary to make people aware of this problem. However, it was found that using electrical hand dryers does not have impact on human health.

Keywords: air, airborne microorganisms, *Escherichia coli*, staphylococci

STRESZCZENIE

Wstęp. W przeciągu ostatnich lat zwyczaje konsumentów znacznie się zmieniły i klienci coraz częściej rezygnują z osiedlowych sklepów na rzecz centrów handlowych, w których mogą spędzić czas, a także skorzystać z bogatych ofert restauracji. Wielu ludzi odruchowo myje ręce przed posiłkami, jednak toalety w centrach handlowych odwiedzane są przez setki osób dziennie, a ich czystość może być wątpliwa. Celem badań była ocena stanu sanitarno-higienicznego suszarek do rąk w toaletach wybranych centrów handlowych w Krakowie.

Materiały i metody. Pobrano powietrze u wylotu suszarek elektrycznych oraz wymazy powierzchniowe wylotów powietrza w suszarkach w toaletach pięciu centrów handlowych. Próbki powietrza pobrano przy użyciu impaktora MAS-100. Oznaczono liczebność bakterii mezofilnych, grzybów, promieniowców, gronkowców i *Escherichia coli*. W przypadku badań powietrza wyniki porównano z zaleceniami Polskich Norm dotyczących jakości powietrza atmosferycznego.

Wyniki. Liczebność drobnoustrojów w badanych centrach handlowych była zróżnicowana. Pod względem liczby bakterii mezofilnych i grzybów powietrze we wszystkich toaletach było niezanieczyszczone. Stężenie promieniowców znacznie przekraczało wartości dopuszczalne w Polskich Normach. Również liczba gronkowców była bardzo wysoka. W jednym z badanych centrów stwierdzono liczne bakterie *Escherichia coli*, zarówno w powietrzu, jak i w wymazach. Jednak liczebność zarówno *E. coli* jak i gronkowców nie przekroczyła granicy minimalnej dawki infekcyjnej.

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Wnioski. W badaniach stwierdzono wysokie stężenia promieniowców i gronkowców. Obecność *E. coli* w powietrzu i w suszarkach daje podstawę do stwierdzenia, że normy prawne regulujące stężenie mikroorganizmów w powietrzu są potrzebne, aby podkreślić znaczenie problemu. Stwierdzono jednakże, że korzystanie z elektrycznych suszarek do rąk nie zagraża zdrowiu użytkowników.

Słowa kluczowe: *Escherichia coli*, gronkowce, mikroorganizmy w powietrzu, powietrze

INTRODUCTION

Over the past several years shopping habits in Poland have changed. Small local shops are being replaced by a growing number of shopping malls, in which spending free time is becoming increasingly popular. Apart from a wide variety of clothing, electronic or grocery shops, people can spend time in restaurants. Although it is not obvious for everyone, most people have the habit of washing hands before meals. Thus, the sanitary condition of toilets, used by hundreds of people every day, is an important issue, as inadequate care of the cleanliness of such places may turn out counterproductive.

Microorganisms do not reproduce in air, because the environment is too dry for them but air is a very good transmitter of microorganisms [1]. Also, Gram-positive bacteria and spore-forming microorganisms (including fungi) are quite resistant to drying, therefore they can dwell in such environment for a long time [1]. It has been found that the transmission of bacteria is more likely to occur from wet than on dry skin. Therefore, proper drying of hands should be an essential part of hand hygiene, especially before meals [2]. There have been concerns, whether using electrical hand dryers is as efficient and hygienic as disposable paper towels [2]. Redway and Fewdar [3] found numerous bacteria in jet air dryer surfaces, including *Pseudomonas aeruginosa*, *Escherichia coli* and various *Bacillus* species, concluding that the hand dryers can contribute to the transmission of potentially pathogenic bacteria.

The presented study was aimed at assessing the sanitary condition of electrical hand dryers located in toilets close to eating places in the selected shopping malls in Kraków.

MATERIAL AND METHODS

The study was conducted based on air sampling by the outlet of air from the electrical hand dryers and on surface swabs of the dryers' interiors. The samples were collected in five shopping malls, in five toilets per shopping centre. The air was sampled using a MAS-100 impactor (Merck, Switzerland). The sampled air volume was 100 litres. Both air and swab samples were collected on Petri dishes containing microbiological media used for enumeration of mesophilic bacteria (Trypticasein Soy Lab Agar, BTL, Poland), fungi (Malt Extract Agar, Oxoid, Great Britain), actinomycetes (Actinomycete Isolation Lab Agar, Biocorp, Poland), mannitol-positive and mannitol-negative *Staphylococcus* spp. (Mannitol Salt Agar, BTL, Poland), *Escherichia coli* (Endo-Les Agar, BTL, Poland). All samples were collected in three replications and data were presented as mean values of those. The air temperature and humidity was recorded using and HT-9213 Thermohydrometer (ATM, China). After sampling Petri dishes were incubated at 37°C for 48 hrs (mesophilic bacteria, *Staphylococcus* spp., *Escherichia coli*) or at 25°C for 3–5 days (fungi) and for 5–7 days (actinomycetes). After incubation, the number of colonies characteristic for each of the examined microbial group was counted and expressed as the number of colony forming units per cubic meter of air (CFU/m^3) in the case of air sampling and the number of colony forming units in the case of surface swabs. For *Staphylococcus* spp. and *Escherichia coli* enumeration on agar plates was followed by microscopic observations of Gram-stained smears. The numbers of airborne microorganisms were compared with the limits for atmospheric air contamination, given in the Polish Standards [4, 5]. The actual colony count was corrected according to the positive hole correction table [6].

Statistica v. 10.0 software (StatSoft, US) was used to calculate basic descriptive statistics and one-way analysis of variance was applied to determine the significance of differences in the number of microorganisms between different shopping malls.

RESULTS

Temperature and relative humidity were measured onsite, during each sampling. However, the conditions prevailing in shopping centres, including their toilets, are constant. Therefore, the temperature during all measurements ranged from 20 to 22°C and relative humidity ranged from 36% to 40%.

The recorded numbers of all microorganisms are presented in tab. I–V for air sampling and in fig. 1-5 for surface swabs. The mean number of airborne mesophilic bacteria varied between the examined shopping centres, from 140 CFU/m^3 in the Centre 2 to over 700 CFU/m^3 in the Centre 5 (tab. I). The greatest number of airborne mesophilic bacteria (1190 CFU/m^3) was recorded in one of the toilets in the Centre 4.

Table I. Numbers of airborne mesophilic bacteria detected in the toilets of the examined shopping centres [CFU/m^3]
Tabela I. Liczebność bakterii mezofilnych w powietrzu toalet badanych centrów handlowych [jtk/m^3]

	Centre 1	Centre 2	Centre 3	Centre 4	Centre 5
Min	30	50	410	250	350
Max	300	280	870	1190	990
Mean	156	140	652	564	732
Median	120	70	630	470	770
Standard deviation	131.64	114.89	174.70	366.58	274.63

Mean numbers of airborne fungi ranged from 14 CFU/m^3 in the Centre 3 to 130 CFU/m^3 in the Centre 5 (tab. II). Also Centre 5 was the one in which the greatest number of airborne fungi was recorded during this study and it was 220 CFU/m^3.

Table II. Numbers of airborne fungi detected in the toilets of the examined shopping centres [CFU/m^3]
Tabela II. Liczebność grzybów w powietrzu toalet badanych centrów handlowych [jtk/m^3]

	Centre 1	Centre 2	Centre 3	Centre 4	Centre 5
Min	50	10	0	0	30
Max	150	70	50	100	220
Mean	86	30	14	32	130
Median	70	30	10	20	140
Standard deviation	40.37	24.49	20.74	39.62	70.71

The number of airborne actinomycetes in toilets of the examined shopping centres was generally low, with the exception of the Centre 1, where both the greatest mean number and the maximum number of these microorganisms was recorded (mean – 454 CFU/m^3, max – 1140 CFU/m^3, tab. III). No airborne actinomycetes were recorded in the Centre 5, where all values equaled 0 CFU/m^3.

Table III. Numbers of airborne actinomycetes detected in the toilets of the examined shopping centres [CFU/m^3]
Tabela III. Liczebność promieniowców w powietrzu toalet badanych centrów handlowych [jtk/m^3]

	Centre 1	Centre 2	Centre 3	Centre 4	Centre 5
Min	30	0	0	0	0
Max	1140	10	10	10	10
Mean	454	2	4	2	0
Median	350	0	0	0	0
Standard deviation	435.24	4.47	5.48	4.47	0

Mean number of mannitol-positive staphylococci ranged from 4 CFU/m^3 in the Centre 1 to 248 CFU/m^3 in the Centre 5. The maximum number of these microorganisms (i.e. 410 CFU/m^3) was recorded in both Centre 5 and Centre 4 (tab. IV). On the other hand, the mean number of mannitol-negative staphylococci ranged from 8 CFU/m^3 in the Centre 1 to 284 CFU/m^3 in the Centre 5. The maximum number of these bacteria was also recorded in the Centre 5 and it was 400 CFU/m^3 (tab. III).

Except for the Centre 1, airborne *E. coli* was not detected or was detected in very low numbers (tab. V). Mean numbers of these bacteria ranged from 2 CFU/m^3 in the Centre 3 to as much as 186 CFU/m^3 in the Centre 1. This was also the place where the greatest number of *E. coli* was recorded, i.e. 340 CFU/m^3.

Table IV. Numbers of airborne mannitol-positive and mannitol-negative staphylococci detected in the toilets of the examined shopping centres [CFU/m^3]
Tabela IV. Liczebność gronkowców mannitolododatnich i mannitoloujemnych w powietrzu toalet badanych centrów handlowych [jtk/m^3]

	Centre 1		Centre 2		Centre 3		Centre 4		Centre 5	
	M+	M–	M+	M–	M+	M–	M+	M–	M+	M–
Min	0	0	0	40	30	20	120	90	180	220
Max	20	20	60	130	240	370	410	240	410	400
Mean	4	8	28	76	140	248	220	142	248	284
Median	0	10	10	50	150	340	200	130	230	270
Standard deviation	8.94	8.37	29.50	45.06	93.54	156.11	117.26	59.75	104.74	70.21

Table V. Numbers of airborne *E. coli* detected in the toilets of the examined shopping centres [CFU/m^3]
Tabela V. Liczebność *E. coli* w powietrzu toalet badanych centrów handlowych [jtk/m^3]

	Centre 1	Centre 2	Centre 3	Centre 4	Centre 5
Min	70	0	0	0	0
Max	340	10	10	20	20
Mean	186	4	2	4	6
Median	150	0	0	0	0
Standard deviation	127.40	5.48	4.47	8.94	8.94

Mean numbers of mesophilic bacteria detected in swabs from the surface of air outlets from examined hand dryers ranged from 12 CFU in the Centre 1 to 930 CFU in the Centre 5 (fig. 1).

Similarly, the smallest number of fungi detected in swabs was observed for hand dryers in the Centre 1 (i.e. 30 CFU), while the greatest number was recorded in the Centre 5 (i.e. 70 CFU, fig. 2).

On the other hand, Centre 1 was the one, where the greatest number of actinomycetes was recorded in the surface swabs from the air outlet of hand dryers (i.e. 18 CFU) and in the remaining shopping centres, values were very low and did not exceed 2 CFU. These results are consistent with the ones obtained for the air sampling (tab. III, fig. 3).

The mean number of mannitol-positive staphylococci in swabs from hand dryers ranged from 2 CFU in the Centre 1 to 244 CFU in the Centre 3, while the mean number of mannitol-negative staphylococci ranged from 2 CFU in the Centre 1 to 184 CFU in the Centre 5 (fig. 4).

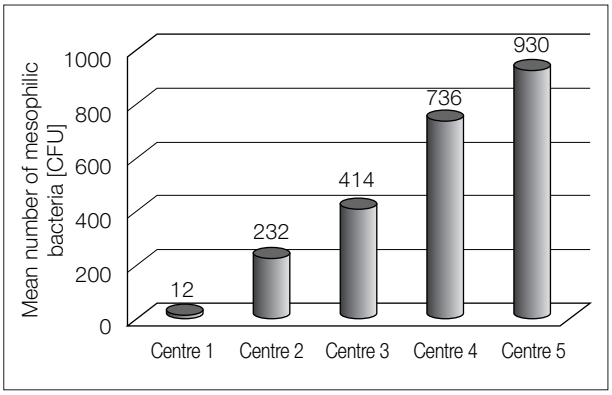

Fig. 1. Mean number of mesophilic bacteria detected in swabs from the hand dryers of each shopping centre [CFU]
Ryc. 1. Średnia liczba bakterii mezofilnych stwierdzonych w wymazach z powierzchni suszarek w poszczególnych centrach handlowych [jtk]

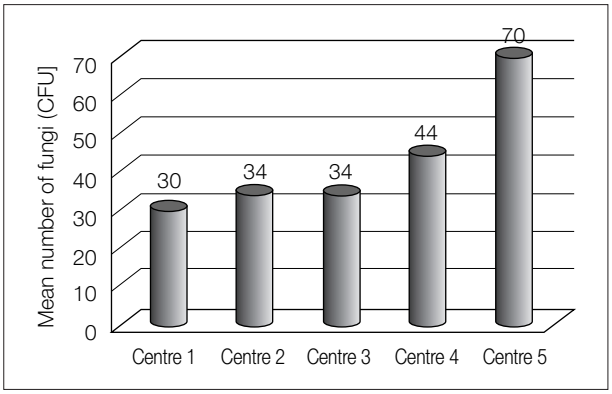

Fig. 2. Mean number of fungi detected in swabs from the hand dryers of each shopping centre [CFU]
Ryc. 2. Średnia liczba grzybów stwierdzonych w wymazach z powierzchni suszarek w poszczególnych centrach handlowych [jtk]

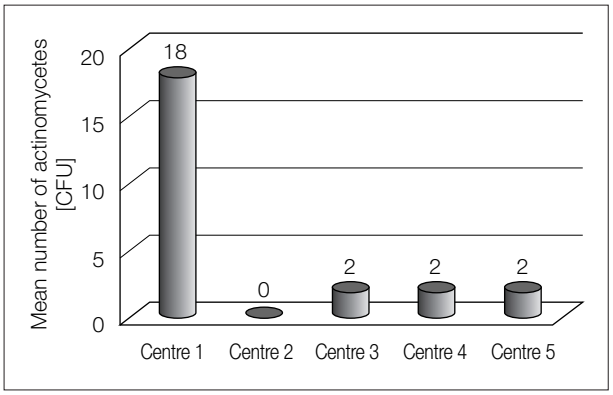

Fig. 3. Mean number of actinomycetes detected in swabs from the hand dryers of each shopping centre [CFU]
Ryc. 3. Średnia liczba promieniowców stwierdzonych w wymazach z powierzchni suszarek w poszczególnych centrach handlowych [jtk]

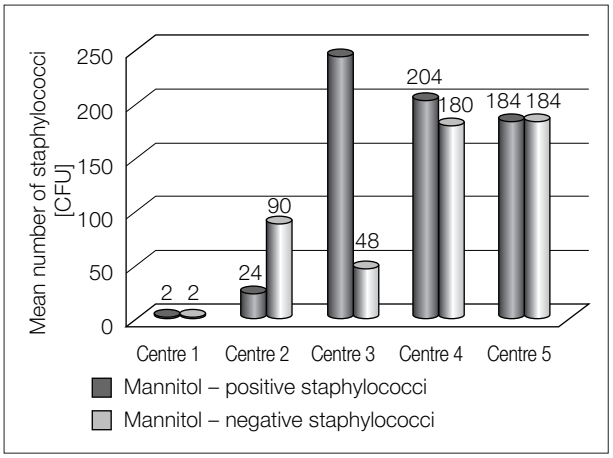

Fig. 4. Mean number of staphylococci detected in swabs from the hand dryers of each shopping centre [CFU]
Ryc. 4. Średnia liczba gronkowców stwierdzonych w wymazach z powierzchni suszarek w poszczególnych centrach handlowych [jtk]

Similarly to the results of air sampling, the greatest number of *E. coli* recorded in swabs from hand dryers, was recorded in the Centre 1, while in the remaining centres, these bacteria were either absent, or recorded in very low amounts (fig. 5).

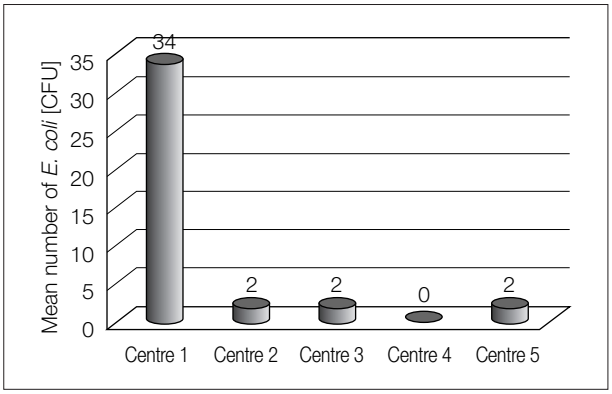

Fig. 5. Mean number of *E. coli* detected in swabs from the hand dryers of each shopping centre [CFU]

Ryc. 5. Średnia liczba *E. coli* stwierdzonych w wymazach z powierzchni suszarek w poszczególnych centrach handlowych [jtk]

The statistical analysis of the results showed that with one exception for the number of fungi in swabs, the differences in the numbers of microorganisms between the examined shopping centres were statistically significant (tab. VI).

Table VI. Results of the analysis of variance concerning the differences in microbial abundance in air and swabs

Tabela VI. Wyniki analizy wariancji dla różnic w liczebności badanych drobnoustrojów w powietrzu i wymazach

Microorganisms	F value (air sampling)	F value (swabs)
Mesophilic bacteria	7.29*	3.95*
Fungi	6.34*	0.87
Actinomycetes	5.39*	6.00*
Mannitol-positive staphylococci	8.79*	5.44*
Mannitol-negative staphylococci	9.52*	4.96*
E. coli	10.08*	3.68*

* – values are significant at $p<0.05$

* – *wartości istotne przy $p<0,05$*

DISCUSSION

The issues related to the personal hygiene, as well as sanitation have been of major concern, even since the ancient times, when the human waste management problems were among the most important ones [7]. Microorganisms, occurring in the air of sanitary premises originate from different sources with people and their sweat or saliva droplets being the most significant [8]. Due to their composition, indoor bioaerosols may cause numerous disease symptoms. It is necessary to remove airborne microorganisms and air ventilation or air conditioning systems are thought to be the best way of accomplishing it; however their efficiency or even cleanliness are not sufficient. As a result, using air conditioning may be responsible for microbial-related health disorders [9].

The number of microorganisms recorded in this study varied between the examined sites, both in the case of air and swab samples. The numbers of airborne bacteria, fungi and actinomycetes were compared with the limit levels provided by the Polish Standards [4, 5]. The concentration of bacterial aerosol exceeded the limit given for unpolluted air (i.e. 1000 CFU/m^3) only once – in the Centre 4. In the remaining cases the air was considered unpolluted. Also, given the fact that the maximum number of airborne fungal cells recorded throughout the study was 220 CFU/m^3 (Centre 5), the air could also be considered as unpolluted.

On the other hand, the concentration of airborne actinomycetes was very high in the Centre 1, where the presence of these microorganisms was recorded in each sample and threshold values for heavily polluted air were exceeded in almost all samples. The minimum value recorded in this centre was 30 CFU/m^3 which classifies the air as averagely polluted. In the remaining sites actinomycetes were either not detected, or they were detected in numbers not exceeding 10 CFU/m^3. The admissible limits of airborne actinomycete concentration are very low and the threshold for unpolluted air is set at 10 CFU/m^3, while the concentration of more than 100 CFU/m^3 classifies the air as heavily polluted [4]. One of the reasons for such low limits is the fact that even very low concentrations of these microorganisms can cause allergic reactions [10].

Considering the number of mannitol-positive and mannitol-negative staphylococci, the air in the Centre 1 was classified either as unpolluted or the pollution was average (tab. IV). However, the numbers of these bacteria were much higher in the remaining shopping centres, as the air pollution was average or heavy in the Centre 2 and in the Centres 3, 4 and 5 the pollution was heavy. Similarly the numbers of both mannitol-positive and mannitol-negative staphylococci recorded in surface swabs from the hand dryers in the Centres 3, 4 and 5 were the highest and ranged from 40 CFU to 490

CFU. Those numbers were similar to the ones recorded in surface swabs from jet air dryers by Redway and Fawdar [3], as they isolated 127 CFU of different staphylococcal species from inner surfaces of the dryers, some of which turned out to be *S. aureus*. However, the concentrations recorded in our study still do not pose a direct threat to human health, as the infective dose of e.g. *Staphylococcus aureus* reaches 10^3–10^8 cells [11].

Although the number of airborne *E. coli* is not regulated, these bacteria fall within the risk group 2 of organisms that can cause illness in people [12]. In four out of the five examined shopping centres *E. coli* were hardly detected. However, in the Centre 1 they occurred in quite high numbers, i.e. ranging from 70 to even 340 CFU/m^3 of air and from 10 to 100 CFU in swabs, with the mean number of 34 CFU. Similarly high number of airborne *Enterobacteriaceae* was observed by Budzińska et al. [13] within the municipal sewage treatment plant. Also Redway and Fawdar [3] detected the presence of different *Enterobacteriaceae* species (i.e. mean number of 85 CFU with the range of 0–1429 CFU) in surface swabs from jet air hand dryers, including *Escherichia coli* (26 isolates in total). Our observations are not too surprising, as toilet flushing is one of the reasons for airborne transmissions of fecal bacteria, including *Escherichia coli* [14]. Even though the infective dose of *Escherichia coli* is relatively large (more than 10^5 CFU) [15], the enterohemorrhagic strains of *E. coli* (e.g. O157:H7) require an infective dose of only about 10 CFU [16].

CONCLUSIONS

The presented study showed that in terms of mesophilic bacteria and fungi the air in toilets of all shopping centres was not contaminated. In the case of actinomycetes the air was heavily polluted only in the Centre No. 1. On the other hand, very high concentrations of both mannitol-positive and mannitol-negative staphylococci were recorded, indicating heavy pollution in almost all shopping centres. Another significant observation was that the presence of *Escherichia coli* was detected both in the air and in the swabs from the hand dryers. The results indicate that the legal standards fully regulating the concentration of all microbial groups, including pathogens, are necessary in order to make the toilet users aware of the threat and to determine the levels, above which corrective actions will be required, such as: introducing more efficient ventilation or replacement of equipment. Finally, it can be concluded that using hand dryers does not threaten human health.

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Address for correspondence:
Anna Lenart-Boroń
Department of Microbiology
University of Agriculture in Kraków
Mickiewicza ave 24/28
phone no.: 126624095
email: a.lenart-boron@ur.krakow.pl