

# EDUKACJA

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## Editorial

Dear Readers,  
the first issue of Biological and Environmental Education is published in English. In 2017 this tradition was sustained by additional financial support acquired thanks to great effort of colleagues from Institute of Education Research. I would like to express my gratitude to Ms. Karolina Kwiatosz and Dr. Marcin Trepczyński. Without their support, this may not happen!  
In this issue we have several interesting scientific review articles to offer. Articles entitled “Wild relatives of potato or less known representatives of the nightshade family” or “Tasty blueberries? Not this time. Everything about poisonous plants in Polish gardens and forests” are reviews that explain well-known plants in Poland to our readers from other countries. For others, probably more global problems might be interesting, e.g. “The idea for biobank”. In this article author explains legal issues regarding collecting

and modifying human biological material. Without doubt, it is emerging problem in modern medicine and life sciences. For those interested in teaching of biology or chemistry, we propose article entitled “The periodic table of elements in chemistry textbooks for junior high-schools”. This is very detailed and interesting review on how periodic table of chemical elements are presented in a number of Polish textbooks. Authors carried out tremendous work enabling it to compare with similar reports regarding other countries. “Educational computer games in geography” presents games useful in teaching of geography. However, I believe that it might be also an

inspiration for teachers of other subjects how to employ IT techniques into teaching. Enjoy first issue of our quarterly journal published in 2017. I also invite you to publish your papers in Biological and Environmental Education. For non-Polish authors we provide an opportunity to publish their articles in English in each issue.

Kind regards,  
Takao Ishikawa

# Tasty blueberries? Not this time

## Everything about poisonous plants in Polish gardens and forests

Krzysztof Bukowski, Irmina Wojciechowska

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### Summary:

Among the plant species occurring naturally in Poland, apart from edible and completely harmless to humans, there are also poisonous ones. Without specific knowledge it is not easy to recognize and distinguish them. To make it even more difficult, those plants are able to develop visually tempting fruits. Such species are the topic of this article.

Plants are toxic due to the poisons they contain. Toxicity is therefore a natural method of defense against being eaten, which directly affects the survivability of species. Sometimes slight contact with a toxic plant is enough to feel detrimental consequences. In terms of the structure, toxins belong to various organic compound groups, e.g. glycosides, alkaloids or they can be derivatives of certain organic compounds. Some of them are harmful even in tiny amounts, like in a yew's case, others- in small doses are herbal medicines known for centuries (as black elder or lily of the valley) and wreak havoc in human organisms after overdosing.

**Key words:** phytotoxins, poisonous plants in Poland, biologically active substances

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### Introduction

Summer, like no other season of the year, inclines to excursions in the bosom of nature. While travelling the length and breadth of Poland, we meet countless number of fauna and flora species. We would rather expect that a walk through the woods or a visit to the city park does not carry any risk. The chance that we meet any predators or poisonous animals on our way is negligible. Plants are rarely identified as a potential danger. They draw our attention by their attractive appearance, color and smell. The society in general is not aware of the threats to the health and life resulting from the accidental contact with toxins contained therein.

First of all we should ask ourselves why plants produce toxic substances. Well, the production of toxins is just one of the defense mechanisms against herbivores. Plants in the course of evolution have developed different ways allowing deterring herbivores. They required adoption of their external structure and physiology.

Defense mechanisms of plants can be divided into mechanical/physical (for instance spines and thorns) and chemical (which are the subjects of our interest in this article). Chemical defense mechanisms are responsible for the synthesis and storage of certain organic compounds produced in the specific metabolic pathways. These are the so-called secondary metabolites, whose name originates from the fact that they are not essential for growth and development, but they have

many other applications. They serve to deter herbivores (repellents), e.g. by giving unpleasant odor or taste to vegetable tissues or irritating alimentary tract after their consumption (Mazid 2011). Secondary metabolites can belong to any group of organic compounds, but these are most often alkaloids (basic nitrogen-containing organic compounds) and glycosides (carbohydrate derivatives containing a non-sugar group).

The construction of toxins and their location in plant tissues differs. The possibility of accidental contact with the toxin through the skin or ingestion explains why small children and pets that are the most vulnerable to poisoning, although it happens that the victims of plant toxins are also adults by their carelessness or lack of knowledge about the collected herbs or fruit. Consumption of parts of toxic plant results in specific symptoms shown by internal organs and usually involves gastrointestinal, respiratory and nervous systems. Dermal exposure to toxic compounds leads to burns, skin allergies and irritation. In extreme cases, poisoning by plant toxins can also lead to death, especially if respiratory and nervous systems are damaged.

Hereinafter we are going to present a number of poisonous berries commonly found in gardens, parks and roadless tracks across Poland. Common characteristics to the selected plants is their prevalence in the territory of Poland and ability to produce fruit in the form of berries, as well as the presence of compounds harmful and toxic to human being in their tissues.

### English/European yew

**English/European yew**, *Taxus baccata*, is an evergreen conifer, famous for its longevity (Fig. 1); we have heard of 100-year old individual specimen. It is rare in Poland (just in a little bit more than 200 stations); however it takes a large area, mostly in the mountains.

The yew stock is falling down partly due to harvesting wood prized especially for hardness. This happens even though yew is formally under protection since the statute issued in 1423 by Władysław Jagiello (!) (Piękoś-Mirkowa, Mirek, 2003). Despite fading number of yew positions in forest areas, it is often present in parks and home gardens because of its decorative properties. Noteworthy are its characteristic red, cuplike arils surrounding the seeds. Arils, as the only part of the plant, do not contain taxin, a poisonous alkaloid, although the seeds inside are highly toxic (Bryan-Brown, 1932). The mechanism of action of taxin on the human body is not

fully known. It probably involves the system of sodium-calcium management (Thuret-Carnahan, 1985) and blocking mitosis and meiosis by interfering with the process of forming the karyokinetic spindle). Anyway, we know that it has the greatest impact on the heart and liver.

First symptoms of poisoning occur after approx. 1-2 hours after ingestion and begin with heart disorders resulting from the problems with the electric conduction system and consequently too low or too high heart rate. They followed by symptoms associated with the alimentary system: abdominal pain, diarrhea and vomit-

ing (Kobusiak-Prokopovich et al., 2016). Damage to the circulatory system can cause disorders in the nervous system, such as aphasia (loss of speech), weakness, and paralysis of the respiratory center. Death may occur due to hypoxia or circulatory arrest (Wilson, 2000).

For many centuries ivy has had a symbolic and religious meaning. As an evergreen it was symbolizing eternity and immortality. An ivy wreath was originally used to decorate poets in Greece, and only later was replaced by laurels. Moreover, these same Greeks and then the Romans adorned wine gods – Dionysus and Bacchus. It was even believed that it has magical properties allowing to separate wine from water (Piękoś-Mirkowa, Mirek, 2003).

### *Hedera helix*

*Hedera helix* is also interesting in the chemical point of view because it contains a lot of organic compounds, such as saponins, phenols, alkaloids and organic acids (Sarva, 2001). Brew made of it has been known for years for its healing properties (mainly to the upper respiratory tract as it is a relaxant to smooth muscle). The extract is used in anti-cellulite cosmetics due to the presence of saponins that lower surface tension, break down fat and improve skin absorption (Sainio, 2001). However, some chemicals contained in ivy are toxic. Its blue-black fruit resembles a blueberry, but contrary to it, it is not suitable for consumption. It is hard and extremely bitter and contains a high concentration of terpene saponin ( $\alpha$ -hederin and hederakoside C) in which the non-sugars part is hederagenin. Consumption of more ivy fruits causes digestive (diarrhea and vomiting) and nervous (hallucinations, impaired consciousness) issues. In turn, contact with the damaged plant tissue may cause skin irritation by allergen containing faltarinol, alcohol having some anti-tumor properties (Burda, 1998).

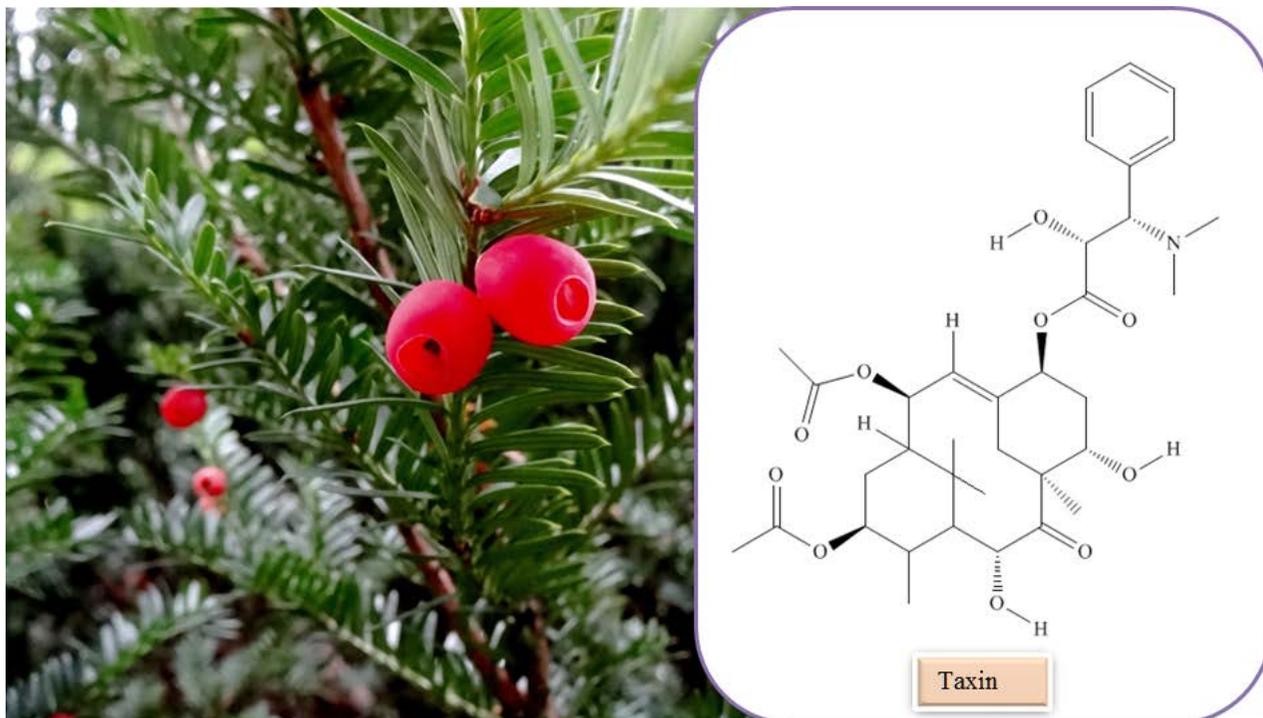


Fig. 1. English/European yew

**English ivy**, *Hedera helix* L., (Fig. 2) is an evergreen vine with leaves with distinctive, triangular flaps.

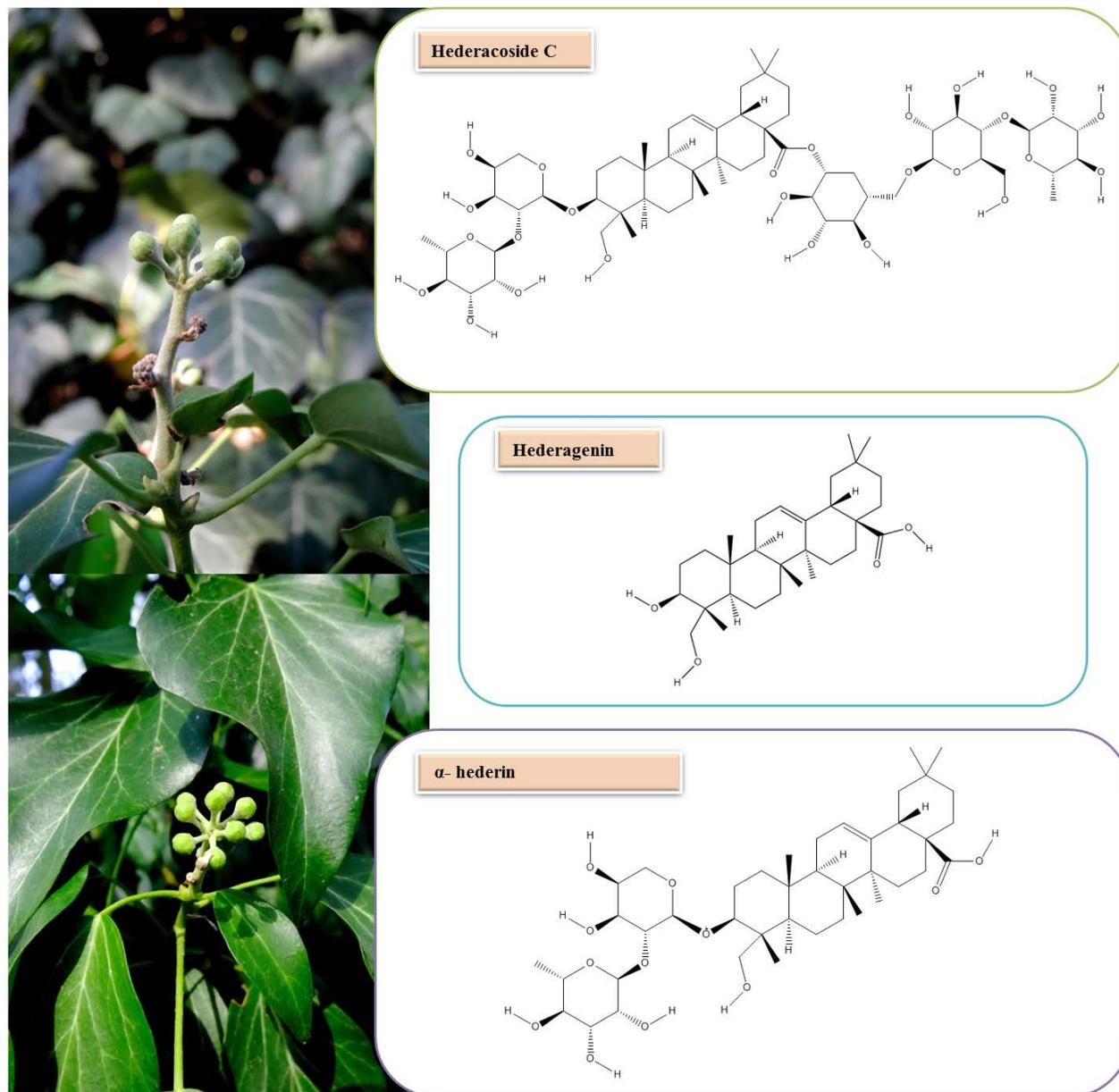


Fig. 2. English ivy

## Wild elderberry

**Wild elderberry**, *Sambucus nigra*, popularly known in Poland as ‘hyčka’, is a shrub having no special soil requirements, common in the meadows, roadless areas or across forest paths (Fig. 3). Its characteristic black berries gathered in pendulous umbels are dainty of birds. They are also recognized as extremely useful in folk medicine and folklore (Atkinson, 2002).

At the time of the Druids elderberry bush was a holy tree. It was believed that any injury done to the brush would bring misfortune to the home of a man who misbehaved towards the sanctity of this plant (Ziółkowska, 1988). This was reflected in the fairy tale of Hans Christian Andersen “Elder-Mother” (<http://www.andersen.sdu.dk>). In addition, it was believed that a short nap un-

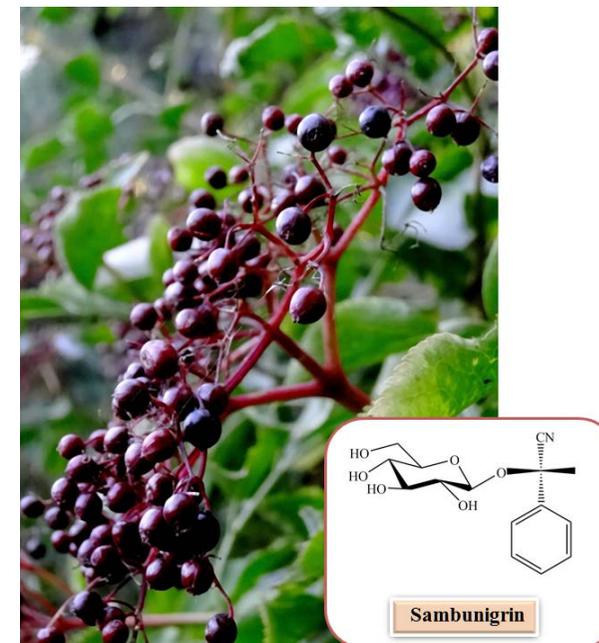


Fig. 3. Wild elderberry

der an elderberry bush leads straight to a meeting with the King of the Elves, and we can easily guess that hardly anyone escaped with his life in such event. Also J.K. Rowling, author of the Harry Potter books, knew the magical nature of this tree making elderberry wands most powerful.

The times of Christian culture were not favourable for this shrub. Elderberry was dethroned along with pagan deities as supposedly constituted building material of Jesus' cross. Also Judas Iscariot hanged himself on the elderberry bush (Grieve, 1931).

This bad reputation has not affected, however, the recognized position of elderberry in folk medicine. Nowadays juice made of elderberry fruit is a well-known remedy against colds, flu, cough, throat pain, inflammation and rheumatism. It is believed in Silesia that the branches of elderberry thrown into the pigsty would protect pigs from any plague. Root extract was once used for dying hair to tarry color and flower umbels fried in batter were quite a dainty for young and old. Flowers consumed on the St. John eve day (or perhaps on Pagan Sobótka) had to provide health for the following year (Ziółkowska, 1988).

Elderberry fruit is suitable for consumption after prior heat treatment. Berries can be fried or cooked, and preserves of them taste perfectly seasoned with honey and lemon. Eating fruit straight from the bush or drinking raw juice is not recommended as it can lead to poisoning, manifested by nausea and problems with the digestive system, dizziness, circulatory problems and even loss of consciousness.

The most important alkaloids of elderberry are sambucinum and sambunigrin. Sambucinum is an alkaloid with laxative properties and does not constitute a threat to human health. Sambunigrin in turn belongs to the group of cyanogenic glycosides (Braun, 2015). This means that the molecule of the compound is made

up of two, sugar- and cyanohydrin parts. As a result of the destruction of the cellular structure of the plant tissue during digestion, cyanogenic glycosides previously stored in the vacuoles are hydrolyzed, and the resulting cyanohydrin is reduced to ketone derivative with the release of hydrogen cyanide molecules, i.e. prussic acid. It is responsible for the toxic effects observed after the consumption of immature and thermally unprocessed elderberry berries. Hydrogen cyanide delivered into the body by inhalation or skin or after being consumed dissociates into cyanide ions, showing strong affinity to cations of iron in the hemoglobin molecule. This results in inhibition of an enzyme responsible for the processes of cellular respiration called cytochrome oxidase. Blocking of the enzymatic system results in interfering with the release of oxygen from the oxyhemoglobin in the tissues, and characteristic in this case is the bright red color of venous blood. The first symptoms of poisoning are: headache, tinnitus, shortness of breath, abnormal blood pressure and heart rate. Developing intoxication leads to coma or death (Dellagrecia, 2000).

Wild elderberry is easily confused with *Hebda lilac*, because the two species differ only slightly by the appearance of leaves. *Hebda* elderberry fruit intake leads to severe poisoning despite the heat treatment since the toxins they contain do not decompose under the influence of temperature (Kremer, 1996).

### Common snowberry

**Common snowberry**, *Symphoricarpos albus*, is a shrub originating from North America, imported to Europe in the nineteenth century due to its undeniable decorative properties (Fig. 4). This bush has alternate bluish green leaves, white-pink bell-shaped flowers and distinctive white berries; it is also easy for shaping. These features caused that the snowberry is often used as an

ideal material for hedges and you can easily encounter it in city parks and home gardens (Seneta, 1997).

Expansiveness shown by snowberry caused its spread also to undeveloped land and wasteland due to her limited requirements for sunlight and soil qualities; although it must be mentioned that she likes limestone, alkaline mountain soils (Haberer, 2008). Snowberry is perfect for the remediation of the land, even those contaminated with oil derivatives (Fedkenheuer, 1980).

White snowberry fruit is loved by birds that contribute to spreading of this plant on wasteland. Protein-rich berries are a delicacy for sheep, cattle and wild, small mammals, which is especially important in winter because these berries do not fall down off the bushes along with first frost, thus becoming the additional source of nutrients during this difficult season for animals (Holeček, 1987).

Native Americans used the mashed fruit of snowberry as a hair shampoo and an antiseptic agent for superficial wounds and skin lesions. Flexible wood of the shrub was used to manufacture foreshafts and the bark of the shrub was used to manufacture foreshafts and the bark of the shrub as a remedy for venereal diseases (Halverson, 1986). It was found, however, that the consumption of snowberry fruit by humans resulted in symptoms of poisoning. Typical symptoms occurring after the consumption of snowberry fruit are vomiting, diarrhea, chills, and sometimes loss of consciousness. In extreme cases, it can also lead to collapse into a coma. Toxic effects are the result of saponins, it is macromolecular compounds from the group of glycosides (derivatives of sugar and saponin, which is an alcohol) (Gilbert, 1995). Saponins are able to lower water surface tension thus acting like soap; they also have antibacterial, antifungal, antiviral and protozoocidal properties. At higher doses, however, the effect of the intake of saponin potent symptoms of gastrointestinal irritation of the mucous membranes. After entering blood, they can lower

blood pressure and cause hemolysis of erythrocytes. In addition, saponins as antagonists to vitamin D, causing a decline in bone mineralization. Severe poisoning results in impaired breathing.

Snowberry berries also contain calcium oxalate crystals, i.e. so called raphides. They are responsible for irritant effect that occurs after ingestion of the berries, as well as intense burning and swelling of the mucous membranes. In extreme cases, swelling of the larynx can lead to death by suffocation (Haratym, 2014).

The last group of compounds which should be mentioned is the alkaloids, especially chelidonium, a derivative of  $\alpha$ -phenanthrene. Its influence on the nervous system is similar to that exerted by morphine, but much weaker. In contrast to morphine, the compound does not cause, however, feelings of euphoria. Chelidonium is a compound of cytotoxic (exhibits toxicity to the cells of the body, because due to solubility in the cholesterol it penetrates cell membranes) because it inhibits mitotic cells. It is also responsible for burning sensations

and nausea. After the consumption of berries narcotic effects can be also observed. The presence of the chelidonium in the snowberry material is scant; however, we should recall here the thought of Paracelsus – *Dosis facit venenum* (only the dose makes the substance not poisonous) and bear in mind different individual sensitivity in response to the toxin.

Two other alkaloids characteristic for snowberry, loganin and secologanin, belonging to irydid glycosides, do not have toxic but only anti-inflammatory properties (Sadowska, 2004).

### Savin juniper

One of the few glacial relics, dating from before the Holocene era is *Juniperus sabina*, popularly called **savin juniper** (Fig. 5). The Sabins, an ancient Italic tribe after which it took its name, used the branches of this tree as a magical artifact that protected them against unplanned pregnancy (Ziółkowska, 1988). During the Ice Age, when continental ice sheet reached the Carpathians, savin was able to make the expansion to the south and survived there to modern times in the area of today's Pieniny on only a few positions (Hryniewiecki, 2008). Soil conditions played a major role in the acclimatization of savin: alkaline limestone substrate combined with well-permeable claystone and sandstone and volcanic rocks. Savin can be seen in its natural environment in the Pieniny National Park: in the area of the gorge of the Leśnicki Stream and Dunajec River Gorge, on such rock formations as Cukrowa Góra or Facimiecha (Mirek, 2008).

Pieniny, which used to be home to savin, now have only a few positions of its occurrence. This is the man and wasteful exploitation of savin juniper we can blame for this state. Savin juniper used to play an important role in folk medicine, where, despite its unpleasant

Fig. 4.  
Common  
snowberry

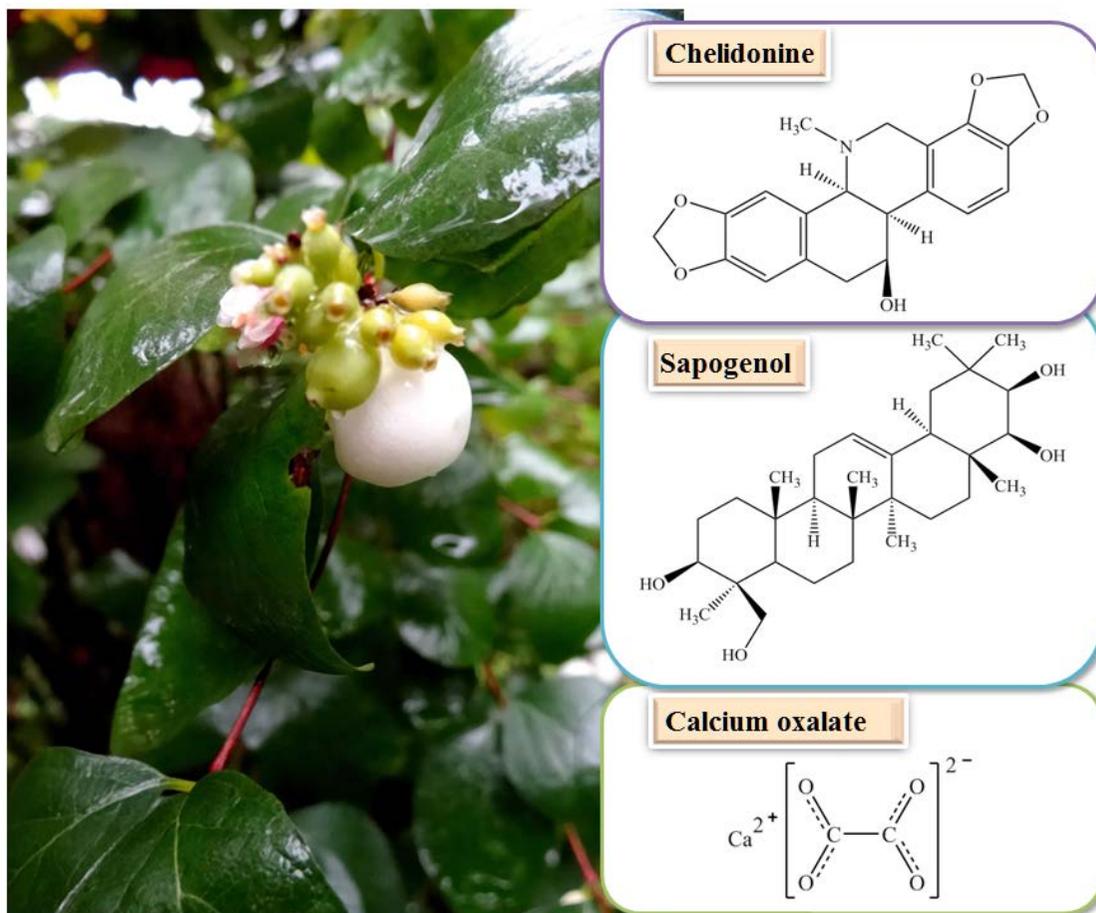
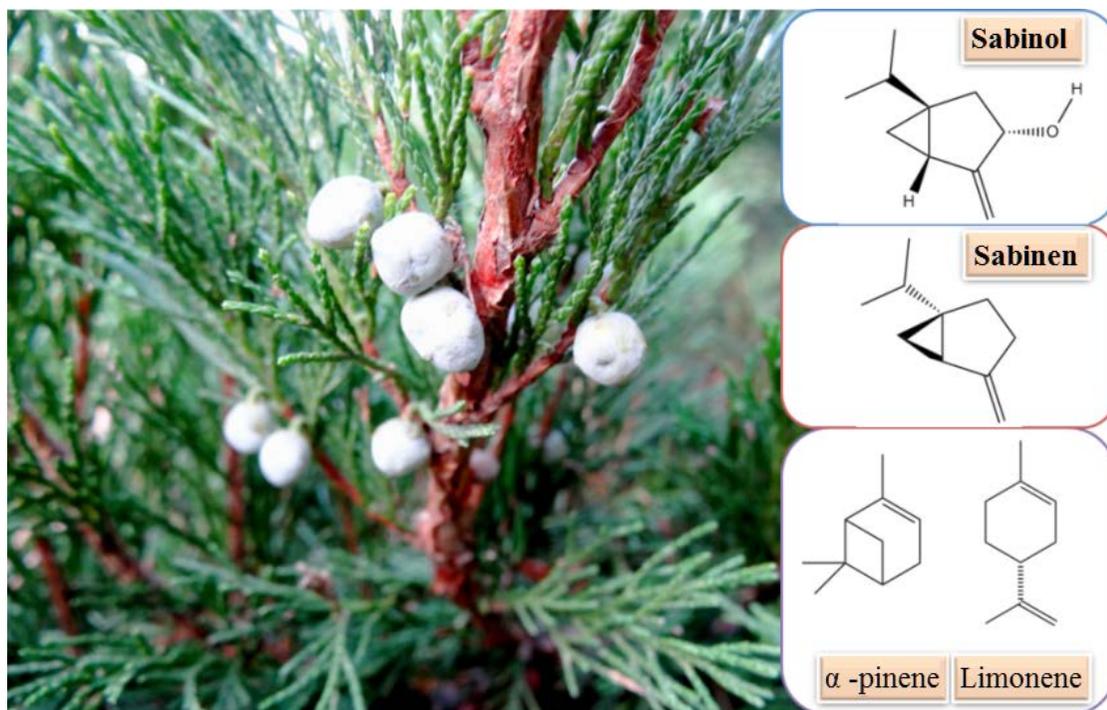


Fig. 5. Savin juniper



smell, was used as an abortifacient (causing high mortality rate in women), antirheumatic, diuretic, anthelmintic mean, also helpful in removing warts (Bohne, 2008). Oil from needle leaves of savin was used as an insecticide and repellent and found application in the perfume industry. Furthermore, people used to make canes savin thought to have the power to ward off domestic demons, vampires and strigoi. A similar habit of wandering with savin canes was also present in the Alps, but nothing is known about its magical connotations (Ziółkowska, 1988). The depletion of natural population of savin juniper results in entering it to the World Red Book of Endangered Species and onto the Red List of Polish Plants and Fungi as a rare and endangered species, although it is a popular and undemand-

ing shrub commonly present in parks and gardens (Mirek, 2008).

Based on the  $LD_{50}$  parameter ( $LD_{50}$  is statistically calculated median lethal dose for a specific animal species), savin juniper is classified as moderately toxic. Due to the poisonous effect of savin special care should be taken not to confuse it with juniper which is used for the production of aromatic alcohols and seasoning meat. Exposure of the crushed parts of the plant to the skin or mucous membrane brings about the irritation or inflammation which may even result in necrosis. Consumption of green parts savin leads to severe poisoning, manifested symptoms of gastrointestinal (nausea, vomiting, diarrhea, abdominal pain), renal failure and hematuria and dysfunction of the nervous system

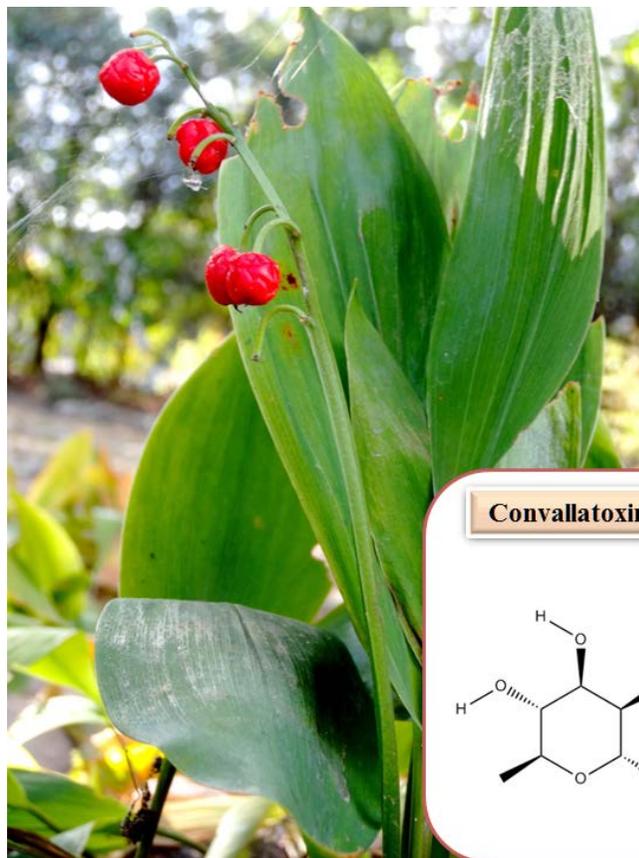
(paralysis, loss of consciousness, breathing disorders). Substances contained in savin juniper lead to congestion of the blood vessels in the abdomen and hence it is an abortifacient (Altmann, 1998). It is believed that the only 6 drops of oil obtained from savin juniper can kill an adult person within 10 hours.

Active ingredients in savin juniper essential oil are mainly monoterpenes: both  $\alpha$ -pinene (a compound of the characteristic odor of pine) and limonene (with intense fragrant of lemons) are widely used in the perfume industry. However, both these compounds are also highly irritant to humans and can cause allergic reactions. These substances are also responsible for the properties of insecticides and insect repellents. Isomers of cadinene and sesquiterpene present in the oil, responsible for the characteristic pungent smell of savin juniper, are not harmful to the human body. Another group of compounds which are derivatives of sabinen acid are sabinen, sabinol and sabinon. They are toxic compounds that can cause disorders of the digestive system, the nervous system, bleeding and kidney damage. The water- and alcohol soluble oil helpful in the removal of warts, can also cause necrosis of the epidermis. Sabinol is, however, a source of odor released after grinding berries or needle leaves of savin and referred to by some people as similar to the smell of cat urine (Dweck, 2009).

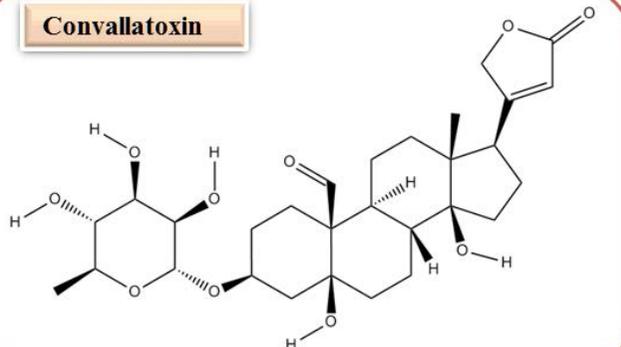
### Lily of the Valley

**Lily of the Valley**, *Convallaria majalis*, perennial known for its small, white flowers and sweet scent, is easy to grow and has low requirements for soil (Fig. 6). It is commonly propagated vegetatively by shallowly buried rhizomes, which facilitates the creation of large colonies, rarely by seeds enclosed in a red berries (Altmann, 1998).

Fig. 6. Lily of the Valley



Convallatoxin



Thanks to its aesthetical properties (falling flowers and elongate leaves mentioned before) lilies of the valley have symbolized the purity of brides for centuries. In France, the first day of May is called the Fête du Muguet (Lily of the Valley Day), to commemorate the events of the sixteenth century, when the French King Charles IX got “lucky” lily of the Valley bouquet (<https://visitnormandy.wordpress.com>). In folk medicine, lily of the valley is known as a remedy for many diseases, e.g. heart issues or swelling. Once it was considered as a symbol of doctors.

This is due to the content of approximately 40 recognized cardiac glycosides (i.e. cardenolides) (Rumińska, 1990) of which the most important is convallatoxin. Its non-sugar part is the steroid moiety of an unsaturated lactone (Kittleson, 1998). Convallatoxin is present in the whole plant, including the berries.

Cardiac glycosides cause inhibition of sodium-potassium pump in myocardial cells, resulting in an increase in intracellular sodium and calcium ions. This in turn translates into increased strength of contraction of the heart muscle while decreasing the frequency of

operation (Atkinson, 2008). This causes that the lily of the valley extracts are used to treat heart failure, cardiac or supraventricular tachycardia. The advantage of drugs based on cardenolides of lily of the Valley is that they are not cumulative (Sarva, 2011), which means they are safe for long-term use, also in elderly.

However, homemade specifics, as well as the consumption of unprocessed parts of lily of the valley, carry some risk – you cannot determine the content of active substances in the preparations made, which may result in overdosing. Poisoning begins with gastrointestinal symptoms, namely diarrhea and nausea (Yang, 2012). Then toxins affect vision (seeing yellow) (Bauman, 2006), and confusion and hallucinations occur. The overdose makes heart rate drop below 60 beats per minute (i.e. bradycardia), and in extreme cases may also result in atrial fibrillation and cardiac arrest (Altmann, 1998).

## Conclusion

The world of plants is extremely rich. The beauty of plants is demonstrated in the shape of their leaves, shape and color of inflorescences, the smell they spread, and the form of fruit, often tempting and resembling those that we are used to seeing on our tables. The true mystery of the world of plants, however, lies in the chemicals contained in the plant tissues.

We do not have to go on a trip to the tropics to meet a plant which can be a threat to us. Just go to the forest, the garden or the nearby park. Exposure to a toxic substance usually occurs through the skin or by ingestion. Poisoning occurs mostly as a result of swallowing colorful berries, looking attractive to us. The observed toxic effect depends only on the content of toxic substances in the consumed plant tissue and the sensitivity of individual organism. Keep in mind that a small dose

may have healing properties but when consumed in excess can lead to severe poisoning. What's more, each of us has an individual sensitivity to chemicals; a few innocent looking fruits can cause vomiting to one person and may be fatal to another one. So what should you do if you experience symptoms of poisoning in people around you? First of all, ensure safety for yourself and the affected person and determine whether she/he is conscious and breathing and break contact with the poisonous substance. It is also necessary to call for help and while waiting for an ambulance trying to determine what caused the poisoning. Also, do not leave the injured person until the aid arrives.

So this why it is worth checking to which species the plant picked fruit belong. Use a plant atlas or a tourist guide. You may pay high price for your mistake.

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# Roundup – pros and cons of super herbicide

Magdalena Błaszak

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## Summary:

The spread of plant protection products (pesticides) in the environment is undeniable fact. Only agricultural products from farms carried out in the organic system (natural-origin insecticides are acceptable and natural methods to combat weeds are applied in such cases) are inherently free from the presence of chemicals. According to a current scientific knowledge and the legislation, the presence of pesticides in agricultural goods and food should not be alarming, provided that the level of pesticides does not exceed the established maximum permissible values (e.g. for cereals it is the range from 0.1 to 20 mg/kg; for sugar beet 15 mg/kg; for fruits, root vegetables and legumes 0.1–0.5 mg/kg). Is the legally recognized presence of synthetic chemicals in food safe for humans and the environment? The aim of the study is to present empirically documented risks, and profits resulting

from the massive use of pesticides, using the example of herbicides with glyphosate (commonly known under the trade name Roundup). Discussion upon the impact of herbicides with glyphosate on living organisms applied the results of research published in peer-reviewed worldwide journals. There is no other common herbicide (containing active ingredient in a form of glyphosate), which inspires much controversy as Roundup and other glyphosate herbicides. Extreme opinions of scientists, farmers and consumers of agricultural products, divided society into two groups: the supporters and the opponents of this preparation. By analyzing various aspects of glyphosate spread within the environment, authors of this work sought to get to the source of conflicting opinions.

**Key words:** plant protection means, glyphosate, health safety of food

fertilizers applied in specific doses and conditions. This system is not as efficient as the conventional one and therefore products of this type are more expensive (Kuś and Stalegna, 2006; Frąć et al., 2011). The integrated system of growing plants can be treated as a compromise between the two previously mentioned (described in a nutshell) extreme cultivation systems. It combines the ideas of mass production that is economically justified, while simultaneously minimizing the environmental burden caused by chemicals (Zimny, 2007).

Taking under consideration the widespread pollution of the environment and food from plant protection products as well as the questionable health safety of certain pesticides, the Commission quite clearly accepted a policy of withdrawal from massive use of pesticides. An obligation to apply the principles of integrated crops protection by all farmers have been introduced in the European Union countries since 2014 following the provisions of Directive 2009/128/EC and Regulation No. 1107/2009/EC. Integrated crops protection is a series of agricultural treatments that prevent excessive growth of pests and weeds, using only non-invasive biological methods (Matyjaszczyk, 2012). However, is this concept reflected in farm operation, and do farmers understand the need of protecting the environment and consumer's health? Other questions arise as well, as whether farmers receive substantial support within the implementation of integrated crops protection on their farms, or if the market offers bio-preparations that can replace pesticides?

## What are glyphosate and Roundup and what they are used for

Each pesticide (or plant protection product) consists of at least one active substance that is devastating for a broader or narrower group of organisms burdensome

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## Introduction

There are three basic systems of growing crops: conventional, organic and integrated. The first one often applies to large cultivation areas and is based on the use of intensive mechanical and chemical treatment and the philosophy of getting high and satisfactory yields with the minimum of work input. Pesticides are often used automatically only to prevent potential yield loss (Fig. 1). Ecological systems of cultivation aim to produce crops without the use of a wide range of plant protection products, based solely on a natural ecological phenomenon occurring in agrosynthesis and biopreparations containing natural ingredients and natural organic



Fig. 1. Aerial spraying of crops using pesticides to eliminate pests or weeds

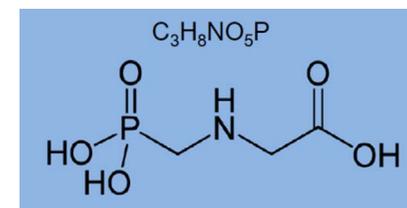
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in agricultural production (e.g., insects, weeds, snails or fungi). Glyphosate is one of many synthetically produced active ingredients of pesticides. Roundup is the trade name of a pesticide containing glyphosate (Biziuk, 2001; Praczyk and Skrzypczak, 2004). There are many herbicides (pesticides designed to eliminate weed) that contain glyphosate (e.g. Avans Premium 360 SL, Glifocyd 360 SL, Klinik 360 SL, Kosmik 360 SL, Taifun 360 SL, Roundup® 360 SL, Roundup Max 2). Herbicides with glyphosate (the first one was called Roundup®) were introduced to the market by Monsanto, an American company, in 1976. The company is still the most important manufacturer and distributor of plant protection products and sells them on a massive scale (close to one million tonnes per year). Monsanto's patent for the use of glyphosate in manufacturing total herbicides expired in 2000, which means that other companies can sell their own herbicides based on that substance. Thanks

to the commercialization of genetically modified crops (with a built-in gene that is resistant to glyphosate, e.g. RR Soy) Monsanto annually gains multi-billion profits from the sales of its products (USD) (Lisowska and Chorąży 2011, Steinmann et al., 2012; Kwiatkowska et al. 2013).

Glyphosate is a phosphoric acid derivative combined with glycine (Fig. 1). In order to enhance the effectiveness of glyphosate, modification of its cell is applied. It is present in the formulations in the form of acid or ammonium, sodium and potassium salts, isopropyl salt and trimethylsulfate salt. In addition to the active substance, Roundup formulations (and other ones containing glyphosate) contain substances that facilitate passage through cellular membranes of plants (so-called adjuvants) and other commercially confidential components. Two greatest benefits having impact on the popularity of glyphosate pesticides are their versatility

Fig. 2. Schematic structure of the glyphosate molecule



(it works on most weeds and its effectiveness depends on the dose) and a wide range of applications (fields, orchards, forests, stubble wasteland, gardens) (Różański, 1992; Praczyk and Skrzypczak, 2004) (Fig. 2).

Upon the contact of herbicide with a sensitive part of a green plant, its growth is suppressed already on the first day. Glyphosate inhibits the activity of an enzyme, i.e. EPSP (5-enolpyruvylshikimate-3-phosphate) synthase, which is a key biocatalyst of the shikimic pathway responsible for the biosynthesis of aromatic amino acids (tryptophan, tyrosine and phenylalanine). Due to the deficiency of aromatic amino acids in the cell, plants die out. These amino acids play an important role in plant metabolism, as they are part of structural, reserve and enzymatic proteins and undergo further transformation generating different metabolites that are important for the functioning of the plant (e.g. phytohormones, lignin precursors, flavonoids, phenylcarboxylic acids, cinnamic acid derivatives). Glyphosate interferes with the process of photosynthesis, thus lowering the concentration of chlorophyll in the leaves of plants; this is destructive to other elements of metabolism and ultimately causes withering (Pieniążek et al., 2004; Kwiatkowska et al., 2013) (Fig. 2). Farmers use the effect of plant dying with the use of glyphosate to accelerate uniform cereal growth (desiccation). Before harvest, they spray the field with herbicide to dry the green biomass and make it easier to harvest (Wróbel, 2006; Jaskulski and Jaskulska, 2011). However, as a consequence, grain with glyphosate is transferred to consecutive produc-

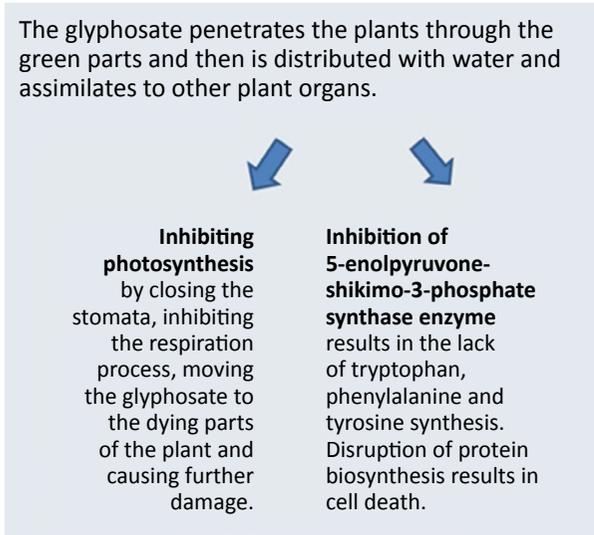


Fig. 3. The mechanism of glyphosate activity in the plant  
Source: own elaboration based on Kwiatkowska et al., 2013.

tion steps, eventually reaching the human and animal body (bread and animal feed are most polluted).

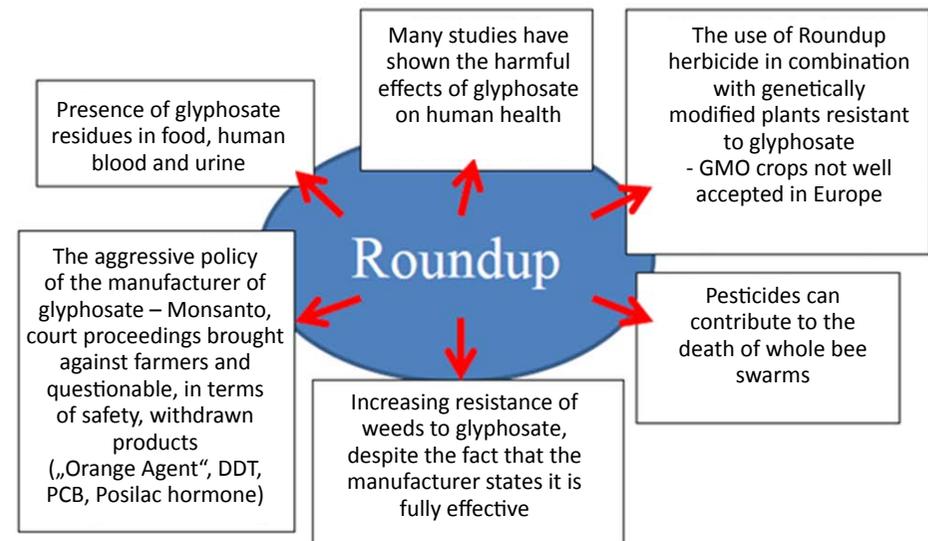
### The efficacy of herbicides with glyphosate; problematic issue of super weeds

The efficacy of weed control methods with herbicides containing glyphosate is confirmed by field studies and the opinions of the users of these substances (Rzymowska et al., 2015). For example, after the application of Sting CT 120 SL herbicide (120 g glyphosate and 285 g of ammonium sulfate in 1 dm<sup>3</sup>) at a dose of 4 dm<sup>3</sup>/ha or Classic 360 SL Glyphosate (360 g of glyphosate in 1 dm<sup>3</sup>) at a dose of 2 dm<sup>3</sup>/ha along with ammonium sulfate (5 kg/ha), almost 100% efficacy in weed control was achieved. Almost all weeds (97-100%) of the following species were killed: goosefoot (*Chenopodium album*),

redroot pigweed (*Amaranthus retroflexus*), barnyard grass (*Echinochloa crus-galli*), redshank (*Polygonum persicaria*), Persian speedwell (*Veronica persica*), and black bindweed (*Polygonum convolvulus*), and 95% of couch grass (*Elymus repens*); only field bindweed (*Convolvulus arvensis*) was resistant – 80% of the weeds remained (Badowski, 2004). The efficacy of Roundup 360 SL formulation was evaluated in another experiment (Lisek, 2012): 360 g glyphosate in one liter of the formulation was applied individually (at 5 dm<sup>3</sup>/ha) and AS 500 SL adjuvant (3 and 1 dm<sup>3</sup>/ha) in an apple orchard. After 28 days after spraying, high efficacy (95-100%) was recorded with chickweed (*Stellaria media*), annual bluegrass (*Poa annua*) and small geranium (*Geranium pusillum*); while lesser efficacy (80-90%) was reached with glyphosate (there was no significant difference between individual use and with adjuvant) for purple archangel (*Lamium purpureum*), common dandelion (*Taraxacum officinale*) and fringed willowherb (*Epilobium adenocaulon*).

The promises made by Monsanto – the manufacturer of the Roundup herbicide – on its total and perpetual effectiveness were doomed to be ruthlessly verified by nature. Over time, the weeds adapt to unfavorable habitat and active substances in pesticides, and sooner or later due to high yield resistant biotypes spread in the environment. It is just a matter of time (Rózański, 1992). The emergence of the glyphosate-resistant weed species first occurred in Australia in 1996. Glyphosate-resistant biotypes of rigid ryegrass (*Lolium rigidum*) were discovered; the weeds appeared for the first (documented) time in orchards, where Roundup had been used 2-3 times a year for 15 years. Since 2006, rigid ryegrass resistance to glyphosate has become a reality also in Europe (France, Spain, Italy). Since 2004, the weeds emerged with increased frequency in the world; today they make 25 species, of which some biotypes show resistance to glyphosate preparations. Complete information on the phenomenon of the development of pesticide resistance in weeds, a full list of new cases and a number of pub-

Fig. 4. Sources of controversy regarding herbicides with glyphosate



lications on this topic can be found on an international website “International Survey of Herbicide Resistant Weeds” (Heap, 2016).

### Controversy over the use of herbicides with glyphosate

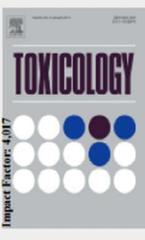
The controversy over the use of glyphosate formulations involves several aspects (Fig. 4). The ones that deserve special attention are:

- Scientific reports on the hazard related to these herbicides, both for people and the environment, connected with the presence of glyphosate and its metabolites in food, water and organisms (Richard et al., 2005; Gasnier et al., 2009; Clair et al., 2012; Koller et al., 2012);
- Suggestions that the herbicides are responsible for bee extinction (Balbuena et al., 2015);

- Information about growing glyphosate resistance in an increasing number of weed species (company assure farmers of 100% efficacy) (Heap, 2016);
- Correlation between glyphosate and transgenic crops that are not very popular in Europe (Benbrook, 2012; Steinmann et al., 2012);
- Aggressive market policy of Monsanto, the leading glyphosate manufacturer, and repeated “mistakes” during the 100-year history of the company (production of “Orange Agent” which was contaminated with dioxin, DDT, PCB, synthetic hormone Posilac) (Lisowska and Chorąży, 2011).

Some studies (of Hardell and Eriksson, 2002; Cavas and Konen, 2007; Benachour and Seralini, 2009; Romano et al., 2010; Cavalli et al., 2013) show that glyphosate or preparations that contain this substance have either a negative impact on human and animal health, or this impact is negligible (several dozen scientific elaborations on the basis of which the European Commission has included glyphosate to the list of permitted active substances). They disorientate public opinion, including farmers and consumers. The main reason for the extremely inconclusive research results is the modification of glyphosate properties by adjuvants. Roundup herbicide is 17-32 times more toxic than glyphosate is on its own (Pieniżek et al., 2003). In addition, the efficiency of pesticides is also affected by environmental conditions (e.g. temperature, soil pH, microbiocenosis composition) and the properties of water used to prepare working fluid (e.g. the content of mineral salts). The development phase of organisms at the time of the application is also important. All of this causes that the studies on the impact of glyphosate or herbicides are very diverse (Pieniżek et al., 2003; Kwiatkowska et al., 2013).

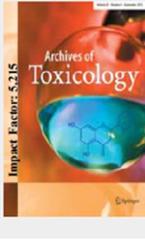
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**Gasnier C., Dumont C., Benachour N., Clair E., Changon M. Seralini G. 2009. Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines. Toxicology. 262:184–191**

Human HepG2 liver cell responses to glyphosate formulations (Roundup Express, Bioforce, Grands Travaux, Grands Travaux Plus) were studied.

- Aromatase activity inhibited at 10 ppm glyphosate concentration (after use of preparations), which impaired normal cell hormone management (levels of androgens, testosterone, estradiol)
- An increase in damage in cellular DNA has been observed (Comet Assay technique), starting from cell incubation in 5 ppm (Grand Travaux)
- Glyphosate preparations were significantly more potent on cell viability (tested with Alamar blue, MTT) than glyphosate alone (lethal effect significant from 10 ppm)



**Koller V. J., Furhacker M., Nersesyan A., Misik M., Eisenbauer M., Knasmueller S. 2012. Cytotoxic and DNA-damaging properties of glyphosate and Roundup in human-derived buccal epithelial cells. Arch. Toxicol. 86:805–813**

Human epithelial cells isolated from the lips (TR146 line) treated with glyphosate and Roundup Ultra Max herbicide were examined.

Significant cell changes were observed at 10-20 mg/gm<sup>3</sup> glyphosate concentrations (Roundup) during the 20 minute incubation (e.g. increased nuclear aberrations that reflect DNA damage, increased micronuclei frequency; nuclear bridges between nuclei). The authors confirm a possible correlation between exposure to Roundup and the occurrence of cancer.



**Richard S., Moslemi S., Sipahutar H., Benachour N., Seralini G. 2005. Differential effects of glyphosate and Roundup on human placental cells and aromatase. Environ Health Perspect. 113(6):716-20.**

The response of human placental cells (JEG3 line) to Roundup and glyphosate was studied.

- Aromatase activity in cells was reduced by 50% already at a concentration of 0.04% of Roundup in the culture, the same amount of glyphosate in the culture at the same time did not affect the enzyme content.
- Cell viability. In ground with Roundup (1%) 70% of cells were killed after an hour of incubation, the same dose of glyphosate alone reduced the number of cells by as little as 10%.

Fig. 5. Summary of the results of studies on the impact of glyphosate and herbicides on human cells (selected scientific)

## The impact of glyphosate and its herbicides on human cells and on mammals, aquatic organisms and microorganisms

There are many publications documenting the negative impact of phosphonate herbicides on cells and organisms (Fig. 4, 5, 6, 7); the most frequently described are the devastating effects of glyphosate that involve (selected from a number of presented peer-reviewed scientific studies):

- Damage to the genetic material, which can result in (or has been proved to result in) the rise of cancer in humans or animals (Marc et al., 2002; Monroy et al., 2006; Paz-y-Miño et al., 2007; Benachour and Seralini, 2009; Mañas et al., 2009; Koller et al., 2012).
- Inhibition of the aromatase, a key biosynthesis enzyme of steroid hormones, which can result in (or has been proven to result in) impaired fetal development, hormonal disorders, cancer of the mammary gland and breast, infertility, impaired sexual behavior in animals or humans (Richard et al., 2005; Dallegrave et al., 2007; Soso et al., 2007; Clair et al., 2012);
- Level and transformation deregulation of retinoic acid in human and animal cells, which may result in (or has been proved to result in) fetal development impairment (Paganelli et al., 2010).

Well-documented toxicity of glyphosate is significant in biodiversity preservation, especially of herbicides containing this substance for aquatic organisms (plants, amphibians, fish, crustaceans) (Sopińska et al., 2000; Relyea, 2005; Cavas and Konen, 2007).

The manufacturer of herbicides containing glyphosate states on the product labels that these substances are “toxic (or extremely toxic) to aquatic organisms and may cause long-term adverse effects in the aquatic en-

vironment (information labels attached to herbicides). Taking the above into consideration, any organisms in water reservoirs (waterholes and ponds), field drainage ditches and ones directly adjacent to chemically protected areas are particularly vulnerable to glyphosate.

Glyphosate-resistant transgenic plants emerged due to microorganisms. Monsanto researchers have isolated genes responsible for the production of enzymes that deactivate the effect of glyphosate (Staub et al., 2012) from the bacteria naturally resistant to glyphosate (e.g., *Agrobacterium tumefaciens* strains, *Achromobacter* sp. *Ochrobacterim antropi*). In general, soil microorganisms make varying response for glyphosate and its herbicides (they may be resistant – tolerant, biodegrading, sensitive). Strains of bacteria and fungi may develop adaptive mechanisms to the presence of the described xenobiotic. There are several mechanisms that cause resistance (Stalker et al., 1985):

- overproduction of EPSPS enzyme (5-enolpyruvylshikimate-3-phosphate synthase) by *epsps* gene amplification. This enzyme is suppressed by glyphosate;
- activity of the alternative EPSPS enzyme that is resistant to glyphosate (*aroA* gene);
- the presence of the GOX enzyme (glyphosate oxidoreductase) that is encoded by the *gox* gene, which in turn catalyzes the degradation of the glyphosate enzyme.

However, some microorganisms do not possess the characteristics that give them glyphosate resistance, and therefore they die upon a contact with it. Glyphosate impact on microorganisms generally does not have long-term negative effects (Weaver et al., 2007). Smaller or larger numbers of glyphosate-resistant microorganisms, that are typically present in soils, replace the vulnerable ones thorough succession. All chemicals change the quantity and quality of microorganisms in the en-

vironment; biological balance is constantly modified (as under the influence of natural environmental factors).

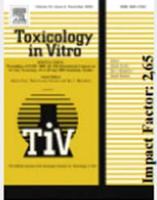
2013 publication (Shehata et al., 2013) on the impact of glyphosate on pathogenic and symbiotic bacteria colonizing chicken intestines brings up disturbing data on the interaction mechanism. It has been shown that the majority of tested pathogenic and opportunistic bacteria (e.g. *Salmonella enteritidis*, *S. gallinarum*, *S. typhimurium*, *Clostridium perfringens*, *C. botulinum*) showed tolerance to glyphosate, while those regarded as positively affecting the functioning of the gastrointestinal tract (*Enterococcus faecalis*, *Enterococcus faecium*, *Bacillus badius*, *adolescentis Bifidobacterium*, *Lactobacillus* spp.) were usually sensitive. The authors of the publication concluded that an unfettered activity of pathogenic (or opportunistic) bacteria, which remained without competition in the body, can cause infection susceptibility in animals and indirectly result in dysfunction of other organs associated with the digestive tract. These results, combined with data on the recently widely described central role of the human microbiome in shaping health, provide a picture of the threat of glyphosate as a substance promoting micro-organisms dangerous to health and eliminating those beneficial (Tilman et al., 2016).

## Supervision over introducing agrochemicals to the market

This begs the question, aren't there any legal regulations concerning the marketing authorization for commercial pesticides? Can be all chemicals traded, regardless of toxicity? Of course, such regulations exist. The European Union has a very extensive and strict system of testing and controlling new active substances and pesticidal preparations (Directive of the European Parliament and Council Directive 2009/128 / EC estab-

**Clair E., Mesange R., Travert C., Seralini G., Seralini E. 2012.** A glyphosate-based herbicide induces necrosis and apoptosis in mature rat testicular cells in vitro, and testosterone decrease at lower levels. *Toxicol. In Vitro.* 26:269–279.

The effect of Roundup Bioforce on rat cell nuclei was studied (Leydiga and Sertoli).



At just 1 ppm of Roundup slight damage to Leydig cells and a drop in testosterone levels by 35% was observed. Glyphosate alone did not significantly affect cells in all variants of culture.

**Romano R.M., Romano M.A., Bernardi M.M., Furtado P.V., Oliveira C.A. 2010.** Prepubertal exposure to commercial formulation of the herbicide glyphosate alerts testosterone levels and testicular morphology. *Arch. Toxicol.* 84:309–317

The effect of Roundup Transorob on rats was studied (testicular and adrenal morphology, hormone levels, sexual behaviour). Testicles and adrenal glands underwent hypertrophy in subjects treated with R. at all doses.

At the lowest dose, the testosterone level decreased by about 30%.

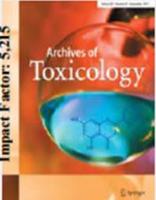


Fig. 6. Summary of the results of studies on the impact of glyphosate and herbicides on animal cells, and the animals themselves (selected scientific papers)

Fig. 7. Summary of research results on the effects of the Roundup herbicide on soil microorganisms.

**Weaver M.A., Krutz L.J., Zablutowicz R.M., Reddy K.N. 2007.** Effects of glyphosate on soil microbial communities and its mineralization in a Mississippi soil. *Pest Manag. Sci.* 63(4):388–93.

The effect of the Roundup Ultra herbicide (applied at field dose and 3 times higher) on microbiocoenosis was insignificant and short-lived. Even at the highest dose, glyphosate did not have a long-term effect (up to a week) on the changes in the composition and amount of microorganisms of a given biovar (specific to the species FEME profile).



**Sopińska A., Grochala A., Niezgodą J. 2000.** Influence of water polluted with herbicide Roundup on the organism of fish. *Med. Weter.* 56: 593–597.

Roundup (4; 6; 8 mg/l) is toxic for carps, it results in a decrease in the performance of the immune system, as well as abnormalities in liver and kidney function, where post-mortem histopathology has shown degenerative changes.

**Cavas T., Konen S. 2007.** Detection of cytogenetic and DNA damage in peripheral erythrocytes of goldfish (*Carassius auratus*) exposed to a glyphosate formulation. *Mutagenesis.* 22(4):263–268

DNA damage of erythrocytes of goldfish was investigated (Comet Assay test). Roundup (5; 10; 15 ppm) was introduced to the aquariums. The number of damaged erythrocytes increased with the dose (even by several dozen %) and with each day (by approx. 10%). After six days of exposure to subsequent doses there were 8%, 30 and 40% more damaged cells than in the control group.

Fig. 8. Summary of the results of research on the effects of the Roundup herbicide on gastrointestinal microbes, isolated from poultry.

**Shehata A. A., Schrod W., Aldin A.A., Hafez M., Kruger M. 2013.** The Effect of Glyphosate on Potential Pathogens and Beneficial Members of Poultry Microbiota In Vitro. *Curr Microbiol.* 66:350–358.

Roundup did not significantly affect the pathogenic species such as Salmonella and Clostridium, whereas the commensal and symbiotic strains of the species *Enterococcus faecalis*, *Enterococcus faecium*, *Bacillus badius*, *Bifidobacterium adolescentis*, *Lactobacillus* were from moderate to susceptible.



lishing a framework for Community action to achieve the sustainable use of pesticides, Regulation of the European Parliament and Council Regulation (EC) No. 1107/2009 concerning the placing of plant protection products and repealing Council Directive 79/117/EC and 91/414/EEC Directive of the European Parliament and Council Directive 2009/127/EC, amending Directive 2006/42/EC with regard to machinery for pesticide application). For a pesticide to reach the client, it has to go through a multi-step journey from laboratory to field testing. The company that plans to launch a new product is required to outsource a broad spectrum of diagnostic testing units. These are substantial financial expenses that need to be reconsidered after a decade on the occasion of security verification of any registered pesticides. Among other things, toxicity tests are carried out on selected species of mammals. Ecotoxicity, biodegradability and effectiveness against pathogens is checked (Biziuk, 2001; Struciński et al., 2006). However, not everything is under control. For example, legislative studies put an emphasis on short-term and not long-term toxicity (studies carried out up to two years). This is important because certain diseases may occur after several years from the exposure to a toxic agent, as tests on rats demonstrated (Romano et al., 2010; St. Clair et al., 2012). Likewise, it was assumed that if any active substance that doesn't accumulate is rapidly excreted from the body, there is no health hazard. However, given the widespread presence of glyphosate in bread, people are chronically – day by day – exposed to this factor despite the lack of accumulation in the tissues (Bojanowska 2011, Kwiatkowska et al., 2013; Chow, 2016). As mentioned, the impact of the sole active substance may be much weaker than of a pesticide containing that substance; pesticides also contain adjuvants – aids, which by their nature, should enhance the toxic effect. Meanwhile, these are active substances that are

closely researched; much closer than pesticides containing a given substance.

The International Agency for Cancer Research of the World Health Organization took a position in the public debate about the safety of glyphosate, and evaluated this product as potentially carcinogenic to humans. Even then, in July 2016, the European Commission extended the company's permission for market operation of herbicides with glyphosate. European Food Safety Authority (EFSA) gave the decisive opinion, basing its positive stance for glyphosate on scientific data compiled on behalf of the Monsanto corporation.

### Summary and conclusions

Demand for herbicides containing glyphosate is driven by farmers, municipal services and home gardeners. Using glyphosate, one can easily and quickly get rid of unnecessary vegetation, eliminate weed from fields, sidewalks, tracks, industrial areas and remove the

vegetation barrier from canals and reservoirs. Farmers apply Roundup on a mass scale to desiccate cereals; it is the main cause of contamination in everyday consumption products such as bakery and confectionery products. Therefore there is a demand for equally effective product that brings profit to companies that offer agrochemicals. Unfortunately, there are also scientific publications – not a few, but and at least dozens – in independent scientific journals, proving the negative effects of herbicides with glyphosate on specific elements of the trophic chain, humans including. There is probably a conflict of interest; on one side there is the industrial giant – the Monsanto company (acquired in September this year by the Bayer pharmaceutical company) and farmers' satisfaction with the effectiveness of herbicides with glyphosate; and on the other hand, there are the legitimate concerns about the health of consumers worldwide. Herbicides with glyphosate will probably be withdrawn eventually from the market (Fig. 9), because even in the United States (which is liberal in terms of

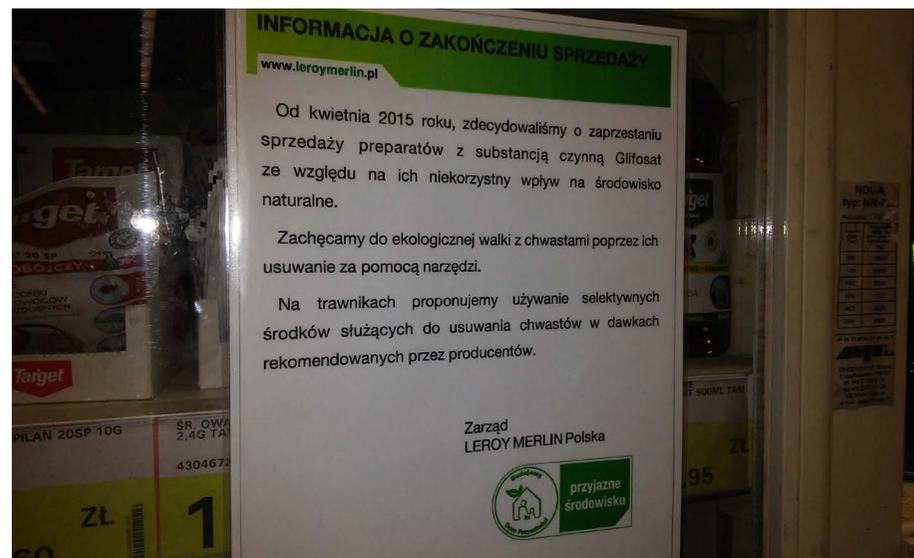


Fig. 9. Information placed on the stand of Leroy Merlin (a chain store in Szczecin).

use of chemicals in agriculture) the concern of those preparations is increasing. A few months ago, the Environmental Protection Agency of State of California put glyphosate on the list of carcinogenic substances.

Despite the unquestioned efficacy of glyphosate, we should be guided by the precautionary principle and should assume that glyphosate is harmful to the environment. Pesticides containing glyphosate should be reasserted for risk (obligatorily, including chronic toxicity), which should be conducted with full transparency, especially for toxicology scientists.

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# Microscopic fungal assemblage colonizing deadwood in the Karkonosze and Tatra Mountains

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## Summary:

The aim of the study was to determine the species composition of microscopic fungi colonizing dead wood of birch, beech, sycamore maple and sorb (Karkonosze Mountains), and black alder, mountain pine, willow, Swiss pine, sorb, sycamore maple and birch in the Tatras. The mycological analysis was conducted in 2015 and 2016 in the foothills and in the lower and upper montane zones of the Karkonosze Mounts, Karkonosze National Park, and in 2016 in the Białka Valley and Chochołowska Valley in the Tatras, Tatra National Park. For both, Karkonosze Mounts and Tatras, the dominant microscopic fungi inhabiting dead wood belonged to the genus *Trichoderma*. The Mycobiota of dead wood in the lower classes of decomposition was characterized by a higher species biodiversity but the lower numbers of colonies isolated.

**Key words:** dead wood, microscopic fungi, decomposition, Karkonosze Mts., Tatra Mts

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## Introduction

Deadwood – as a complex of dynamically changing microhabitats – is an important element that affects the entire forest ecosystem (Pyle and Brown, 2002; Staniaszek-Kik, 2014). Depending on the tree species and the degree of decay remaining wood necromass modifies the abiotic environment, contributing to the formation of mosaic microrelief. It has a huge impact on the modification of local sunlight, moisture accumulation and buffering temperature and moisture changes. These changes favourably affect the biological activity contributing to its development (Solon, 2003).

Residual necromass is an important reservoir of common, rare and protected species influencing the growth of species diversity (Bartnik, 2007). Groups especially related to the specific microhabitat of deadwood are bryophytes, fungi, lichens, slime moulds and invertebrates (Staniaszek-Kik, 2014). Wood with varying degrees of decay contributes to the development of small vertebrates: mammals and birds. Examples include woodpeckers, which have high demands on the degree of decay and volume (trunk circumference and height) of the accumulated necromass. Based on the inventory of bird species from the group of secondary cavity nesters we can assess the degree of decay of the matter left in



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the forest and the approximate size of dead trees. This is due to differing preferences in the selection of sites for nesting and foraging by different species (Bunnell et al., 2002; Ciach, 2011). There is also stressed the predisposition of the occurrence of selected species of fungi and lichens in forest ecosystems of varying intensity of use. By identifying species mycobiota it is possible to determine the degree of naturalness of the ecosystem and the following changes in biocenoses (Sippola et al., 2000; Czyżewska and Cieśliński, 2003). Fungi, as one of the few organisms decomposing plant cell walls, actively participate in the process of wood decay. They serve an invaluable role in the release of the micro and macro elements concentrated in the wood, needed for the development of biocenoses (Kwaśna et al., 2016).

Dieback of trees is often caused by pathogenic sac fungi. They utilize carbohydrates, proteins and fats. They are isolated from live and dead tissues in tree, as well as insect involved in the spread of fungi. With the decreasing abundance of the environment in easily absorbed compounds, saproxylic and saprophytic fungi occur in the presence of wood. Many of them decompose structural components of wood (cellulose, hemicellulose, lignin) unavailable to other microorganisms. This specific form of decay is led by *Basidiomycota* division. They are accompanied by bacteria and *Ascomycota* form of fungi, which: (i) have the ability to degrade wood components (among the others, representatives of *Xylariales* family with *Daldinia*, *Hypoxylon* and *Xylaria* genera) (ii) are not capable of wood decay and draw nutrients from the products of wood half-decay and metabolites of associated fungi. They all serve as decomposers: decompose and as a result disintegrate organic matter and increase the amount of inorganic matter in the environment. Also mycorrhizal fungi find their niche in the final stages of wood decay (Stokland et al., 2012; Sour et al., 2016; Sour et al., 2016b). 20% of fungi in

dead tree trunks are mycorrhizal fungi (Franklin et al., 1981). Improving the conditions for tree growth (especially conifers), they contribute to the success of natural regeneration of forests and vegetation development on new positions.

The role of saprophytes in forest ecosystems, including *Ascomycota* phylum, is often underestimated. While decomposing wood, they participate in the circulation of matter in the nature, and contribute among the others to the creation stable humus, stabilization of pH, increase of water capacity and improvement of the lumpy structure of soil. By shaping habitat conditions preferred by different types of plants and animals, they increase immunity and durability of forests and prevent fires. They also contribute to improving forest health through the production of valuable secondary metabolites (antibiotics, enzymes and vitamins) and encouraging the development of predatory insects and spiders, which are natural enemies of harmful insects (Bartnik, 2007).

The topic of wood decay caused by fungi has been raised so far by many authors. Particularly noteworthy are the studies of Savory (1954), Seifert (1983), Crawford et al. (1990), Worrall, et al. (1997), Harju et al. (2001), Venäläinen et al. (2003) and Fukasawa et al. (2009, 2011). In recent years, the European Parliament has stressed the importance of necromass in shaping forest ecosystems. It recommended member countries of the European Union to take appropriate measures to maintain optimal levels of deadwood in forests (Anon 2011).

The aim of the conducted studies was to determine the species composition of microscopic fungi colonizing birch (*Betula* L.), beech (*Fagus* L.), sycamore (*Acer pseudoplatanus* L.) and rowan (*Sorbus* L.) deadwood in the Karkonosze Mountains and the black alder (*Alnus glutinosa* Gaertn.), mountain pine (*Pinus mugo* Turra.), willow (*Salix* L.), Arolla pine (*Pinus cembra* L.), rowan

(*Sorbus* L.), sycamore (*Acer pseudoplatanus* L.) and birch (*Betula* L.) deadwood in the Tatra Mountains.

### Methodology of the researches

Mycological analysis included birch (*Betula* L.), beech (*Fagus* L.), sycamore (*Acer pseudoplatanus* L.) and rowan (*Sorbus* L.) deadwood in the Karkonosze Mountains. In contrast the material for the research in the Tatra Mountains was black alder (*Alnus glutinosa* Gaertn.), Mountain pine (*Pinus mugo* Turra.), Willow (*Salix* L.), Arolla pine (*Pinus cembra* L.), rowan (*Sorbus* L.), sycamore (*Acer pseudoplatanus* L.) and birch (*Betula* L.) deadwood.

Samples were taken three times during the growing season, i.e. in the spring (April/May), summer (June/July) and fall (October/November) of 2015-2016 in the Karkonosze Mountains and of 2016 in the Tatra Mountains. Research posts in the Karkonosze Mountains in 2015 included three areas of the lower and upper montane of the western districts of the Karkonosze Mountains National Park: Chojnik, Szrenica and Kocioł Szrenicki. In 2016 the posts were located in the foothill areas (Góra Żar and Szerzawa), the lower and upper montane of the Karkonosze Mountains National Park (Petrovka, Wilcza Poreba, Kocioł Łomniczki, Łomniczka Valley) (Table 1, Figure 2). No mycological research of sycamore deadwood was carried out dur-



Fig. 1. Beech deadwood in the Karkonosze Mountains

Source: own elaboration

ing the second year of the research. Research posts in the Tatra Mountains were located in the Białka and Chochołowska Valley (Table 1). In addition, one post was located in the vicinity of the TPN Nature Education Centre in Zakopane (Figure 3).

Field researches were determining the degree of wood decay by Pyla and Brown scale (2002); and then 10 ca. 5-cm-long pieces of wood were collected with a sterile tool from a depth of about 1-2 cm of one of the selected objects (coarse woody debris or standing

deadwood) on 1 monitoring post to determine their colonization by microscopic fungi. The surface of the wood pieces was then flushed with a 1% sodium hypochlorite solution for 5 seconds. The next step was laying six pieces of ca. 0.5 cm-long wood fragments onto each Petri dish with solidified and acidified PDA (potato glucose agar) medium. Fungi growing out of the fragments of wood were cleaved onto PDA slants and identified to the species based on morphological characteristics (construction of the mycelium, the shape and dimensions of the spores, the shape and dimensions of conidiophores, sporulation forms and others) using available keys (Pitt and Hocking, 2009; Watanabe, 2011).

### Findings

In 2015 a total of 11 species of fungi were isolated in the Karkonosze Mountains, whereby *Trichoderma harzianum* from the wood of all tree species researched (mountain ash, maple, beech and birch) on all surveyed positions (the Mumlawski Peak, Szrenica, Kocioł Szrenicki and Chojnik). In turn, the second dominant species in mycocenosis of deadwood, *T. polysporum*, was not isolated only from maple deadwood. More species of fungi were identified in the lower grades of wood decay, and some of them, e.g. *Botrytis cinerea* and *Fusarium culmorum*, did not inhabit more decayed wood. 7 species of fungi in a total of 39 isolates were detected on birch deadwood of 2nd degree decay; while in turn: in maple deadwood of 5th degree only one species of fungus (80 isolates); in rowan deadwood of 4 degree decay – 4 species of fungi (67 colonies); in birch deadwood – 4 species (68 isolates) with clear predominance of *T. harzianum* (Table 2).

A total of 19 species of fungi were isolated from deadwood in the second year of studies conducted in

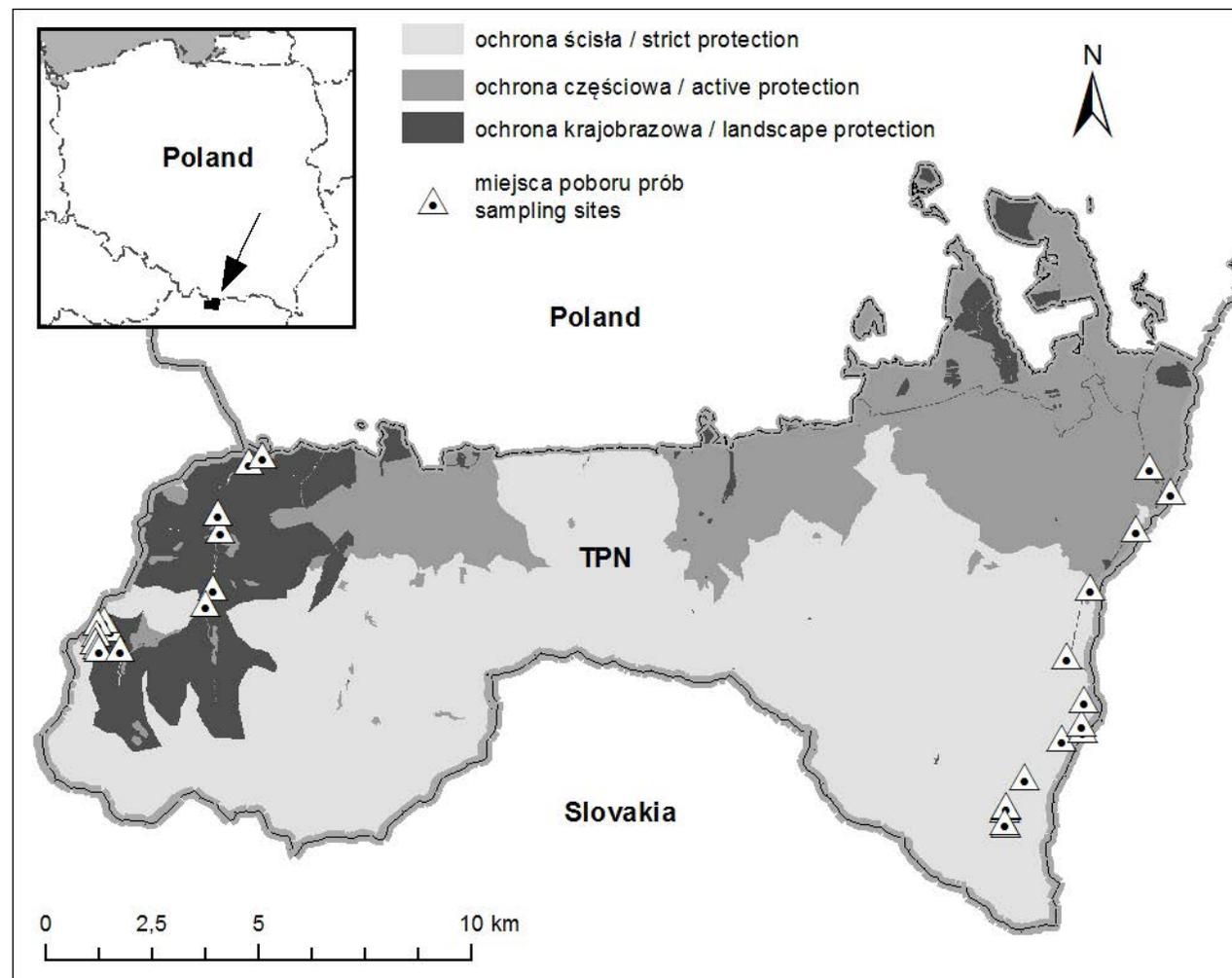


Fig. 2. Distribution of research posts in the Karkonosze Mountains National Park

Source: elaboration of Marcin Wierzbicki, the Karkonosze Mountains National Park

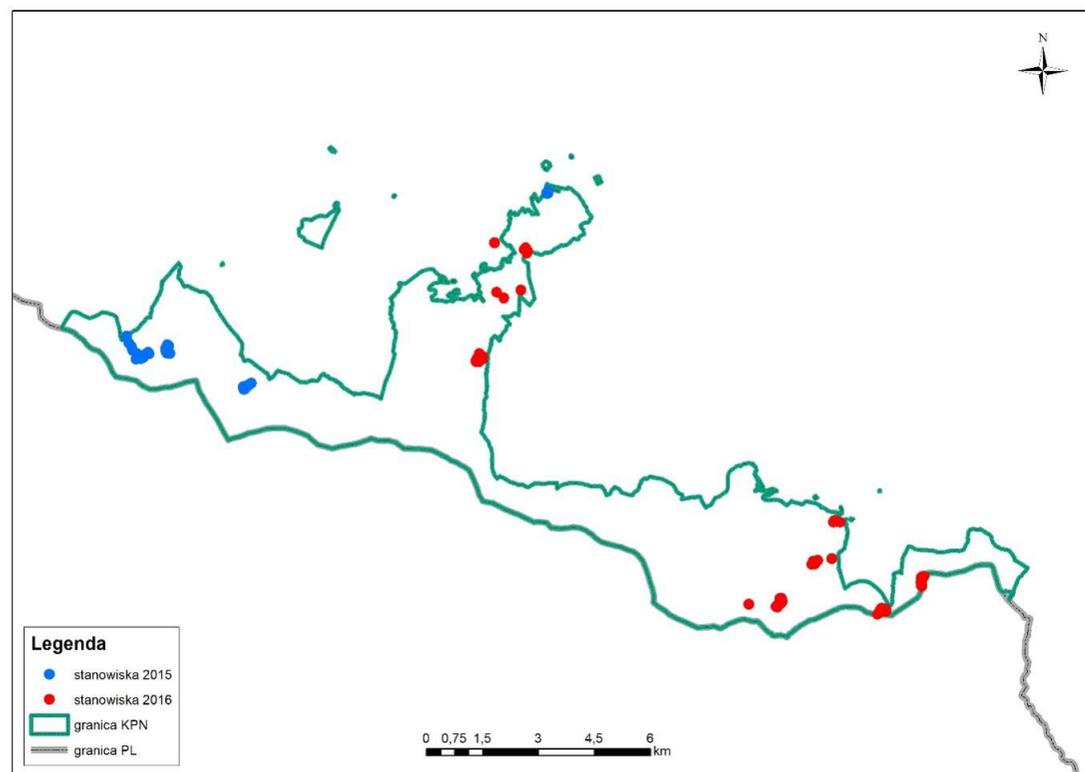


Fig. 3. Distribution of research posts in the Tatra National Park

Source: own elaboration

the Karkonosze Mountains. It has been found that contrary to birch wood and rowan most fungi of the *Trichoderma* genus were isolated from beech deadwood. The biggest share in mycocenosis of beech deadwood had species of *T. harzianum* and *T. polysporum*. Beech wood can be characterized by greater biodiversity of mycocenosis than birch and rowan deadwood. 15 species of fungi were isolated from beech wood in spring, whereas this value for birch species totalled 5 and for rowan – 10 (Table 3).

Upon analysing species composition of fungi present in different species of deadwood in the Tatra Mountains, it can be said that most species and colonies were found in rowan deadwood; 5 species and 37 colonies, respectively. Five species of fungi were isolated also from willow wood with respectively fewer colonies. Fungi of the *Trichoderma* genus were not only isolated from Swiss pine deadwood, but unlike the Karkonosze Mountains, *Trichoderma spp.* were not dominants (Table 4).

Fungal species	Deadwood / decay class				
	beech 3	birch 2	mountain ash 4	sycamore 5	birch 4
<i>Alternaria alternata</i>		3			1
<i>Alternaria botrytis</i>			1		
<i>Aspergillus niger</i>	3				
<i>Botrytis cinerea</i>	20				
<i>Fusarium culmorum</i>	1	2			
<i>Fusarium oxysporum</i>		1			1
<i>Mucor hiemalis</i>		1			
<i>Penicillium notatum</i>	15		12		
<i>Trichoderma harzianum</i>	30	12	37	80	63
<i>Trichoderma polysporum</i>	6	10	17		3
<i>Trichoderma hamatum</i>	3	10			
Total	78	39	67	80	68

Tab. 2. Species composition of microscopic fungi isolated from deadwood in the Karkonosze Mountains in 2015 (average number of colonies)

Source: own elaboration

## Discussion

Based on the achieved results it was concluded that the fungi of the *Trichoderma* genus – *T. harzianum* and *T. polysporum* – have the highest share. Fungi of the *Trichoderma* genus are commonly present in the environment and are capable of very rapid colonization of deadwood (Cardoza et al., 2006). They can be found in soil and are responsible for the decomposition of organic tissue (Grondona et al., 1997). Deadwood is thus

a kind of reservoir of fungal isolates, which can then be used in various industries (Bartnik, 2007). Fungi of the *Trichoderma* genus may be used in a biological protection of plants against diseases caused inter alia by fungi of the *Fusarium* genus (Grondona et al., 1997, Błaszczuk et al., 2014). Fungi were also observed at the posts in the Karkonosze Mountains and the Tatra Mountains. They could be found on wood by accident or also take part in the so-called mildew wood decay (Sour et al., 2016b). They can be the source of many diseases of plants, both cultivated and wild, but in this case they behaved like typical saprotrophs, decomposing dead organic tissue (Wagah and Muthomi, 2007).

It was found that in the lower classes of decay, wood is populated by a larger number of species, often other than those inhabiting deadwood in the higher classes of decay. This found confirmation in the studies of other researchers (Oszako, 2004, Czekaj and Smith, 2010). The same authors also emphasize the fact that the role of microscopic fungi in the decay of deadwood it is not known to the very end. They probably „open” the door for other groups of fungi and other organisms responsible for the process of decay of deadwood (Sour et al., 2016).

Particularly noteworthy is the fact that a large number of both species and colonies were found on beech deadwood in the Karkonosze Mountains. Increasing the share of beech population increases the biological activity of the soil, stopping unfavourable process of podsolization (Kabbalah et al., 2013). Thus finding so extensive colonization of the beech deadwood by fungi can prove their positive role in shaping the future of natural regeneration of this species in the Karkonosze Mountains.

## Conclusion

We found in this study that the dominant microscopic fungi inhabiting deadwood in selected areas of the Karkonosze and Tatra Mountains are fungi of the *Trichoderma* genus, mostly *T. harzianum* and *T. polysporum*. Lower degree of wood decomposition indicates a much larger variety of species of microscopic fungi than in the higher classes of decay. Some diversity of the mycocenosis of deadwood was also found, depending on the type of wood and its degree of decomposition.

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# The idea for... biobank – just a few words

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## Summary:

The use, collection and modification of human biological material/the human body is a difficult, controversial and challenging subject demanding deep analyses of all the ethical, social and legal aspects. Use of the human body for experimental purposes for or without the reward is often criticized. It is clear, however, that not all researches on new medicinal products, medical devices or cosmetics can be carried out on animals only. Contribution of a human being in experiments and clinical trials (including organs, tissues or cells) is the only way to verify safety and efficacy of a tested method or substance. Storage of human biological material intended for tests demands meeting conditions provided by legal standards and showing respect for the human body and human dignity; that is why biological material must be, as a rule, stored in cell and tissue banks (biobank). Any entity that wants to operate a bio-

bank must meet a number of complex requirements before entering this narrow, difficult and demanding market. This is the result of legislative chaos and fragmentation of laws at the national and EU level, but also social, ethical or religious prejudice. However, biobanks are an indispensable research tool for understanding genetic or environmental grounds of many diseases, e.g. hereditary ones. Biobanks can undoubtedly revolutionize the health market and contribute to the further development of personalized medicine. However, the entity willing to establish a cell and tissue bank must meet and take into account several criteria. Any entity considering the foundation of a biobank wonders whether this activity will be profitable and whether it can be included in the chain of clinical trials.

**Key words:** biobank, human biological material

cells means. Detailed rules on this matter have been included in the provisions of the Polish Act of 1 July 2005 on the collection, storage and transplantation of cells, tissues and organs (hereinafter: the Transplant Act; detailed information on the law, no, etc. is missing).

## Qualification of cell and tissue banks

Art. 1 of the Transplant Act determines the rules for the collection, storage and transplantation of cells, including hematopoietic cells of bone marrow, peripheral blood and umbilical cord blood, tissues and organs derived from a living donor or a cadaver, as well as the principles of testing, processing, storage and distribution of human tissues and cells. Although the law defines a cell and tissue bank as an organizational unit operating in the collection, processing, sterilization, storage and distribution of tissues and cells, which can also collect or test tissues and cells (art. 2 item 1 point 1), art. 25 determines explicitly that cell and tissue banks are created for the collection, processing, sterilization, storage and distribution of tissues and cells for transplantation. In addition, art. 2 item 1 point 14 clarifies that testing within the meaning of the Act are any operations that involve tests determining the suitability of cells, tissues or organs for transplantation in humans. From the analysis of the provisions of the Directive and the Polish Act one can draw a conclusion that the wording of the Directive that regulates handling of human tissues and cells “intended for human use” has a broader meaning than the one introduced in Polish law using the term of “transplantation”. Due to the wording of the regulations, cell and tissue banks in Poland performing operations not intended for transplantation cannot be recognized as cell and tissue banks. Therefore, for the qualification of the entity it is essential to define the use of cells and tissues. If the cells or tissues are processed,

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## Basic legal status

EU regulations on transplantation can be found in respective directives. Standards on quality and safety for the donation, procurement, testing, processing, preservation, storage and distribution of human tissues and cells and products derived from them intended for human applications are covered by Directive 2004/23/EC

(art. 2, item 1). In accordance with the Directive, a cell and tissue bank (biobanks) is a bank or a unit of a hospital or another body where activities of processing, preservation, storage or distribution of human tissues and cells are carried out. The facility of this type can be also responsible for collection or testing of tissues and cells (art. 3 point o) of the Directive). The Directive does not, however, define what the term of testing tissues and

stored, etc. beyond this intention, we cannot talk about a biobank. This is the first criterion to be taken into account when creating a biobank.

In addition, it should be noted that the same Transplant Act also applies when cells, tissues or organs are obtained in connection with their removal during some other medical intervention carried out as a treatment not a transplantation procedure (art. 21 of the Transplant Act). The acquisition and the use of such acquired parts of the body, however, requires adequate notification of the donor and receipt of donor's conscious, informed and prior consent (art. 22 of the Bioethics Convention).

However, it appears that there are no cons to operate a biobank for the purposes of an experimental medical treatment (introducing new or partially proven diagnostic, therapeutic or prophylactic method by the physician to achieve direct health benefits by a person being treated or a particular patient) and an experimental medical research (intended for expanding medical knowledge and conducted on healthy and ill people; permissible if participation in it is not associated with the risk, or the risk is low and is not disproportionate to the potential positive results of such an experiment), in particular a clinical trial being a type of an experimental research (in accordance with art. 21 of the Act on practicing professions of a physician and dentist (OJ 2008, No. 136, item 857).

Some biobanks uniquely qualify their operations as focused on the collection, processing, storage and distribution of cells which are the subject of scientific research, which will be eventually used in humans (such as Biobank at the University of Warmia and Mazury in Olsztyn, Faculty of Medical Sciences; poltransplant.org.pl). The use of stem cells is of particular importance in researches on medicinal products. Thus stem cell banks constitute important support in conducting clinical tri-

als. Among the certified stem cell banks one can find for instance: Public Stem Cell Bank in Chęciny at the Regional Centre for Science and Technology; Diagnostyka Stem Cell Bank Sp. o.o. in Cracow; Progenis – Stem Cell Bank in Krakow; Cell Bank of the Department of Cell Biology of the Faculty of Biochemistry, Biophysics and Biotechnology at the Jagiellonian University; Bank of the Laboratory of Cell and Tissue Engineering of the Malopolska Biotechnology Centre. Conducting clinical studies using stem cells contributes to the development of personalized medicine in a special way – allows for specific therapy tailored not only for a specific disease, but for specific groups of patients or selected patients, including searching for effective treatments (of cancers for instance).

For this reason, this sort of entity is established to acquire human tissues and their preparation for human use (processing, preparation, processing), storage and distribution in accordance with accepted legal principles and technical standards (Komender 2004, 13-17). But there is no requirement that each unit must perform all the activities referred to in art. 2 item 1 point 1 of the Transplant Act.

Therefore, an entity that aspires to be a biobank must meet a number of requirements, in particular to obtain a permit from the Minister responsible for health affairs to carry out the planned activities (art. 25 of the Transplant Act) and to follow the requirements of the Transplant Act in this regard.

### How to obtain a permit to conduct a biobank

Any entity willing to operate a biobank must submit an application for an administrative decision allowing such activities (art. 27, item 5 of the Transplant Act). Therefore, in accordance with art. 26 item 2 of the Transplant Act, any entity applying for authorization

submits an application to the National Center for Tissue and Cell Banking (hereinafter: the Center).

The application for the permit should reflect the type and the scope of planned activities and specify both types of tissues and cells, as well as all the operations that they will be subject to. For example, the application can include:

- “gathering, processing, storage and distribution of hematopoietic cells of bone marrow and peripheral blood for transplantation purposes”;
- “collection, testing, processing, storage and distribution of hematopoietic cells of umbilical cord blood”;
- “collection, processing, sterilization, storage, testing and distribution: allogeneic and autologous musculoskeletal grafts, allogeneic and autologous

**Person responsible** meets the requirements of art. 28 item 2 of the Transplant Act, so she/he has at least higher education in the field of medical or biological sciences and two years of professional experience gained in a biobank or entities operating in the field of processing, preservation, storage, distribution, collection and testing of human tissues and cells.

#### Elements of the applications (art. 26 item 6 of the Transplant Act)

- Document identifying a person authorized to represent the entity
- Information on the number of employees and their qualifications (these persons should go through a special training)
- Opinion state sanitary inspector on meeting the requirements set out in the Regulation of the Minister of Health dated on 20 November 2006 on professional sanitary requirements for cell and tissue banks (Journal of Laws No 218, pos. 1598)
- List of rooms and devices, organizational structure, responsibilities of employees, expected scope of activities
- List of cooperating entities having impact on the quality and safety of tissues, plus detailed specification of recommended activities along with carbon copies of agreements concluded with these entities
- Name of the person responsible for following the Transplant Act in the entity

mucosal and connective tissue grafts, allogeneic and autologous blood vessel grafts, allogeneic and autologous cell grafts” (examples from <http://www.poltransplant.org.pl/banki.html>; access: 12.01.2017)

According to art. 26 item 5 of the Transplant Act, a biobank shall obtain a license to operate within the declared scope as far as it meets the following conditions:

- It employs qualified personnel, including a person responsible for ensuring that the biobank follows the provisions of the Transplant Act and the rules laid down in the quality assurance system;
- Its facilities and equipment received a positive opinion of the competent sanitary inspector;
- It presents a draft quality assurance system referred to in art. 29.

The permission is granted for a period of 5 years (art. 26, item 4 of the Transplant Act).

The entity subject to inspection should expect the following two main areas to be covered:

- fulfillment of the conditions required to obtain a permit, i.e. any requirements on the qualification of employees, premises and equipment, and the quality assurance system. The quality assurance system involves the following documents:
  - standard operating procedures;
  - guidelines;
  - code of conduct;
  - reporting forms;
  - donor cards;
  - information on the final destination of tissues or cells.

PERMIT APPLICATION PROCESS	
A. Up to 1 month	The Centre carries out formal assessment of the application and in case of a positive result requests the Minister of Health to carry out an inspection in the entity that submitted the application
A1. Up to 7 days upon receipt of the notification	The proposal does not meet formal requirements. The Center calls the applicant to rectify the shortcomings with the instruction that failure to remedy the deficiencies within the prescribed period results in leaving the application without consideration.
B. Up to 1 month	The Minister of Health conducts or recommends conducting inspection by the Center in the entity that submitted the application. (art. 35 item 2 of the Transplant Act). (See details of the inspection below)
C. Up to 1 month since the receipt of recommendations	The Centre sets a deadline of control of the applicant.
D. Up to 7 days before the inspection	The Centre notifies the entity about the date of the inspection and its scope.
E. Up to 14 days upon ending the inspection	On the basis of the application, observations of the inspection and submitted documents, inspection protocol is prepared, and its two copies signed by inspectors are forwarded to the auditee.
E1. Up to 14 days upon the receipt of the post-inspection protocol	The audited entity may submit objections to the submitted protocol or accept it and undertake the recommendations made during the audit, relating to the removal of shortcomings (misconduct, non-compliance). In the case of the approval of such a protocol the entity signs and returns one of the received copies and sends it to the Center with a timetable covering the implementation of the recommendations made. In the case of objections to the protocol, the entity submits them to the Minister of Health.
E2. Up to 14 days upon submitting objections	Minister takes into account or rejects the objection in his final decision.
F. Up to 1 month upon the receipt of the report on the implementation of post-inspection recommendation	Upon receiving the letter on the implementation of recommendations with accompanied evidence, the Center conducts the assessment of the submitted documents.
G. Up to 1 month since positive verification of introduced recommendations	The Center applies to the Minister of Health for issuing the permit to the entity in accordance with its request indicated in the application including post-inspection report in the application.
H. Up to 1 month upon the receipt of the post-inspection conclusion from the Center	The Minister of Health shall forward the application, together with copies of attached documents to the National Transplant Council (hereinafter KRT) for the review of the application (art. 26 item 3 of the Transplant Act).
I. Up to 1 month since KRT session	During the following session KRT issues its opinion on the request of the Center forwarded by the Minister of Health, and the Chairman of KRT forwards its opinion to the Minister of Health.
J. Up to 1 month upon the receipt of KRT opinion	The Minister of Health shall assess whether the entity applying for the permit and its subcontracting entities meet the statutory conditions and decides whether to issue or to refuse the permit.
K. Operations upon the decision of the Ministry of Health	The Center is notified by the Minister of Health about having issued a decision and in the case of a decision to grant the permit it enters the biobank's data on the public website. In case of a negative decision, the entity requesting the permit may apply to the Minister of Health for reconsideration of the case in accordance with art. 127 of the Code of Administrative Procedure (OJ 2016 pos. 23).

Specific requirements regarding the quality system that should be met by the biobank have been included in the Regulation of the Minister of Health of 9 October 2008 on the requirements to be met by a quality assurance system in the biobank (Journal of Laws 2008 No 190, item 1169).

- meeting further requirements of the Act in respect to:
  - labeling and packaging of tissues or cells and documenting these activities. Requirements on labeling, monitoring and criteria for safety and quality of cells and tissues and organs are provided for by art. 7b-37e of the Transplant Act, and the Regulation of the Minister of Health of 2 April 2010 on the unique marking and monitoring of cells, tissues and organs (Journal of Laws 2010 No. 75, item 486);
  - ensuring the highest quality of tissues and cells during their distribution;
  - storage of tissues and cells under monitored conditions;
  - labelling of cells, tissues or organs in a way that allows the identification of a donor using a unique code (according to the Regulation of the Minister of Health of 2 April 2010 on the unique marking and monitoring of cells, tissues and organs);
  - collection and storage of documentation;
  - security and protection against unauthorized data additions, deletions or modifications;
  - medical records of donors and transfer of information to unauthorized persons;
  - the procedure to resolve data discrepancies;
  - providing protection against unauthorized disclosure of data, ensuring monitoring capacity of the tested cells, tissues or organs;
  - conducting the validation of all processes;

The range of characters for the unique marking for the collection of:

- bone marrow and hematopoietic cells of peripheral blood – from 4 000 to 4099;
- hematopoietic cells of umbilical cord blood – from 4 100 to 4199;
- cells, tissues and regenerating cells or tissues other than bone and hematopoietic cells of peripheral blood, umbilical cord blood – from 4 200 to 4299;
- vascularized organs – from 4 300 to 4399.

Additional labeling information allowing for identification:

- country of collection;
- name and address of the entity collecting cells, tissues or organs;
- year of collection;
- serial number of collection;
- type of cells, tissues or organs collected;
- type of collection;
- class, attribute and modifier defining the operation of processing or storage;
- medical products and materials in direct contact with the cells, tissues or organs.

- identification of critical moments of all the processes that should be controlled based on the determined acceptance criteria;
- conducting qualification of the equipment, technical devices and the environment hosting the process;
- entering into agreements with entities collaborating, cooperating with collection teams and concluding contracts for storage with natural persons;
- exporting or importing tissues and cells, respectively, from and to the Polish territory.

## Responsibilities of a biobank in regard to other entities

The fact that biobanks have obligations to verify whether any entity, whose activities affect the quality and safety of tissues and cells processed in cooperation with the entity, complies with certain criteria of the Transplant Act, is not without significance. It is also important in respect to the assessment of a biobank whether it conducts genetic tests (e.g. typing for transplantation of hematopoietic stem cells, the detection and identification of antibodies), sequences DNA or modifies genetic material.

Any biobank is obliged to respect the rules of data protection, as personal data concerning a potential donor, the donor, the potential recipient and the recipient are confidential and shall be protected under legal requirements of professional and business secrecy and the provisions relating to medical records maintained by medical entities (art. 19 of the Transplant Act).

## Acceptability of compensation

The only act in international law that regulates the issue of researches on biological material is a soft law reflected in the Recommendation of the Council of Europe (2006) on research on human biological material. This act emphasizes the general obligation to inform and obtain informed consent from donors of biological material, both in the case where the material is collected for a particular biomedical experiment and when it has been previously collected to conduct another experiment or for any other purpose than scientific.

The reasons for this are complex. First of all, there are big differences in normative terms as for the status of the human body and its parts in individual countries. The European law has prohibited the commercialization

of the human body and its parts what is reflected in art. 3 item 2 of the Charter of Fundamental Rights of the European Union (*the principles of non-commerciality*), art. 21 of the European Convention on Bioethics and art. 7 of the Recommendations of the Council of Europe (2006) (Jabłońska, 2013, 123-125). Concretization of the principles of exclusion of the human body and its parts from the market is regulated by the Biotech Directive, which contains a provision on the prohibition of patenting the human body and its elements, as well as techniques recognized as violating public order and morality (art. 5 and 6 of the Directive). Domestic legal orders about this issue are also treated variously. In Germany, for example, parts of the human body that have been disconnected (isolated) are can be traded, but must not be a source of financial income. In Britain, the Human Tissue Act 2004 does not give a man any property rights to the biological material originating from his body but some courts seem to allow the possibility of treating the human body as an object. In Poland, the provisions of the Transplant Act exclude biological material from the market which is treated as *res extra commercium*.

Secondly, a very big social and ethical controversy arises from the issue of maintaining the appropriate balance between two factors: business benefits and social benefits from the commercial use of results of researches on biological material. The conflict between business and public interest is fueled by the issue of protecting rights of individual donors of biological material. In this context, there are two groups of views to be highlighted. The first one states that research on human biological material are less ethically controversial because they involve less risk for the patient and therefore can and should be conducted for the common good, in line with the principle of freedom in scientific researches. The second group says that due to the fact that third parties can get access to information about

a man (and often more people related with him) as a result of research on human biological material, there is a risk of violation of fundamental values such as dignity, autonomy, privacy and protection personal data of the donor material.

In Poland, the provisions of the Transplant Act exclude biological material from the market. Such biological material are large organs (kidney, lung, heart), and cells and tissues of skin or blood stem cells.

Above all, Poland is not yet a part to the European Convention on Bioethics (the Convention was signed by Poland on 7 May 1999, But has not been ratified until now). Nevertheless, even if the Polish law prohibiting commercialization of the human body and its parts could not be stemmed directly from art. 21 of the Convention on Bioethics, this rule will result from the system of protection of personal interests adopted in the Polish legislation and settled in the Polish case law, as well as legal concept reflected in the literature that the human body and its parts must be classified as elements closely related to the personality of man; and thus belong to the realm of his personal rights. Consequently, such a protection and disposing of the human body and separated parts of the human body are subject to the wider regime of protection of personal interests (personal interests that come into play here, especially psychological integrity, personal inviolability, health, life, privacy, etc.). According to the judgment of the Supreme Court of 5 July 1973, III CRN 161/73, conducting various medical and anthropological researches, examinations, collection of fingerprints, blood, hair, body secretions, etc. can lead to the violation of personal rights, including his physical integrity. In this context as well, the issue of consent of the holder is particularly important.

Such an interpretation is favored by the reference to the definition laid down in Directive 2004/23/EC of the European Parliament and of the Council as re-

gards traceability requirements, notification of serious adverse reactions and events and certain technical requirements for coding, processing, preservation, storage and distribution of tissues and cells human (EU OJ L 294, 25.10.2006, p. 32).

Art. 3 of the Transplant Act introduces the principle of free donation of tissues, cells and organs. Art. 3 item 1 of the Transplant Act expressing this rule says that no payment or any other pecuniary or personal benefit can be requested or accepted due to the collection of cells, tissues or organs from the donor. This provision correlates with the prohibition of the commercialization of the human body and its parts expressed in the EU and international documents mentioned above. On the other hand, art. 36 states that proceedings on the cells, tissues and organs in the meaning of their collection from living donors may be carried out only by entities operating in the field of medical treatment within the meaning of the Act of 15 April 2011 on medical activity, and having permits issued by the minister responsible for health affairs for performing such activities (art. 36 p. 1a of the Act). This provision imposes the obligation for any biological material to be collected only by authorized institutions. At the moment, in the light of Polish regulations, collection of any biological material for research can be conducted only by a doctor and a dentist (but not by, for example, a geneticist, biologist or biochemist).

A biobank must not also pay compensation to the healthcare entity that provides organs, tissues or cells in the amount exceeding any necessary return for incurred costs and burdens associated with the storage of biological material, the additional protection balanced with the lack of costs associated with the disposal of collected biological material. A biobank does not have to provide any payments or rewards for donors, if they do not incur any additional costs or burdens when their bi-

ological material is collected on the occasion of another surgery which they decide for independently from the decision of forwarding their living biological material to a biobank. In the result, there is no problem with the assessment of excessive rewards or payments that would encourage to donate organs for remuneration (which is in turn would be subject to the charges on trafficking of human biological material) or constitute too high incentive for a donor of biological material that would prevent him from making conscious decision.

The ban on compensation for donated tissues and cells does not prohibit the biobank against the collection of fees for the transportation of tissues or cells, their storage or processing or cultivation, and for the transportation of collected cells or tissues to the health-care entity conducting transplantation (pursuant to art. 3 of the Transplant Act). The interpretation of these provisions leads to the conclusion that return of costs is due the entity conducting given actions, not the entity of the donor.

## Conclusions

Undertaking business activity as a biobank demands meeting a number of legal requirements, and obtaining the permit is time-consuming. Nevertheless, conducting business activity as a biobank allows to earn certain income and to develop space laboratory. Currently there is no law regulating operation of biobanks in Poland. There are also a lot of questions of ethical and legal nature in conducting a biobank. Their activity is particularly governed by the right to privacy and requirements relating to the so-called, prior obtained and informed consent for the use of biological material, but the contents of the received statement may raise a number of concerns, and ultimately the final content of the consent on the specific handling of the biological material may

be difficult to determine. The number of restrictions is significant; however, it does not mean that the establishment of a biobank is elusive. There are 44 biobanks of different range of specialties regarding collected tissues and cells in Poland registered in the KCBTiK register. Biobanks operating on the market are located predominantly at hospitals and universities. Therefore, these are entities supporting activities of hospitals and university hospitals, certainly not geared to achieving significant financial benefits.

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# Wild relatives of potato or less known representatives of the nightshade family (Solanaceae Juss.)

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## Summary:

Nightshade family (Solanaceae Juss.) is represented in the domestic flora by both native species and of the foreign origin, including invasive. Characteristic feature of many taxa of the nightshade family is the presence of different kinds of active substances from the group of alkaloids (nicotine, atropine, scopolamine), responsible for their toxic properties. Not many people are aware that it embraces vegetables (e.g., potatoes, tomatoes, peppers and eggplant) as well as stimulants (e.g., tobacco) and poisonous plants. From the last group noteworthy Polish species are: bittersweet nightshade, henbane and deadly nightshade. Solanaceae for centuries have been used in folk medicine in many regions of the world, and the substances contained in them were also used in many sectors of conventional medicine. They were also bound with many folk beliefs.

**Key words:** nightshade (Solanaceae), flora of Poland, poisonous plants, protected plants, alkaloids

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## Introduction

The family Solanaceae (Solanaceae Juss.) comprises, depending on taxonomic approach, from 2,300 to 2,930 species, classified into over 90 genera (Eich, 2008). The greatest variety of species can be found in the tropical zone, but Solanaceae also occur in other regions of the world except the circumpolar areas. They include both herbaceous and ligneous plants with pentamerous, sympetalous and polysymmetric flowers, frequently of astonishing colors (e.g. the genus *Petunia* Juss.). Their fruits are of the capsule or berry type, gladly consumed by animals and humans (as e.g. tomato plant *Lycopersicon esculentum* Mill.) (Rutkowski, 2014). The characteristic of Solanaceae is their content of various active alkaloid substances (nicotine, atropine, scopolamine), which determine the properties of individual species. They affect mainly the central nervous system and depending on the dose consumed may produce hallucinations, loss of consciousness, convulsions, and may even cause death.

Solanaceae include cultivated vegetables (i.e. potato, tomato, bell pepper or eggplant also known as aubergine), stimulants as e.g. cultivated tobacco (*Nicotiana tabacum* L.), and highly poisonous plants. Mentioned among the latter representatives of domestic flora should be e.g. deadly nightshade (*Atropa belladonna* L.),



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bittersweet (*Solanum dulcamara* L.), or henbane (*Hyoscyamus niger* L.). One should bear it in mind that potato tubers (*Solanum tuberosum* L.) may be just as dangerous. Consumption of a sprouting potato tuber may cause a serious food poisoning. The so-called “spots” from which the sprouts grow should be removed due to their high content of harmful solanine. Just as harmful are greenish tubers, which – like leaves – contain more alkaloids: solanine and chaconine. The substance is only inactivated to some extent through heat treatment, which is why potatoes should not be consumed raw. Particularly dangerous is consumption of the fruits of *Solanum tuberosum* (small round berries) due to their highest solanine content (Sołtys, 2013).

The Latin name of the family Solanaceae refers to psychoactive properties and probably stems from the word *sol*, which means „sun”, *solament* – „consolation, solace”, or *solari* – „soothe, ease” (Rajewski 1996). On the other hand, the English name “nightshade” suggests negative associations with the discussed plants (Ciechomska, 2014). This relates probably to their use as ingredients of magical formulas and poisons in antiquity and the Middle Ages. Today, their potential – or the potential of the substance they contain, to be exact – is used mainly in medicine. The example is atropine, a compound found in the leaves and roots of belladonna. It is used in symptomatic treatment of the Parkinson’s disease or as a mydriatic in vision screening (Ciechomska, 2014).

## Selected representatives of Solanaceae in Polish flora

### Native species

Deadly nightshade (*Atropa belladonna* L.), also known as belladonna, is among the most characteristic native plants children have been warned against for ages

due to its poisonous properties. It can be found mainly in clearings but also in forests and scrubs. The sites of its occurrence are located in Southern Poland, mainly in the lower ranges of Sudety and Karpaty mountains (Piękoś-Mirkowa and Mirek, 2006). It is easily distinguishable due to its brown- and violet-colored corona and fruits in the shape of large and shiny black berries (Fig. 1). The perennial may grow up to 2 meters high (Rutkowski, 2014). The Latin name of belladonna is derived from *Atropos* – the Greek goddess of destiny (who cut the thread of life, which means that the plant's name reverts to its poisonous properties), while “belladonna” means „beautiful lady”. Nightshade's unusual properties were already known in antiquity. In ancient Rome, belladonna berries were used to give the eyes a specific shine and to dilate the pupils (Szary, 2013). In the Middle Ages, nightshade was among the main ingredients of the „witch ointments” that produced hallucinations (Szary, 2013). The properties are caused by tropane alkaloids – atropine, belladonna, hyoscyamine, scopolamine – contained in nightshade. The substances are now used in medicine. The herbalist's raw materials –



Fig. 1. Deadly nightshade (*Atropa belladonna*)

Source: Wikimedia Commons (2016)

nightshade leaves and root-stock – are antispastic and analgesic agents utilized in many branches of medicine: for example, atropine is used to dilate the pupil for the purpose of eye screening in ophthalmology. It is also used to ease the attacks of bronchial asthma or renal colic, and also in the treatment of cholepathies (Volak and Stodola, 1987). The plants from which the extract is obtained for pharmaceutical purposes are cultivated as those naturally occurring are partly protected (Rutkowski, 2014; Regulation, 2014). One should bear it in mind that nightshade is really dangerous: just 3-4 berries consumed by a child may cause death (Hennenberg and Skrzydlewska, 1984).

Another wild relative of potato that occurs naturally in Poland is henbane bell (*Scopolia carniolica* Jacq.) (Fig. 2). The rare species grows in Eastern Carpathians and in Pieniny Mountains. It occurs most often in scrublands, highly shadowed forests (it prefers alder wetlands, beech forests, mountain sycamore forests), at the base of midforest rocks, on rocky slopes, and less frequently – in herb communities (Piękoś-Mirkowa and Mirek, 2006). In the Western Carpathians, it was



Fig. 2. Henbane bell (*Scopolia carniolica*)

Author: Joanna Gołębiewska

planted in graveyards and around shrines (Szary, 2013). It is a protected plant (Regulation, 2014) – its sites of occurrence are endangered particularly in alder forests, which suffer from flood control operations (Piękoś-Mirkowa and Mirek, 2006). Like its relatives, henbane bell contains substances that are dangerous for human health: hyoscyamine and scopolamine, which may permeate the skin. Its roots and rhizomes are particularly poisonous. The symptoms of poisoning relate to the nervous system (flush, dilated pupils, agitation, hallucinations, frenzy), the cardiovascular system (tachycardia) or the respiratory system (dyspnea and paralysis leading to death) (Szary, 2013). Small doses are used in medicine to reduce the smooth muscle tone, and due to its impact on the nervous system, the plant is also used in surgery and psychiatry (Czikow and Łaptiew [Chikov and Laptjev?], 1987). In the past ages, the peoples of Eastern Carpathians used henbane bell as an anesthetic and effective cure for alcohol poisoning; the plant also had the opinion of an effective aphrodisiac (Szary, 2013).

Bittersweet (*Solanum dulcamara* L.) is a common species throughout the plain and in lower mountain areas (Szafer et al. 1986). It prefers moist habitats, as e.g. river banks. It often occurs in alder swamps and ash-alder meadows (Witkowska-Żuk, 2013). In Europe, the plant occurs naturally; however, it turned out to be invasive once it was introduced in the North American flora (Witkowska-Żuk, 2013). As opposed to the other discussed species of Solanaceae, it is not an herbaceous, but a subshrub with a lignified stem. It is easily identified due to its flowers with a violet corona and yellow stamina as well as the red egg-shaped berries (Rutkowski, 2014) (Fig. 3). Its name is derived from the bitter-sweet taste of its berries, which are better left untasted – the plant is highly poisonous. For many ages, it was used in folk medicine as an expectorant, laxative and diuretic. This is no longer the case today, as an overdose



Fig. 3. Bittersweet (*Solanum dulcamara*)  
Source: H. Zell (A), Christian Fischer (B), Wikimedia commons (2016)



Fig. 4. Black henbane (*Hyoscyamus niger*)

Source: Parik Ilme, Wikimedia commons (2016)



Fig. 5. Black nightshade (*Solanum nigrum*)

Source: Andre Engels, Wikimedia commons(2016).

may be dangerous: excessive consumption of saponines contained in bittersweet causes hemolysis (Krejca and Macku, 1986). Bittersweet also contains steroid alkaloids: soladulcidine, solasodine and tometidenol (Różański, 2008).

#### Non-native species

As opposed to the species described above, black henbane (*Hyoscyamus niger* L.) is a plant of non-native origin. It is classified as an archeophyte, which means that it came to the territory of today's Poland before the Age of Discovery (16<sup>th</sup> century). Originating from the Iranian-Anatolian province, the plant reached Europe in the Neolithic Age, and the earliest archeological finds bearing the traces of its occurrence in the territory of today's Poland date from the Iron Age (Sudnik-Wójcikowska, 2011). Its most common habitats include fallows, roadsides, areas near human dwellings and rubbles (Kuźniewski and Augustyn-Puziewicz, 1986). Black henbane is easily identified in the field due to its cream-yellow corona petals with the characteristic dark violet reticulation and the large violet stamina (Fig. 4). Also its odor is characteristic, exceptionally strong and offensive (Stewart, 2011). Despite such clear diagnostic

features, cases of black henbane poisoning do occur. Sometimes the plant is consumed on purpose to produce hallucinations, as it contains a mixture of alkaloids including hyoscyamine, scopolamine and atropine (Kossak, 1995). The plant was particularly popular during the Middle Ages as an ingredient of the famous ointments that supposedly helped witches fly (Szary, 2013). The legend is not completely without grounds as the sense of floating is an inseparable symptom of black henbane poisoning (Kossak, 1995). Consumption of any fragment of the plant (each of its parts being poisonous) may cause paralysis of the central nervous system. The herb's strength was known already in ancient Egypt, about 2500 B.C. – it served as the ingredient of a potion that could instantly kill even the strongest persons, but was also used in moderate doses as a pain killer (Kossak, 1995). In Polish folk medicine, black henbane was used as an analgesic, diastolic, anti-asthmatic and anti-inflammatory agent, especially in parodontopathies (Kuźniewski and Augustyn-Puziewicz, 1986).

Another relative of potatoes, which came to the territory of today's Poland before 1500 (i.e. also an archeophyte) is the European black nightshade (*Solanum nigrum* L.). It is known to have arrived in Europe al-

ready during the Neolithic Age but its origins have not been determined yet. It is supposed to originate from Atlantic coast or from the Mediterranean area (Sudnik-Wójcikowska, 2011). It is common in the plains and lower mountain areas (Szafer et al., 1986). The species includes several subspecies, forms and varieties that differ from one another as regards sprout pubescence, berry color and leaf crenation. The plant is usually small (growing up to 0.5 meter high) with lozenge- and egg-shaped leaves with sinuate indentations gathered in an corymbothyrusus, white flowers with yellow pistils and shiny black berries up to 1cm diameter (Rutkowski, 2014) (Fig. 5). The plant also features variable content of glycoalkaloids (especially solanine) – their concentration varies from organ to organ and from population to population. Most dangerous, however, are unripe fruits and leaves (Sudnik-Wójcikowska, 2011; Kaźmierczak, 2015). The symptoms of solanine poisoning include diarrhea, dyspnea and brown color of urine indicating renal damage (Kaźmierczak, 2015). Black nightshade is a synanthropic plant related to man-transformed or –created habitats. Its convenient ecological niches include waste land, areas near human dwellings, ground adjoining fences, the vicinity of sewers, root crops cul-

tivation areas (as weed), and especially in areas where the soil is heavy (Żuławy) or excessively manured with nitrogen (Sudnik-Wójcikowska, 2011).

During the Age of Discovery, new and unfamiliar plant species were brought to Europe on a large scale. Many taxons of foreign origin became naturalized also in Poland where they occur naturally today. Neophytes – the name of non-native species that arrived after 1500 – can also be found among “potato’s wild relatives” (Kornaś and Medwecka-Kornaś, 2002). They include e.g. devil’s snare (*Datura stramonium* L.), probably brought to Poland with wool or soya during the first half of the 17th century from south-eastern areas of North America or South-European areas of USSR and western Asia (Szafer et al., 1986, Sudnik-Wójcikowska, 2011, Tokarska-Guzik et al., 2014). It is a species that does not invade natural plant communities (epiphyte) and occurs mainly in anthropogenic habitats, i.e. in ruderal habitats as well as field and garden crops (Sudnik-Wójcikowska, 2011). Devil’s snare is a large plant with a branched and slightly hairy stem, strong dark green leaves and flowers with a tubular calyx and

a white funnel-shaped corona (Fig. 6). It bears pouch-shaped fruits with characteristic long and rigid spikes and gradually spilling kernels with a reticular pattern (Sudnik-Wójcikowska, 2011). The plant arouses interest mainly because of its psychoactive properties due to the presence of poisonous tropine alkaloids (mainly hyoscyamine and scopolamine), tannins and organic acids in all of its organs (Kuźniewski and Augustyn-Puziewicz, 1986). It was used already in antiquity as a pain killer, soporific and aphrodisiac (Greene and Patterson, 1996; Herbert and Jagiełło-Wójtowicz, 2009). In the Middle Ages, it was used to increase the strength of beer (Müller, 1998). It also served as an ingredient of poisons the preparation and use of which was severely punished, including the death penalty for poisoners (Klepacki, 2007). Devil’s snare was also used by the followers of Buddha, Shiva or the bloody goddess Kali, who mixed it with food to produce visions (Sein Anand, 2009). The plant causes both somatic changes which consist in relaxation of the smooth muscles and inhibition of the secretion of fluids (including mucus, sweat, gastric juice) (Ożarowski and Jaroniewski, 1987), and psychic chang-

es as it provokes hallucinations. Cases of sexual abuse are known where the victim lost consciousness having been treated to devil’s snare seeds by the abuser (Müller, 1998). Despite its toxic properties, attempts were made for some time to use *Datura* extract and seeds to cure manias, epileptic fits (Steenkamp et al., 2004), as well as rheumatism and arthralgia (Angielczyk, 2011; Wdowiak, 2013). In many underdeveloped countries, the plant is still used today for healing purposes. In Nigeria, a mixture of devil’s snare and palm oil serves as a compress to treat painful insect bites, while in Nepal it is used as a pain killer, and – mixed with milk – for deworming. In Pakistan, women apply it to their breasts to prevent flabbiness (Garie and Subedi, 2013). Due to absence of legal regulations governing the cultivation and use of devil’s snare, the plant serves as an available and cheap drug. It is often used by young persons who are unaware of the consequences (Cunningham, 2008). It causes intense side effects preceded by highly realistic and unpleasant experiences that may lead to profound psychosis. The symptoms of devil’s snare poisoning include e.g. convulsions, tachycardia, dysuria, dryness of the mouth and increased pulse rate. Intoxication may persist for as long as several days and often leads to coma (Markiewicz, 2012; Motyka and Marcinkowski, 2014).

Another neophyte from the family Solanaceae, which occurs naturally in Poland, is bladder cherry (*Physalis alkekengi* L.). It is a perennial herbaceous plant with small green-whitish flowers. It has a large, much inflated, minium-red calyx hiding a shiny orange berry-type fruit (Fig. 7) (Rutkowski, 2014). It came to Poland from southern areas of Central Europe, south-eastern Europe and south-western Asia during the latter half of the 19<sup>th</sup> century (Sudnik-Wójcikowska, 2011). Due to the intense color of its calyx, it is used nowadays for decorative and culinary purposes. It is edible and may be consumed both raw and processed, e.g. as marmalade.



Fig. 6. Devil's snare (*Datura stramonium*)

Source: Júlio Reis (A), H. Zell (B), Wikimedia commons (2016).



Fig. 7. Bladder cherry  
(*Physalis alkekengi*)

Source: Bff (A), Friedrich Böhringer (B), H. Zell (C); Wikimedia commons (2016).



Fig. 8. Chinese wolfberry  
(*Lycium barbarum*)

Source: Danny S (A), AnRo0002 (B), Wikimedia Commons (2016)

Water extracts from bladder cherry fruits have detoxifying properties and increase urination and thus also elimination of harmful metabolites. They also reduce inflammation and edema, and regulate metabolism due to their content of flavonoids and saponines (Różański, 2007). It can be found in man-transformed habitats, such as gardens, allotments, shrubs or waste land within residential areas (Sudnik-Wójcikowska, 2011).

Chinese wolfberry (*Lycium barbarum* L.) (Fig. 8) is a neophyte like the previous two species; it is treated as a spreading threat to the native flora that is hard to eliminate (Tokarska-Guzik, 2012). It came to Poland from China in mid-18<sup>th</sup> century. Owing to its resistance to drought and high temperatures and tolerance of high nitrogen concentrations in the soil, it is planted all over Poland on river bank protections, buttresses, slopes and various heaps for their protection against erosion (Sudnik-Wójcikowska, 2011). Like most species of the family Solanaceae. Chinese berry is classified as poisonous

(Szafer et al., 1986; Rutkowski, 2014). Cases are known of poisoning with its fruits of both humans and animals (Henneberg and Skrzydlewska, 1984). Surprisingly, despite their toxic properties, the fruits of Chinese berry and its close relative *Lycium chinense* Mill. are valued delicacies in Asia, where they are boiled and added to soups, rice, chicken or pork dishes. They are also used to prepare herb teas, juices, wines and fruit cordials, and also powdered and added to dietary supplements and tablets (Bogacz, 2009). The fruits are popular under their commercial name of „goji”. They were used for ages in traditional Chinese medicine to treat diseases of the lungs and heart as well as rheumatism over 2.5 thousand years ago. Today, they are a regular ingredient of many persons' diet, which is due to discovery in their composition of a water-soluble bioactive polysaccharide complex (LBP – *Lycium Barbarum* Polysaccharides) whose properties enhance immunity, delay aging and contribute to cancer prevention (Gan et al., 2004; Amagase et al., 2009; Kulczyński and Gramza-Michałowska, 2014). Besides, they are an excellent source of vitamins, minerals (e.g. phosphorus, copper, zinc, selenium, calcium and iron), carotenoids and polyphenol compounds as well as proteins, carbohydrates, fats and unsaturated fatty acids of the omega-6 group, enhancing the efficiency of operation of the nervous system, brain, vision, liver and heart (Quian et al., 2004; Luo et al., 2004; Amagase et al., 2009; Bogacz, 2009; Cieślak and Gębusia, 2012). One should bear in mind, though, that the goji fruits should not be consumed unprocessed as they may disturb the functioning of the nervous and alimentary systems.

### Recapitulation

The family Solanaceae comprises not only the popular cultivated plants (potato, tomato or bell pepper) but

also a variety of naturally occurring species. Found in Poland are both native and non-native species, including invasive taxons that threaten the native flora. Some plants (henbane bell) are protected, but most are common synanthropic plants, often growing in the vicinity of human dwellings. Many have poisonous or medicinal properties that have been utilized for ages. One should bear it in mind that Solanaceae consumed as hallucinogens are extremely dangerous and may cause permanent changes of the central nervous system, serious disturbances of the alimentary and cardiovascular systems, and even death.

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# Exploring the world using the sense of smell

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## Summary:

The sense of smell, also known as olfaction, is one of the chemical human senses. This means that sensory stimuli are received by the human body through contact with chemicals. The smell becomes recognizable when the responsible chemical meets certain requirements e.g. it becomes volatile. Chemicals with similar structures can make an impression of radically different aromas. A slight change in the spatial structure or removing one atom from a molecule may be enough to make an odour pleasant. Sometimes, the concentration of the substance decides on the nature of the smell – the same chemical compound can make evoke the smell of flowers or of rotting flesh. As it turns out, the sense of smell also plays an important role in the sense of taste.

**Key words:** fragrances, organic chemistry, human senses, smell

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It is hard to imagine a world without smells. It's not just about the inability to enjoy the aromas of freshly ground coffee, English roses or the earth after rain. Impairment of the sense of smell, called anosmia, affects even as much as 6% of human population and leads not just to the impoverishment of smell sensations, but also to the disturbance of taste perception and... recognizing emotions (Croy et al., 2014). The goal of this paper is share basic information about aroma compounds. In this article, you will find information on how the human body copes with smells and how the chemical structures of aroma compounds influence the type of smell sensation. We will hereby present and illustrate differences in the chemical structure of some organic compounds that may seem to be irrelevant, but actually influence their properties in a significant way.

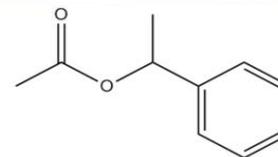
The sense of smell is one of the most primitive ways of perceiving the surrounding world. This may be associated with predators hunting for their prey and may seem to be insignificant for modern humans. Nothing could be more wrong!

Smell is associated with a human being from the first moments of our lives. The smell of a mother's body is one of the first recognized by an infant, and so is the smell of food and the baby's environment. This is actually a period of life when odors start to play an important role in creating memories and emotions, which is attributed to the proximity of the olfactory system and the limbic system in the human brain. Each of us can name at least a few smells that connote good – or to the contrary, bring up bad – memories. Sometimes a single smell can suddenly recall completely forgotten emotions and memories. Research conducted on a group of volunteers confirm the hypothesis that the sense of smell serves as a communication channel between people – in this original way, we can sense each other's fear, dismay or disgust and the alarm of others in our area about a serious threat (De Groot et al., 2012). In 2004, the Noble Price was awarded to Linda B. Buck and Richard Alex for their research, which proved that as much as 2% of the human genome is involved in coding smell receptors, also known as odorant receptors, over

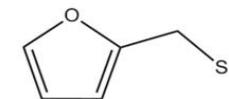
Fig. 1. Aroma compound structures with exemplary origins:

a – perfume component: gardenia flower aroma,  
b – freshly brewed coffee aroma

Photo: Irmina Wojciechowska



1-phenylethyl acetate



mercaptan furfuryl

half of which are active genes. This fact proves just how important smell stimulants are to people (Nobel Media AB, 2004). The desire to modify the smell of one's own body is nothing new. What once served as a camouflage and a way to blend into the crowd, has become a way to stand out. We mask our individual smell to become someone else, to highlight our individuality and expose particular features of our personality. It is impossible to provide a single reason as to why a sensual fame fatale should smell of ambergris and musk, and a successful man of citrus and cedar, just as there is no way to assign certain smells to universal labels to which everyone with a working nose can agree. There are as many opinions about smells as people; however, it seems obvious that a person smelling nice to us will generate more sympathy. But here comes the hippocampus again, demanding its weighty role, controlling our emotions and memories (Brud and Konopacka-Brud, 2009).

Defining the nature of smell is not an easy task; therefore theories on how we identify smells have frequently divided scientists into two camps.

We can draw one conclusion from the explanations presented in Wright's vibration theory (Wright, 1961) or Amoore's stereochemical theory (Amoore, 1952): it is not just the 3-D structure of a compound that determines the way something smells, but also the presence of certain functional groups.

The smells that we detect are built from chemical compounds. To receive aroma stimulants, a compound needs to be volatile – this is a necessary condition. The presence of osmophores, functional groups present in aroma compounds, is also important. Usually, the compounds that contain functional groups with built-in oxygen atoms, such as hydroxyl, ether, aldehyde, ester or ketone groups, tend to create pleasant sensory impressions, unlike the groups with built-in sulfur or nitrogen atoms, such as the thiol group. However, there

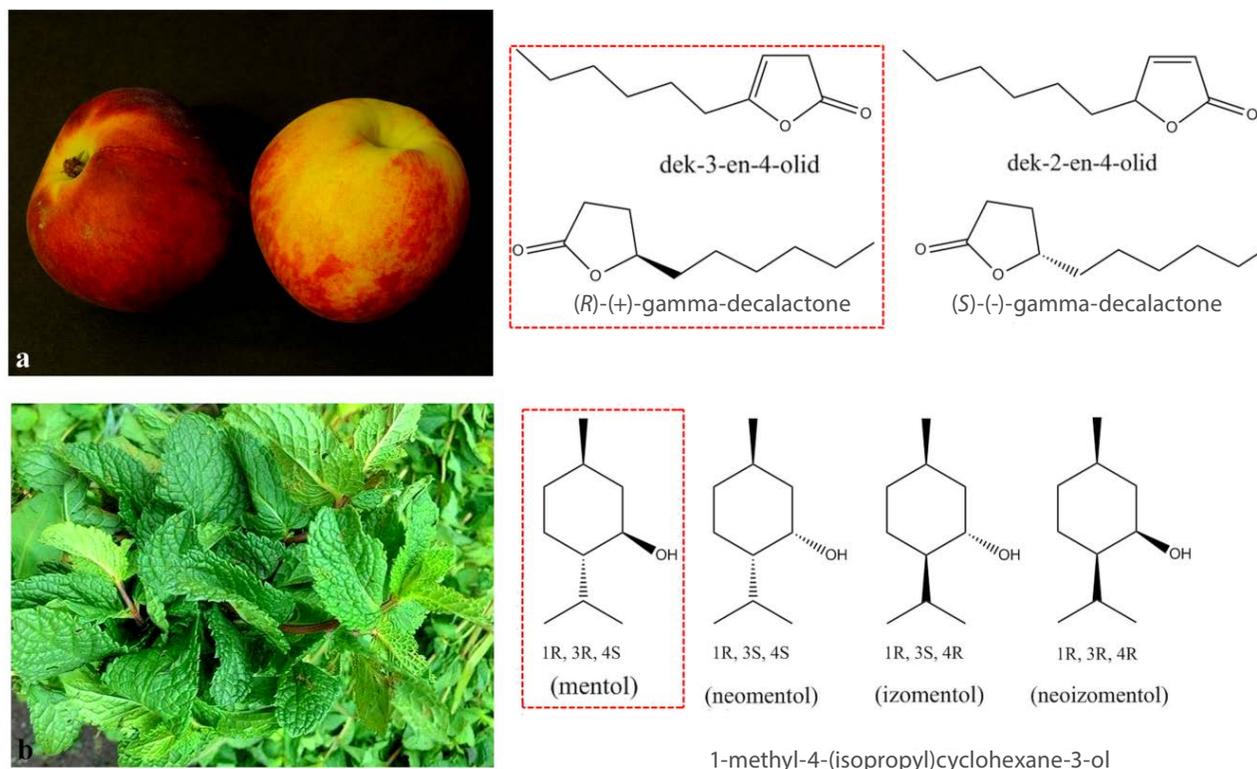


Fig. 2. The connection between isomerism and the chemical properties of organic compounds: structures colored red contain the smell of peach (a) and mint (b)

Photo: Irmina Wojciechowska, Aleksandra Wojciechowska

are some exceptions to this rule, for example furfuryl mercaptan (Fig. 1), which contains a thiol group, but is responsible for the delightful smell of freshly brewed coffee (Sunarharum et al., 2014; Mitka and Saryńska, 2012; Mills, 1995).

Any person working with the chemistry of smells can sometimes predict the aroma of a compound just from its structure – the presence of aroma rings, unsaturated bonds, or heteroatoms. This has a huge impact on designing new aromas and on the production of

compounds that can replace natural scents that are difficult to acquire. A good example is synthetic vanillin, which has excellent productivity and successfully replaces traditional natural vanillin acquired from a *Vanilla planifolia* plant (Turin and Yoshii, 2002).

Popular and cheap nitro-musk produced on a large scale for the cosmetics industry replaces natural musk that costs a fortune. This type of progress must be enjoyed by Siberian musk deer, as the production of this beloved scent has caused their destruction since the time

when poachers were searching for this lucrative source of income. It is also important to mention the group of fatty aldehydes containing from 10 up to 12 carbon atoms in their structure; without them, the world-famous fragrance composition of Chanel No. 5 could have never been developed (Mitka and Staryńska, 2012).

It also happens that traditional chemical synthesis cannot meet the demands of the consumer market. This is when biotechnology comes into play, as in the case of gamma-decalactone, a cyclic ester with an annual production of several hundred tons. As a result of chemical synthesis, we can obtain a racemic mixture of products, such as *R* and *S* enantiomers of gamma-decalactone. The first has the recognizable aroma of peach and the second one – of mango (Fig. 2). To avoid the creation of racemate, the desired product is obtained on an industrial scale from *Yarrowia lipolytica* yeasts (Krzyczkowska et al., 2009).

Gamma-decalactone is not the only example of how much influence the 3-D structure of compounds has on smell sensations. A widely known aroma compound is menthol, actually (*1R,3R,4S*)-1-methyl-4-(isopropyl)cyclohexane-3-ol. Even though it has three isomers, only the levorotatory menthol is responsible for the distinctive, mint taste and smell and its refreshing cooling effect. The remaining isomers do not have these properties, even though the structure differences between them are slight (Fig. 2).

Gardenol, also known as 1-phenylethyl acetate, has a distinct smell, described as green, sweet and flowery, bringing to mind gardenia flowers (hence its popular name). This compound is found, for instance, in La Panthere, the elegant fragrance composition from the Cartier fashion house. On the other hand, its constitutional isomer 2-phenylethyl acetate, smells like ripe, honey peach and apricot (Fig. 1). Such examples can be

multiplied. All you have to do is to move an unsaturated bond in a compound of dec-3-en-4-olide to change the pleasant fruity smell into a distinct fungal aroma typical for dec-2-en-4-olide (Brud and Konopacka-Brud, 2009).

There is also the interesting case of eliminating just one carbon atom from an alkyl substituent in a cyclic lactone ring. A compound containing an aliphatic string composed of 5 atoms of carbon in its structure was named cognac lactone, while the compound with one less carbon atom was named whiskey lactone (Fig. 3). Both of these compounds are, of course, used to aromatize the respective alcohols from which they take their names (Krzyczkowska et al 2009).

The 3-D structure influences not only the type of smell our noses perceive, but also its intensity. It was determined that dextrorotatory nootkatone enantiomer, a grapefruit-like smelling compound, is a thousand times more detectable than its levorotatory isomer of the same aroma. This means that we are able to determine the smell of a dextrorotatory isomer as grapefruit-like at a thousand times lower concentration than in the case of its levorotatory enantiomer (Furusawa et al., 2005).

The dependence on concentration for determining the smell of a substance is a typical characteristic of aroma compounds. Usually, the higher the concentration of a compound, the more abhorrent is its smell. For example, isobutyric acid has a strong, piercing smell, but when diluted, it turns out to be pleasantly fruity; 2-methylbutyric acid changes its aroma from sharp, irritating and “cheesy” to pleasantly fruity; and isovaleric acid from cheesy and unpleasant to herbal with a hint of nut and coffee (Krzyczkowska et al., 2009). Even more surprising examples are skatole and indole, two products of the tryptophan metabolism: their high concentration is responsible for the smell of mammalian feces, but in lower concentrations, they release flowery aromas

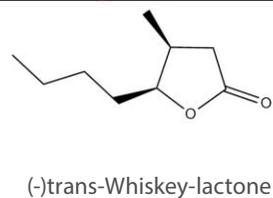
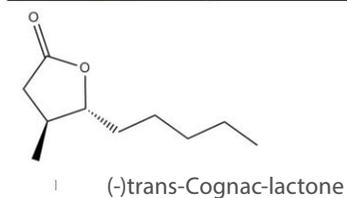


Fig. 3. A small difference in the compound structure results not just in a different smell, but also taste, which is noticeable, for example: in the compounds that are the aroma components of cognac (a) and whiskey (b)

Photo: Maria Teresa A. Reis

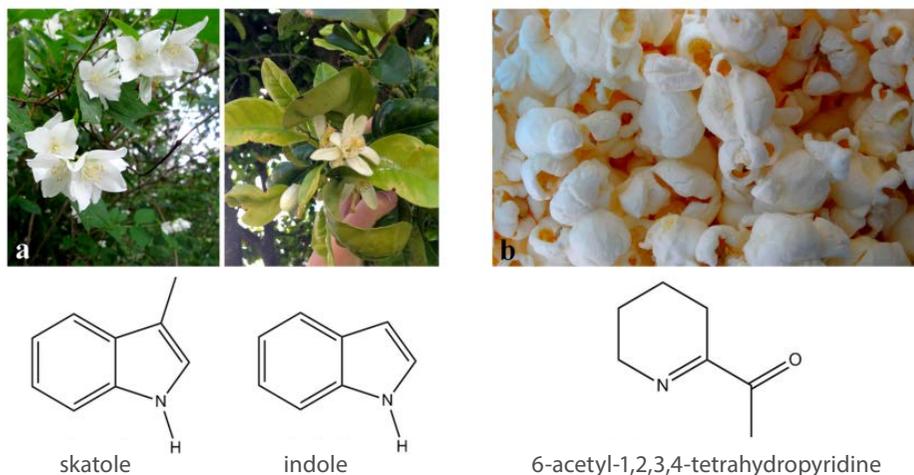


Fig. 4. Skatole and indole at low concentrations smell like orange flowers and jasmine (a); 6-acetyl-1,2,3,4-tetrahydropyridine is responsible for the aroma of popcorn and fresh bread (b)

Photo: Irmira Wojciechowska

(Fig. 4). Moreover, skatole is used to aromatize tobacco (Bera et al., 2014).

It is not always possible to get rid of an unpleasant smell by dilution. A good example is two biogenic amines, putrescine and cadaverine, also known as death aromas. These are products of amino acids, ornithine and lysine metabolism, respectively, and the first ones to be produced in a decomposing body after death. Their almost immediate appearance creates the opportunity for rescue dogs to quickly find bodies under the rubble of collapsed buildings. It is also important because, aside from their disgusting smell, these compounds – belonging to the ptomaine group, i.e. so called cadaverous poisons – are harmful to human health and toxic in high doses. Moreover, it is interesting to point out that putrescine is also responsible for common “morning breath” (Hussain et al., 2013).

The sense of smell is not the only chemical sense of a human being. In case of the sense of taste, we can talk of the high correlation between the structure of food compounds and the emotional assessment of the sen-

sual sensations we perceive. Since 2015, a new developing science called neurogastronomy has been arousing the interest of many people. This field of science studies the connections between the functioning of human senses and perceived tastes. In other words, the light in a restaurant, the color of a plate or the texture of your meal each plays a key role in the perception of taste. The smell we receive is even more important (University of Kentucky, 2015).

The human nose serves several functions. Two of them constitute the subject of this article. The first one is to receive external stimulants, i.e. to examine the flow of information coming from the environment. The second function is related to sensing the smell of what we have inside our mouths, i.e. the perception of internal stimulants. Oral smell is stronger than the smells coming from the outside, so even a small concentration of aroma is enough to notice it. Some researches proved the hypothesis that we cannot properly assess the taste of a meal unless we can sense its aroma (Bałczewska, 2000). Without the ability to smell, some tastes become suppressed and are hard to recognize, while the others,

such as, for example, the taste of chocolate, disappear altogether (Shepherd, 2015).

Shops selling bread take advantage of the phenomenon of the correlation between the senses of smell and taste and use a synthetic aroma compound called 6-acetyl-1,2,3,4-tetrahydropyridine (Fig. 4) to aromatize the air with the smell that recalls the smell of bread crust, fresh popcorn and crunchy buns to customers. This pleasant smell, which may have nothing in common with the actual quality of the particular bakery's products, recalls a taste that we know. We succumb to the emotional reaction to the smell, which allows us to sense the taste in a fuller and more pleasant way (Adams et al., 2004; Harrison and Dake, 2005).

A world without smells would be undoubtedly poor. Human emotions and memories, our communication and the expression of who we are and who we would like to be to others, would also be impoverished. Without the information sent by the sense of smell, we would ignore the dangers we face. The nature of smell itself is incredibly complex: from the mechanisms by which the human body receives smell signals ending with the structures of smell-stimulating chemical compounds themselves. In the end, it is difficult not to come to the conclusion that our lives would be significantly changed without smells; they are of great importance to us, since they help in perceiving the world that surrounds us.

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# Properties, application and degradation of plastics

Agnieszka Szyszkowska, Dagmara Galas

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## Summary:

The aim of the study was to present the role of polymeric materials in various industries. The article discusses the statistics related to the global production of plastics in the years 1950-2015. The paper presents the properties and application of polymer materials, and also made the characteristics of the processes of degradation of polymers, detailing the processes induced by chemical agents, physical and biological. Attention is paid to the characteristics of the biodegradation process. The work has also raised issues associated with the development of ever-larger amounts of polymer waste.

**Key words:** polymers, biodegradation, plastics

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## Overview

This study is aimed to present the role of polymers in various economic sectors. The article describes statistics related to international production of plastics in the years 1950-2015. It provides properties and applications of polymer materials and characteristics of polymer degradation processes with details paid to processes generated by chemical, physical and biological factors. Special consideration was paid to the characteristics of the biodegradation process. The study also addresses issues related to the development of the increasing amounts of polymer waste.

## Introduction

Polymer-based plastics are commonly available as materials used for making day-to-day items and specialized products such as prosthesis. They are often used to replace conventional materials such as wood, glass or paper. Every year, increasing amounts of polymer materials are manufactured. Polymer production in Poland amounts to approximately 2.1 million tons of polymers per annum (Endo et al., 2008) with global annual production reaching 300 million tons (Cordier et al., 2008). Synthetic polymers are widespread due to their ideal mechanical, chemical and physical properties. In addition, these properties greatly improve these materials' resistance to natural decomposition and microbial activity being the main cause of biodegradation and disposal of these materials (Saruchi et al. 2016).

## Aim of the study

This study is aimed to review the literature concerning the issues related to polymer material biodegradation. It addresses statistical data related to the world-

wide manufacture of plastics and presents properties and applications of polymer materials. It discusses the polymer degradation process with special attention paid to biodegradation.

## Review methods

This study provides a review of Polish and English literature devoted to production and biodegradation processes involving polymer materials up to the year 2016. The literature was searched for in the PubMed as well as in Elsevier and Springer databases with the use of the following keywords: polymers, biodegradation, degradation, polymerization.

## Review results

### Worldwide production of plastics

Polymers are macromolecular organic compounds resulting from polymerization, i.e. bonding of single molecules (mers) into larger sections (polymers). They comprise the basic component for the production of

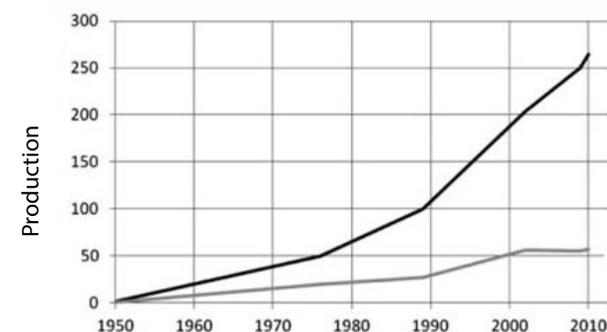


Fig. 1. Plastics production volume in Europe and around the world in the years 1950–2010

Source: *Plastics Manufacturers in Europe Report*, 2010.

plastics (materials made of modified polymers, either natural or synthetic, and modifying additives, e.g. dyes).

In the recent years, a continuous growth in the production of plastics has been observed in Europe and around the world (Fig. 1). Between 1990–2000, the global production volume of plastics grew by approx. 100 million tons and further growth is being observed from year to year (Fig. 2). In 2010, 24% of plastics were produced in China thus, making this country the world's leading manufacturer of plastic. Due to a growing level of significance of polymer materials, their production grows on a year-to-year basis (Plastics Manufacturers in Europe Report, 2010).

In 2014, there was a 5% growth (as compared to 2009) in the production of plastics in China making it still the largest global manufacturer of plastic materials. The percentage of Asian countries in global production of plastics in 2014 was 42% and 20% for the European countries (Plastics Manufacturers in Europe Report, 2015).

### Properties and applications of polymer materials

There is an increasing use of polymer materials due to their properties such as low weight, easy processing, durability, mechanical resistance, chemical resistance and low production costs. They have been applied in various industry sectors. In addition, they are also used as composite components to improve their physical and mechanical properties. This combination allows the user to obtain materials featuring low weight, biodegradability, high durability and stiffness, corrosion resistance and low friction coefficients. The polymer materials have been applied in numerous industry branches such as construction and electronic industry, medicine, transport, and home appliance manufacture.

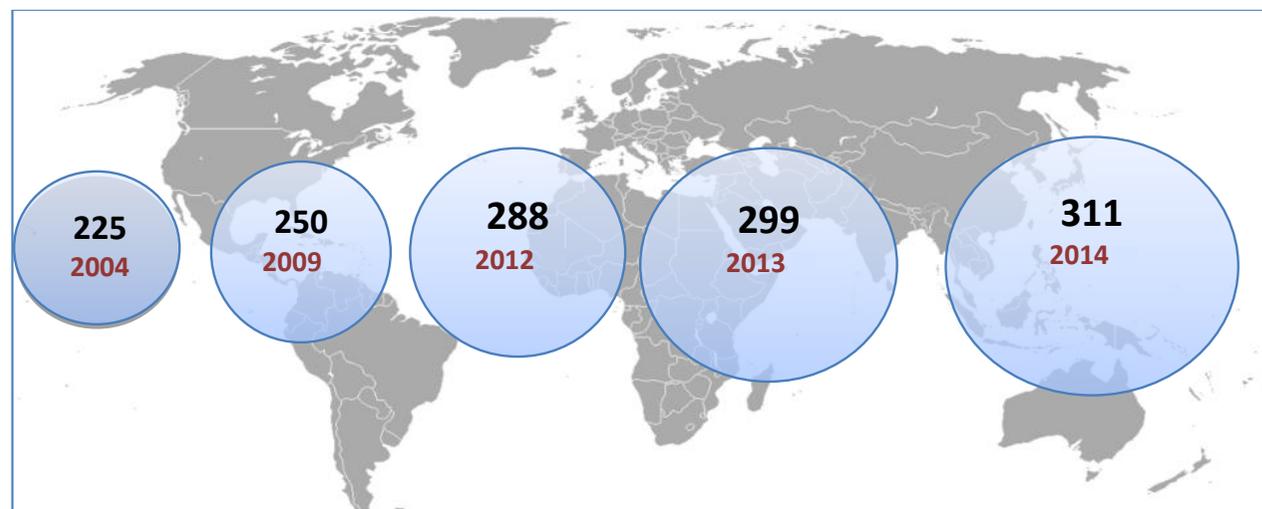


Fig. 2. Global plastics production growth over the years (in millions of tons per annum)

Source: own elaboration on the basis of *Plastics Manufacturers in Europe Report*, 2015.

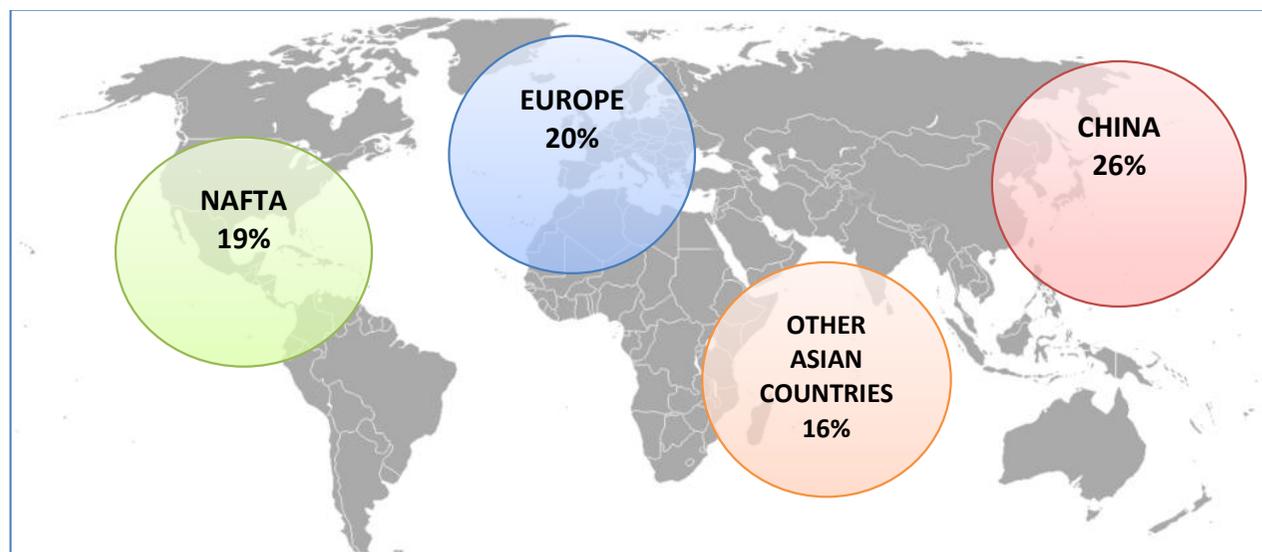
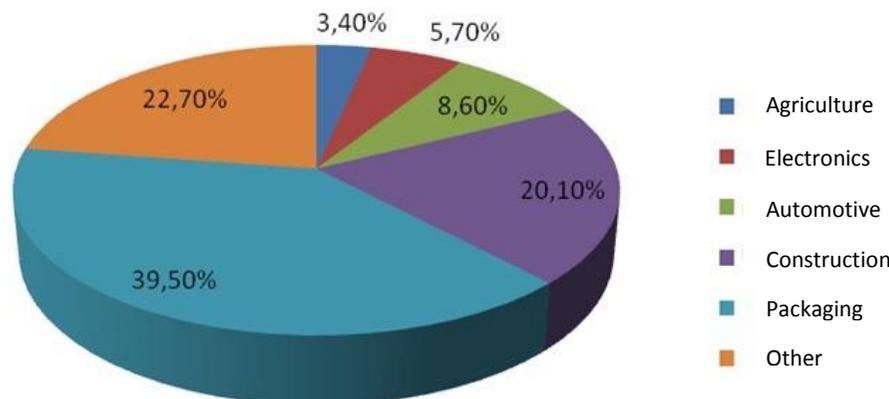


Fig. 3. Percentage of global production of plastics in 2014; NAFTA (North American Free Trade Agreement)

Source: own elaboration on the basis of *Plastics Manufacturers of Europe Report*, 2015.

Fig. 4. Plastic material applications worldwide in 2015

Source: own elaboration on the basis of *Plastics Manufacturers in Europe Report*, 2015.



Just like in the previous years, in 2015, the largest amount of plastics was used to make various types of packaging (approx. 39.5%). 22.7% of plastics are used in the manufacture of home appliances, furniture, sport and medical articles. Furthermore, polymers are used in construction and automotive industries as well as electronics and agriculture (Plastics Manufacturers in Europe Report, 2015).

The most popular synthetic polymers include polyethylene (PE), poly(vinyl chloride) (PVC) or poly(ethylene terephthalate) (PET). The polyethylene created as a result of polymerization is commonly used to make plastic bags, bottles, packaging and foil (Shah et al., 2008). It also features extreme resistance to degradation. An estimated environmental decomposition time for polyethylene is approx. 300 years (Kyrikou et al., 2008) making it an enormously burdensome material for the environment. It generates disposal-related problems. The poly(vinyl chloride) is created as a result of vinyl chloride polymerization process. It is commonly used in the production of leads, cables, carpets, catheters and syringes. The poly(ethylene terephthalate) is a synthetic polyester applied in the manufacture of fast-drying fibers, photographic films, clothing, bot-

tles and packaging of various types. The environmental degradation time for poly(ethylene terephthalate) ranges from 16 to 48 years (Shah et al., 2008).

#### Degradation of polymers

Depolymerization and degradation are polymer chain-destroying processes leading to polymer molecular mass limitations (Porejko and Zakrzewski, 1974; Rojek, 2011). The depolymerization causes polymers to be converted into monomers, thus making it a reaction opposite to polymerization. This process is used, inter alia, in plastic recycling processes as it allows the user to recover the monomers that can be reused for synthesis. An example of thermal depolymerization applied in recycling processes is decomposition of poly(methyl methacrylate) (*the so-called Plexiglas*). The monomer obtained as a result of this reaction comprises a substrate for re-polymerization (Żwir and Sychaj, 2007). Polymers can also decompose into low-molecular compounds other than monomers. For example, polyolefins exposed to UV and VIS radiation decompose while creating macroradicals and hydrogen. Then, under the influence of atmospheric oxygen, an oxidization process occurs that creates polar groups. Consequently, the

polymer becomes brittle, it cracks while changing its color and losing its mechanical properties. The polymer decomposition processes may be caused by both physical factors (temperature, light) and chemical factors (acids, alkalis). Quite frequently, plastic exploitation processes involve polymer degradation processes that cause polymers to be disintegrated into fragments of large masses (but of smaller molecular masses as compared to those of the original polymer). The degradation may occur under the influence of physical factors (ionizing radiations, ultrasounds, sunlight, high temperatures), biological factors (enzymes, bacteria, fungus) and chemical factors (air, etc.). The following are found to be the most important effects of polymer degradation process:

- Separation of atoms and functional groups from polymer chain leading to changes in chemical structure of a single structural unit;
- Random ruptures within main carbon chain;
- Creation of bonds between structural units belonging to various polymer chains (cross-linking process);
- Introduction of lateral substituents into the main polymer chain (Florjańczyk and Penczek, 2002; Stevens 1983; Czaja 2005).

#### Types of polymer degradation

The type of the factor causing multi-molecular compounds to decompose provides the most frequent basis for the classification of polymer degradation processes (Kaczmarek and Rabek, 1997; Mucha 2002; Zinowicz et al., 2003.). The following types of polymer degradation are distinguished:

Degradations occurring under the influence of physical factors:

- **Mechanical degradation** refers to macroscopic effects that occur in polymers due to fragmenta-

tion, grinding, freezing, melting, etc. The shearing forces generate tensions capable of overcoming the energy of valence bonds between polymer chain carbon atoms. This results in structural changes of the material that are either local or can include the entire surface (Booth, 1963).

- **Thermal degradation** occurs when a polymer changes its properties under the influence of higher temperature. These changes may be of reversible and irreversible nature. The reversible changes include phase transformations, supermolecular-structure disaggregation and transformation of polymer into viscous liquid state. As regards the irreversible changes, they refer to above flow-temperature processes which are often accompanied by the process of freeing low-molecular volatile compounds such as carbon dioxide, alkanes, alkenes, amines and water (Villetti et al., 2002; Madorsky and Straus, 1959). Quite frequently, plastics contain additional components (e.g. dyes, fillers, stabilizers) that may react with polymers in higher temperatures thus, causing **thermal and chemical degradation**.
- **Photochemical degradation** occurs under the influence of light. The light-absorbing chromophoric groups in the polymer chain must be present for this reaction to occur. The products made of such polymers are at risk of being exposed to sunlight or may get damaged as a result of this type of degradation (Kumari et al., 2001).
- **Degradation by radiation** occurs under the influence of X-rays and gamma radiation. It leads to structural changes in polymers, mainly to cross-linking, generating volatile products and cyclization. Degradation triggered by high-power radiation occurs more rapidly as compared to degradations imposed by other factors (Żenkiewicz, 2005).

Degradations occurring under the influence of chemical factors:

- **Atmospheric degradation** occurs in line with photo oxidation and thermal oxidation. The photo oxidation is the result of UV radiation in the presence of oxygen and occurs mainly on polymer surface. The thermal oxidation takes place in increased temperatures. The process may occur in the entire volume of the material. The atmospheric degradation leads to changes in chemical composition of polymers and molecular masses and it also can lead to cracks and gouges on the surface (Guarrotxena and Millan, 1999).
- **Chemical degradation** is initiated by chemical compounds of low molecular masses and leads to destruction of polymer materials.

Degradations occurring under the influence of biological factors:

- **Biological degradation** refers to environmental decomposition of polymer materials following a specific period of time due to the activity of enzymes discharged by microorganisms under the conditions that are favorable for their growth. This consequently leads to shorter polymer chains, changes in physical and chemical properties as well as mechanical properties of polymers (Grabowska, 2010).

Generally, a polymer degradation triggered by physical factors is often referred to as a polymer ageing process whereas in case of chemical factor-triggered degradations, it is called a polymer corrosion (Rabek, 1977).

#### Biodegradation

Biodegradation (*gr. bios – life, lat. degradatio – reduction*) is a specific property of some of polymer materials and it refers to decomposition of materials under the influence of biotic factors. Microorganisms treat

polymers as potential sources of organic compounds (sugars, amino acids, etc.) that can be transformed into life-sustainable energy. Biodegradation is not a process limited merely to the world of microorganisms. Microorganisms are always present in a material biodegradation process while part of the whole mechanism may be of an abiotic character (Shah et al., 2013; Scharnweber, 2016). On the most frequent basis, polymers degrade in a two-step way by going through initial and final degradation phases (Fig. 5). The first phase includes macroscopic changes such as discolorations, increased brittleness and decreased physical properties of polymer materials. These modifications occur due to the impact of sunlight, oxygen, water, temperature, tensions and microorganisms. The primary carbon-carbon bonds in the polymer chain are ruptured thus, creating shorter chains. This leads to a decreased molecular mass which is the result of hydrolysis in the water environment with or without the participation of enzymes under the abiotic conditions. The reduced number of branches and molecular mass of the compound causes it to become more available for microorganisms carrying out a proper biodegradation process. In the second phase, the created polymer fragments are mineralized into carbon dioxide, water and biomass (oxidative conditions) or methane, carbon dioxide and biomass (non-oxidative conditions). Standard organic compounds degraded by microorganisms must first reach the inside of the cell either through passive diffusion or specific transport systems. However, in case of large-size polymer substrates, the biodegradation process is initiated by extracellular enzymes which trigger an initial decomposition of the compound (Lucas et al., 2008; Eubeler et al., 2009; Krzan et al., 2006; Briassoulis, 2006).

A lot of factors, such as polymer type (molecular mass, crystal and amorphous phase, specific surface development degree, porosity level), microorganism type,

discharged enzyme type and variable conditions during current reactions (pH, temperature, humidity), impact the biodegradation process. This process is facilitated by soils abounding in humus that comprise an environment suitable for the development of microorganisms (Kołwzan et al., 2005). It is assumed that during biodegradation two types of reaction occur – hydrolysis and oxidization. These reactions may occur either in a simultaneous or consecutive way. Biodegradation processes tend to be time consuming and changes to mechanical properties, loss of mass and a decrease in degradation levels occur gradually (Leja and Lewandowicz, 2010; Webb et al., 2013).

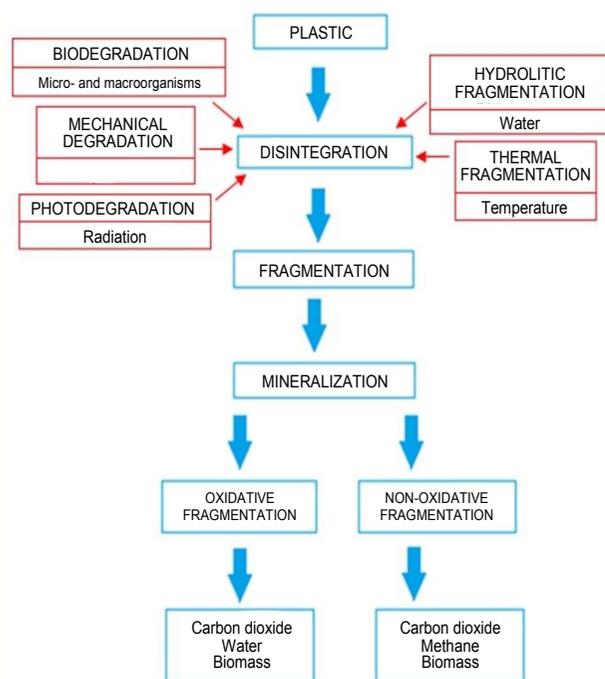


Fig. 5. Polymer degradation process.

Aside from plastics utilization, the biodegradation process is also applied in sewage treatment plants as part of fermentation-based purification processes carried out in biological ponds. Biodegradation is also used for bioremediation (removal of impurities from sub-soil waters and soils with the help of microorganisms) or purification of soils contaminated with petroleum products (Kumar et al., 2011).

### Oxo-biodegradation

Oxo-biodegradation of plastics consists in decomposing plastic into smaller fragments which are then subjected to further biodegradation. The process is accelerated by external factors such as a prodegradant (catalyst) (Rodrigues da Luz et al., 2014). The prodegradants are usually salts (stearates, dithiocarbamates) of transition metals capable of changing the oxidation level (Fe, Co, Mn, and others) (Paukszta, 2015). Another stage is the mineralization process with the participation of microorganisms. The physical factors that activate the decomposition process include solar radiation (UV), temperature, pressure and mechanical damages. The oxo-biodegradable materials degrade in both open and closed systems and do not require the presence of water. Their decomposition time is shorter than for standard plastics and may also be adjusted to user's needs by the manufacturer. The oxo-biodegradable plastics may also be manufactured from recovered raw materials (Gibas and Rymarz, 2009; Portillo et al., 2016). The oxo-biodegradation of plastics in natural environment occurs under the influence of oxygen and is accelerated by solar radiation. Fragments of plastic are absorbed by the microorganisms which transform it into carbon dioxide, water and biomass.

### Biodegradation vs environment

An ability to succumb to biodegradation processes is currently a desirable property of plastic products. It eliminates the long-term waste storage requirement. The advantage of biodegradable products is that they decompose quickly into very small fragments. However, nano- and picoplastic resulting from this process may be swallowed by live organisms or penetrate through cell membranes and directly damage the inner organs of the organisms. On the other hand, traditional plastics are not biodegradable and remain in the environment as a growing ecological threat (dangerous plastic components may penetrate all trophic levels). Another advantage of biodegradable plastic packaging is the option to collect such products together with organic waste and then to utilize them by composting in industrial installations to prevent costly recovery. Organic waste composting processes are based on natural biochemical processes and are relatively safe in environmental terms (Stachurek, 2012; Gross and Kalra, 2002; Kucharczak et al., 2010).

### Conclusions

Growing market demand for polymer plastics stimulates increased production of these products and along with it comes the creation of enormous amounts of waste (25.8 million tons in 2014 in EU states). Plastics feature a very extensive decomposition time causing great difficulties related to their utilization. However, these materials are pretty comfortable to use and for this reason new plastic degradation methods are still being searched for. Expanding our knowledge in this area is still of great significance as degradation methods applied nowadays are still far from being perfect.

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# Educational computer games in geography

Wojciech Pokojski

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## Summary:

The Internet provide access to interactive websites and applications on-line for learning.

The article presents an overview of the didactic games in a field of geographical education available mainly in the form of websites and online applications enabling interactive learning. This article contain evaluation of these games.

**Key words:** didactic games, geography, Street View

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## Introduction

At the time of functioning of the information society, it is the duty of the teacher to use various techniques supporting the learning process in the classroom. The development of the Internet and computer techniques has contributed to many ingenious applications and programmes dedicated to conveying information and acquiring knowledge. A teacher willing to enrich his or her toolkit and to make his or her students' learning more diverse and reaching for such tools should be

able to first evaluate them critically, and then to recommend the selected, best ones to the students. Through identification of learning assisting applications and programmes, a teacher may build the new learning environment, as described by M.M. Sysła (2009), for himself or herself and for the students through the creation of conditions for acquiring skills: "seeking, ordering and using information from various sources and effective use of the information technologies". According to Z. Osiński (2009), the use of information technologies in teaching is aimed at obtaining by students key competences to prepare young people for successful functioning in the reality of information society.

Skilfully introduced into a series of lessons, educational games enable development of memory, perceptiveness, attention, logical associating and reasoning skills (Nodzyńska, 2011), they teach perception of rules and are an element that improves the attractiveness of classroom activities (Czepiżak, Wądołowski). According to Kisiel (2011), introduction of educational games into the teaching process enriches curricula not only with multimedia elements, but also interactive ones, which should lead to a more attractive and effective instructional process.

The first computer programmes dedicated to teaching geography emerged in the 1980s, electronic atlases became common in the 1990s (Pliszka, 1997), which were then superseded along with the development of the Internet with interactive maps, geoportals and virtual globes that belonged to a new subcategory of GIS – called webGIS (Pokojski, Pokojska, 2012). The possibility to use virtual globes in school teaching were presented in one of earlier works (Pokojska, Pokojski, 2015).

The Internet is an element of everyday activity of teenagers, 86.2% of them use the web on a daily basis, while 43.2% of young people are constantly online

(Lange, Osiecki, 2014). As results from the report of the Education Development Centre, as many as 76% of young web users use the Internet to do their homework and seek information. Contemporary students often start looking for information by means of the computer, so it is worthwhile to show students online resources that will facilitate studying geography and make it more diversified. In the opinion of Pliszka (1997), this task should be fulfilled above all by the teacher and the application of a computer programme for teaching purposes should bring the expected result in the form of built-up or consolidation of knowledge, for the "computer-assisted education" defined by J.M. Morbitzer (2007) to be common end efficient also in the area of teaching geography and nature.

The use of computer games may have a very positive impact on motivation for learning, which is testified to by studies conducted in Greece (Papastergiou, 2009) among secondary school students; some of the students used games in the educational process, while others studied in the traditional way. Those who used games obtained better results at the test administered at the end of the experiment. Similar studies conducted in Turkey on a group of primary school students showed better motivation for studying and, consequently, better outcomes obtained by students who used a computer game concerning continents and countries of the world with respect to the other students (Hakan et al. 2009). Similar conclusions were drawn during an experimental study carried out in Canada (Lotherington, Ronda, 2009):

## Educational games and their role in geography teaching

Some educational games that function as computer software are available at web portals that provide access

to installation files of computer programmes and applications. At the [dobreprogramy.pl](http://dobreprogramy.pl) portal, in the category Geography, one can find installation files of several computer games, including those described below, Seterra and World Geography. Installation files, as well as games, available previously in the form of computer programmes transformed into online applications, can be found through web search engines by entering an appropriate query.

One of the main educational goals in the primary school core curriculum is to identify features on the map, countries, mountain ranges, places where specific landscape types dominate, etc.<sup>1</sup> Educational games may also be used to teach geography at the lower secondary level, as the connections and spatial relations between human and the geographical environment are the foundation of education at that educational level. One of the goals of education at the third educational level in the subject of Geography is the ability to use the map to locate the most important geographical features in the world and in Poland, and exercises and tasks with maps should form a basic and integral part of most lessons of Geography (Core Curriculum...).<sup>2</sup> Educational games combine education with entertainment, they give the possibility to convey knowledge in a more interesting and easily absorbable way. Among other things, they enable broadening the knowledge of the location of countries, cities, expanding the ability to recognise landscapes and finding out spatial relations between landscape features. In addition, through the limited time for task completion, the “teach” making decisions and show the effects of the decisions made, they enable simulation of behaviour in the real world. Thanks to the

1 Core Curriculum for general education in primary school. Source: [https://men.gov.pl/wp-content/uploads/2014/08/zalacznik\\_2.pdf](https://men.gov.pl/wp-content/uploads/2014/08/zalacznik_2.pdf)

2 Core Curriculum of geography, 3rd stage of education. Source: <https://men.gov.pl/wp-content/uploads/2011/02/5e.pdf>.

use of educational games, their participants can develop the so-called spatial reasoning skill and learn to orientate themselves in the field.

Below, there is a list of a few popular online games and applications in the area of geography, which can, in a simple and intuitive way, facilitate learning geography, especially mastering the spatial location of places and features on the map. They can be successfully used and presented during lessons of nature in the primary school, when students learn how to use the map. Some of them, due to the presented issues, may be used in geography teaching in lower secondary schools. Due to different scope of the presented games and applications, the subjective ranking (in the table) is only aimed

at helping the teacher and students to choose those that are the most useful, instructive and helpful in consolidation of acquired knowledge. The overview includes games that do not require a fast microchip or too high IT skills. The first versions of some of the selected games were developed almost 20 years ago, so they may discourage a contemporary web user with their simplicity of execution, poor graphic design and lack of animations. However, that also makes them simple, intuitive and often, despite the passage of time since their origin, still attractive. The overview does not include city games and games related to Geographical Information System (GIS), which use recording of the route covered or location of the place obtained through the GPS.

Name of the game	Type	Downloaded from	Scope and usefulness of the game	Rating
Geoquessr	Online application	<a href="http://geoguessr.com">http://geoguessr.com</a>	Recognising places where photos were taken, pointing to the locations on the map, relations nature – human – economy	5
World Geography (Geografia świata)	Computer programme	<a href="http://dobreprogramy.pl">http://dobreprogramy.pl</a>	Work with the map, verifying knowledge, puzzles – setting up a map	5
Seterra	Computer programme and online application	<a href="http://dobreprogramy.pl">http://dobreprogramy.pl</a> <a href="http://online.seterra.net/pl">http://online.seterra.net/pl</a>	Work with the map	5
Geography Games (Gry geograficzne)	Online application	<a href="http://www.gry-geograficzne.pl/">http://www.gry-geograficzne.pl/</a>	Work with the map, a selection of problems, indicating the correct element on a graph or diagram	4
Enigeo	Computer programme	<a href="http://www.enigeo.org/pl/">http://www.enigeo.org/pl/</a>	Work with the map	4
Geostrefa – geography games	Online application	<a href="http://www.geostrefa.pl">www.geostrefa.pl</a>	Work with the map, puzzle – setting up a map	3
Geography – educational games	Online application	<a href="http://geografia-gry.strefa.pl/">http://geografia-gry.strefa.pl/</a>	crosswords, a selection of tasks, quizzes	3
Toporopa	Online application	<a href="http://www.toporopa.eu/pl/">http://www.toporopa.eu/pl/</a>	Work with the map	3

Table 1. List of described games and applications

Source: own study.

## Characterisation of the selected games

### Geoguessr.com

The commonly known Google Maps are a tool that facilitates finding features on the map. The service is classified as a geobrowser (Rzeszewski, Jasiewicz, 2009), its basic function is geolocation, consisting in finding the location of a feature. Not all Google Maps users know about the possibility to look for places with known geographic coordinates through entering the coordinates of the place sought, expressed in degrees, minutes and seconds of latitude and longitude. From the point of view of combining education with fun, the Street View service should be noted. It covers panoramic photos, taken with the use of a special recording tool that makes it possible to capture a panorama of 360 degrees horizontally (Pokojska, Pokojski 2012). Panoramic images from Street View, an educational game called *Geoguessr.com* was developed.

It consists in guessing the place where panoramic photos were taken and indicating that place on the world map (Fig. 1). Before the game, it is possible to choose either panoramas from the whole world, or limit the area where they are taken to continents, countries or cities, or thematic sets, such as stadiums of Europe. After indication of the place where the photo was taken, the application “calculates” the error in distance with respect to the actual place of taking and awards a number of points reversely proportional to the obtained error.

After indicating 5 places of taking a panorama, there is a summary identifying the errors made. The seemingly easy task requires the player to use his or her knowledge about vegetation formations and their zonal distribution, knowledge of issues related to the type of agriculture, landscape variation, development of road network and settlements, knowledge of foreign languages (a place may be located easier thanks to road

signs), location of cities or names of rivers (found on road signs). Other useful aspects include knowledge about left-hand or right-hand traffic, physical and cultural anthropology (people in the street), popularity of car makes in specific countries and many other aspects of human life. The application is extremely valuable, as it enables combination and verification of knowledge from many areas of science and is recommended to everyone, especially secondary school students. Logging onto the game makes it possible to enter into rivalry with several players, and in the paid version, each user may choose interesting places and prepare the game for other participants. The game is so “engrossing,” that players should be warned of the possibility of addiction.

### World Geography

The *World Geography* programme, which needs to be installed, can be downloaded free of charge from the



Fig. 1. Geoguessr.com screenshot

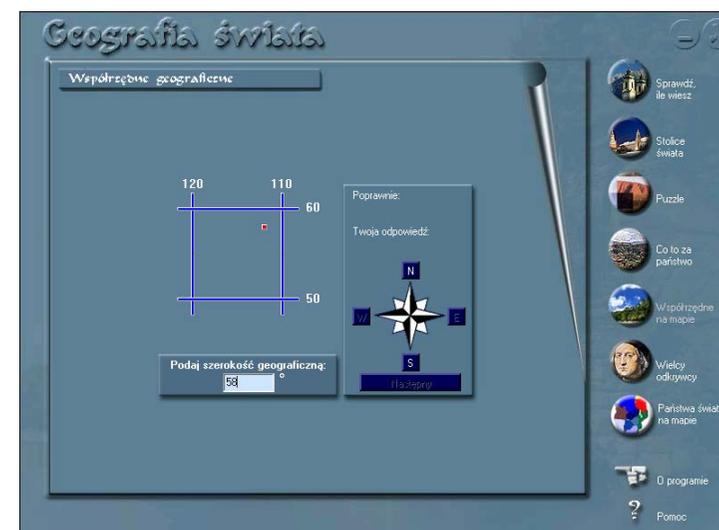


Fig. 2. Window of the World Geography programme with the Map Coordinates module launched.

dobreprogramy.pl<sup>3</sup> website. The programme enables learning the basic and selected problems of geography, its functionality goes beyond simply asking about the location of features on a map. One of the options is *puzzle*, beside which there are modules like *Map Coordinates* and *Great Explorers* (Fig.2). As regards the *Check what you Know* module, it is a test of geographical knowledge, in which the right answer must be checked.

The game is simple and intuitive, and its popularity is testified to by the data – since 2009, it has been downloaded from the portal dobreprogramy.pl 75,000 times and it has been highly rated by the website users. The rating of the game was 5 points and it may be recommended to students of both primary and secondary schools.

### Seterra

*Seterra*<sup>4</sup> is an educational game that contains more than 100 quizzes, and whose major slogan is “Learn geography while having fun”. In the game, one should indicate the location of continents, countries, capital cities and larger cities, as well as recognise the flags of specific countries. The territorial scope of the programme is mostly limited to Europe and North America. It is worth pointing out that *Seterra* has been developed since 1998 and it is available in 30 language versions. The programme has been downloaded from the website dobreprogramy.pl (the Polish version) around 20,000 times and has been very highly rated. For those who prefer to use an online application, there is also the English language version online.<sup>5</sup> It contains the same modules as the installation version. The use of other language

3 Geografia świata: <http://www.dobreprogramy.pl/Geografia-swiata,Program,Windows,11633.html>

4 Seterra – installation package: <http://www.dobreprogramy.pl/Seterra,Program,Windows,11839.html>

5 Review of Seterra programme on dobreprogramy.pl <http://online.seterra.net/pl>

versions of the game (including the English one) enables “incidental” learning of geographical names in foreign languages, the game may be used in the classroom also by foreign language teachers.

It is worthwhile to quote one of the reviews posted at the dobreprogramy.pl website by a person using the nick **80mentor**:

At the start, I would like to recommend that very good programme for learning geography. Seterra is an excellent amanc of all kinds of quizzes, thanks to which we can check our knowledge of the location of continents, countries, cities, islands, mountains, flags, etc. The programme is clear in its form and all quizzes are visible in the main window, they are also divided by topic, which determines the content of the questions to be solved against the clock, the highest score table is available in the background, which motivates to improve one’s results. Beyond doubt, the programme is an invaluable help for school and university students, as well as all people passionate about geography. I recommend it.<sup>6</sup>

The author of the article fully concurs with that opinion. It is worth noting that, beside guessing the location of cities, countries, provinces (the administrative division for Poland according to voivodeships), we can also select an option with the selection location on the map of the greatest islands, volcanoes, oceans, seas and lakes. After completion of a session, the online player can publish his or her result through the social networking service Facebook.

### Geography Games

*Geography Games – play and learn about the world*<sup>7</sup> is a set of games and tasks consisting in indication of the right item, most often a country, on the map (Fig. 3). This part of the game can be recommended to primary

6 <http://www.dobreprogramy.pl/Seterra,Program,Windows,11839.html>

7 <http://www.gry-geograficzne.pl/>

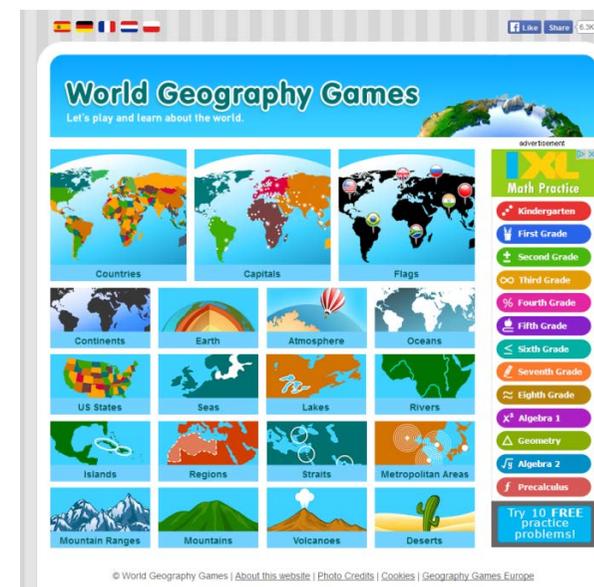


Fig. 3. List of games on the website <http://world-geography-games.com> (the Polish version is available at [gry-geograficzne.pl](http://gry-geograficzne.pl))

school students to help them in learning the location of specific countries. Lower secondary school students can make use of that part of the game which consists in verification of knowledge through selecting the correct reply option from the list or indication of the right element on a graph or diagram. For instance, the Earth game enables consolidation of knowledge about the geologic layers of Earth (Fig. 4).

The application is available in several language versions, and it has been developed, just like Toporopa, by EastDock Media from the Netherlands. Quizzes concern almost all countries of the world, the information comes from Wikipedia and CIA World Factbook, while information concerning volcanoes come from The Global Volcanism Program.



Fig. 4. The Earth game launched at gry-geograficzne.pl

## Enigeo

*Enigeo*<sup>8</sup> contains two modules: the quiz mode and the exploration mode. The game is available in 15 language versions, including Polish. Questions concern names of countries, capital cities, and their location on the map, as well as flags and national anthems (Fig. 5). The game must be downloaded and installed, but its use is not complicated. Besides, interacting with the game forces the user to choose the difficulty level and scope of questions. The game can help students of grades 4-6 of primary school in consolidation of knowledge about some countries.

8 <http://www.enigeo.org/pl/>

## Geography Puzzles

On the *geostrefa.pl*<sup>9</sup> website, which contains materials for teaching geography intended for students and teachers, one of the tabs of *Geography Games* contains *Geography Puzzles*. Using the games requires registration and logging on. The seemingly easy game makes it possible, unlike most games described in this article, rather than to indicate the location on the map, to assemble puzzles – a physical map of Poland, or an outline map of Poland. The puzzles were prepared in three versions: easy, difficult and very difficult. The game “teaches” a very important element of geography education

9 [http://www.geostrefa.pl/puzzle\\_z\\_geografii,12.html](http://www.geostrefa.pl/puzzle_z_geografii,12.html)

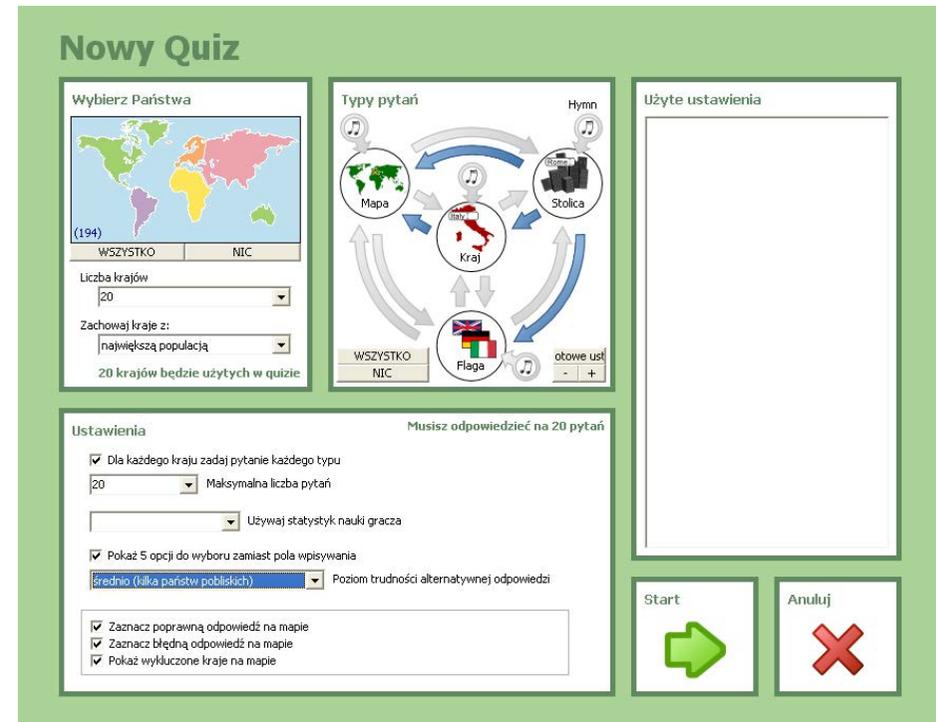


Fig. 5. Configuration panel of Enigeo

– spatial relations between geographical features. Due to different difficulty levels, it can be recommended to students of primary and lower secondary schools.

## GEOGRAPHY – Educational Games

On the *GEOGRAPHY – Educational Games*<sup>10</sup> website, there are available crosswords, matching games, and selection tasks concerning general issues (astronomy, lithosphere) and dedicated to specific continents, in categories like flags, lakes, rivers, capital cities. For the territory of Poland, there were placed tasks concerning

10 <http://geografia-gry.strefa.pl/>

symbols of national parks and rivers. This is the second of the described games which does not use maps.

### Toporopa

*Toporopa*<sup>11</sup> is the title of a website containing educational games that concern European countries, regions, cities, flags, monarchies, mountains, waters, and other issues. Simplifying slightly, one may say that it is a version of Geography Games that contains questions about Europe. The Polish language version is one of 15 language versions. The use of the game is very easy and intuitive. Besides questions concerning indication on the map of geographical features, such as straits, lakes, countries, metropolis, attention should be paid to quizzes concerning European Monarchies and European Battles. In the ranking, the game received the lowest score, yet it may be recommended for nature lessons of primary school students.

### The use of games in nature and geography lessons

Educational games cannot substitute material developed in the form of a textbook, an atlas or exercise book. However, they may be a supplement that enables reviewing material related to location of features or enabling checking knowledge in the lessons of nature and geography.

The presented games may be used as support of the teaching process; Geography puzzles can be used during lessons on *our homeland and other European countries* to a good effect. The game may also be used during lessons dedicated to *contour map* and *band-like arrangement topographic zones in Poland*, when its part consisting in arrangement of the Physical Map of Poland can be utilised.

<sup>11</sup> <http://www.toporopa.eu/pl/>

As regards the game *Seterra*, it may be used as a teaching aid during nature lessons in grade 5 to teach the location of countries of the European Union. Using the Google Maps application and virtual panoramas from the Street View service, the teacher can indicate and discuss typical landscapes of Poland in the classroom, illustrating them with appropriate examples of lowland, highland and mountain landscapes.

In grade 6, a section of the curriculum dedicated to *lands and oceans* is taught in nature lessons, with indicating the location of continents and oceans of the world map as one of the learning objectives. The following games can be used to consolidate the obtained knowledge: Geography games – quizzes *Continents, Oceans, Seas, Seterra, World geography, Enigeo*.

During lessons about the landscapes of the Earth, the Street View application and the game *Geogessr* can be helpful – while using them, the teacher may indicate and discuss typical landscapes, characteristic for specific climatic zones. Finding characteristic landscapes with the use of the Street View application may be a tool used by the student while preparing a homework assignment, an essay or a presentation.

While discussing the rotation and revolution of Earth, the animations found at the website *Interactive Sites for Education*<sup>12</sup> may be a useful supplementation of the textbook. For instance, the *Earth's orbit*<sup>13</sup> animation may facilitate understanding of the principles and consequences of Earth's revolution around the Sun and rotation around its axis.

Educational games may also be used during geography lessons in lower secondary schools.

Most of the discussed games can be used to consolidate knowledge concerning the geographical position and the location of points and areas on the map, in

<sup>12</sup> <http://interactivesites.weebly.com/earth-moon-and-sun.html>

<sup>13</sup> <http://www.ictgames.com/dayNight/index.html>

which context the coordinates module in the World Geography game is the most worthy of recommendation.

To consolidate the knowledge of the political division of Europe, one may use the geographical games of *Seterra, Toporopa* and *Enigeo*. During lessons dedicated to the review of geographical regions of Poland, the teacher can, using the Street View module in the Google Maps application or the *Geogessr* game, present characteristic landscapes for specific regions. The games may be used not only while working with the map, but the choice of tabs on the Geographical games enables learning and consolidation of knowledge about the structure of the atmosphere and the Earth internal structure (the Atmosphere and Earth tabs).

### Conclusion

Consolidation of knowledge of the location of a place on the map, quizzes and tasks available in computer games enable combination of learning with fun, and most of all develop spatial imagination. Some of the games are a few or over a dozen years old and may discourage teenagers with unattractive graphic design, but they are simple, intuitive and do not require a fast Internet connection in the case of online games.

A teacher who uses the online resources may make students more interested in geography, as well as convey knowledge more quickly. Thanks to it, young people will be better prepared for productive functioning in the information society and they will improve the self-development skills (Pokojski, 2012). The subjective assessment is only aimed at pointing out to teachers and students of those games and applications, which, according to the author, are useful in consolidation of geographical knowledge (received a score of 5). The games presented in the article have been highly rated as a teaching aid by teachers – students at postgraduate

studies in the area of teaching geography and nature organised by the Department of Geography and Regional Studies of Warsaw University.

On the Internet, there are numerous lists of games intended for nature education, and due to the English language versions also for teaching the English language in primary schools. The list presented by the National Geographic<sup>14</sup> is valuable. At the beginning of the presented list, beside educational qualities, their role in development of the decision-making skills was highlighted. Educational games are also made available by environmental institutions. On the website of the American agency NOAA (National Oceanic and Atmospheric Administration)<sup>15</sup> a portal of games and interactive activities concerning oceans and the atmosphere can be found. The authors aimed at making the users of the games aware of the environmental problems and to promote the right types of behaviour in the natural environment. For instance, the game WaterLife: Where Rivers Meet the Sea<sup>16</sup> concerns the ecosystem of ocean estuary, the game Recycle City<sup>17</sup> concerns sustainable development of a city, and participants of the game may learn how to segregate waste and reduce energy consumption. Next, the UCAR Center for Science Education<sup>18</sup> website offers a set of games related to weather, climate and atmosphere. A student using that type of games may understand the factors that shape weather and the way in which the climate changes. Issues related to weather and climate occur both in nature and geography curricula.

It is worth mentioning that a separate group of geography teaching aids, not discussed in the article, is

formed by interactive games and map applications related to Geographic Information Systems (GIS), to be used on PCs or mobile devices, including those that use the GPS to record the route travelled or mark visited points. The group may include also the so-called city games, like the game GIS & Go promoted by ESRI and the game Pokémon Go, very popular in the summer of 2016.

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14 <http://nationalgeographic.org/education/games-and-interactive/>

15 <http://games.noaa.gov>

16 <http://games.noaa.gov/oscar/welcome.html>

17 <https://www3.epa.gov/recyclecity/>

18 <https://scied.ucar.edu/games>

# The periodic table of elements in chemistry textbooks for junior high-schools

Marcin M. Chrzanowski, Irmina Buczek, Małgorzata Musialik, E. Barbara Ostrowska

*Elements are not disparate entities but form interrelated families (...). That we understand the origins of periodicity (...) means that we understand the personalities of the elements. Chemistry deals with entities that have personalities rather than their component parts, and it is right, I think, to present systematic as a story of the interaction of personalities*

Atkins, 2005

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## Summary:

The analysis of chemistry textbooks for the 3rd stage of education was carried out in order to obtain in-depth information on the degree of realization of the first educational goal from general requirements (learning outcomes) of the core curriculum: *A student obtains and processes information from various sources with the use of information-communication technologies.* The range of occurrence of content related to the periodic table of elements in chemistry textbooks for the 3rd stage of education was investigated. The choice of this source of information was dictated by the provisions of the curriculum for general education on the one hand, and on the other, by the fact that the periodic table is a foundation of modern chemistry – the good command of the periodic table not only allows to systematize the knowledge, but also, to anticipate and understand the properties of chemical elements. We analyzed all the series of chemistry textbooks for junior high schools,

which have been approved for use in schools by the Ministry of Education since 2009. The study results indicate that the content of all series of textbooks contains the periodic table of elements along with the materials helpful in forming the skills of reading data from such source of information. The most authors of textbooks also took care of that the periodic table of elements was present in every part of the series, which should help students in consolidating the ability to use this tool. The colors most often used in periodic tables to indicate the nature of the chemical elements were different shades of blue and pink, which may help in consolidating the knowledge, but it can also lead to the formation of students' misconceptions about the properties of elements.

**Key words:** core curriculum, textbook, periodic table of elements, Mendeleev's table, the 3rd stage of education (ISCED 2)

## 1. Introduction

Pursuant to Regulation of the Minister of National Education of 23 December 2008 (MEN, 2008), implementation of the core curriculum of preschool and general education started in individual Polish school types beginning from the school year 2009/2010 (MEN, 2009). The provisions of the core curriculum are formulated as descriptions of results of the process of education as at the end of the specific level. They include knowledge and skills specific for each subject taught at school, listed as general and detailed requirements. It is worth stressing that they comply with the key competences mentioned in the Recommendations of the European Parliament of 18 December 2006 (Federowicz and Sitek, 2013).

As a consequence of implementation of the new core curriculum, textbooks were introduced taking provisions of that new curriculum into account. A textbook for general education should contain *substantive and illustrative materials matching the presented teaching content, and make it possible for students with various abilities to acquire skills defined in the core curriculum of general education* (Journal of Laws of 8 July 2014, item 909) (MEN, 2014).

The core curriculum for chemistry taught within the 3rd level of education formulates three general objectives that describe the student's expected achievements in terms of skills required to master the subject. The first of them relates to the skill of acquiring and

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processing information from a variety of sources, the second one – to reasoning and application of acquired knowledge in practice, and the third one – to the mastering of practical skills in laboratory work. The teaching content (detailed objectives) are also stated as the student's expected achievements but pertain to individual skills described with operating verbs, as e.g.: the student *describes, explains, enumerates, provides examples, uses* etc. In the commentary to the core curriculum for chemistry, the following is mentioned among the basic sources of chemical information: tables, graphs, drawings, schemes and source texts. This publication is a fragment of the description of a literature-based analysis of chemistry textbooks for the 3rd level of education relating to the periodic table. The analysis was quantitative and at the same time qualitative (Pingel, 2009). Analyzed was the formulation in the textbooks of contents relating to the periodic table of the elements – the chemist's tool containing systematized knowledge about all chemical elements and their basic properties. The reading of information contained in table, as well as analysis and interpretation of such information, is among the major skills that the students should acquire within the chemistry course at the lower secondary school (Nuffield Science Teaching Project, 1972). Therefore, particular attention was paid within the analysis to specific aspects of the textbook content that may help towards the shaping of the skill or acquiring and processing information contained in the periodic table of chemical elements.

It should be stressed here, however, that a mere presence in the textbooks of contents presented as the periodic table does not necessarily lead to better educational achievements of students using such textbooks. The periodic table is in fact just a tool that may yield good results if used appropriately by the student working under the teacher's supervision.

Examination year	2012		2013		2014		2015				2016	
	Task Number	Easiness index	Task Number	Easiness index	Task Number	Easiness index	Task Number		Easiness index		Task Number	Easiness index
Task reference number in the science part of the examination sheet and its easiness												
Analysis of data from the periodic table	7	50%	7	57%	8	66%	7	10	59%	43%	7	#

Table 1. Results of selected chemistry tasks included in the lower secondary school leaving examination based on the new formula

Source: <http://www.cke.edu.pl/index.php/egzamin-gimnazjalny-left/informacje-o-wynikach>

Legend: „-“ - the sheet contained no chemistry task measuring the skill of analysis of data presented in the form of graphs; „#” - the students' results were not yet known during preparation of the publication.

How do students cope with acquiring and processing of information (including specifically information contained in the periodic table)? Some conclusions in this regard can be drawn from their lower secondary school leaving examination results. The examination verifies the knowledge and skills acquired by the student. The results achieved by students after introduction of the new core curriculum in chemistry tasks measuring the ability to analyse data presented as graphs or tables are disappointing. According to the task easiness index assumed by the Central Examination Commission CKE (Jakubowski and Pokropek, 2009), the tasks are difficult or moderately difficult for the students (CKE, 2015; IBE, 2012; IBE, 2013). Table 1 presents the task solution rate (easiness index) of tasks included in the lower secondary school leaving examination based on the new formula and testing the aforementioned skills. It appears that almost a half of the students encounter problems trying to solve tasks that require analysis of data obtained from the periodic table.

In view of the relatively high difficulty of tasks measuring the skill of analysis and interpretation of various source data, and of the fact that textbooks are the teaching aid that is most often used by teachers (Musialik, Ostrowska, Poziomek, 2014), the following working hypothesis was formulated: the chemistry textbooks for the 3rd level of education insufficiently shape the skills of acquiring and analyzing data from various sources such as tables and graphs, and specifically – the periodic table of chemical elements.

## 2. Purpose of the project

Chemistry textbooks for the 3rd level of education were analyzed from the viewpoint of their specific presentation of the core curriculum's first objective of education. In particular, the analysis aimed at answering the following questions:

No.	Series No.	Series title	Item within series	Textbook title	Textbook author	Publisher
1	1.1	Ciekawa chemia [Interesting Chemistry]	1/3	Podręcznik gimnazjalisty. Part 1. Lower Secondary School Student Textbook]	Hanna Gulińska, Janina Smolińska	Wydawnictwa Szkolne i Pedagogiczne Sp. z o.o. (WSiP)
	1.2	Ciekawa chemia [Interesting Chemistry]	2/3	Podręcznik gimnazjalisty Part 2. Lower Secondary School Student Textbook]	Hanna Gulińska, Janina Smolińska	Wydawnictwa Szkolne i Pedagogiczne Sp. z o.o.
	1.3	Ciekawa chemia [Interesting Chemistry]	3/3	Podręcznik gimnazjalisty Part 3. Lower Secondary School Student Textbook]	Hanna Gulińska, Janina Smolińska	WSiP
2	2.1	Chemia. Podręcznik dla gimnazjum [Chemistry. Lower Secondary School Textbook]	1/3	Chemia 1. Podręcznik dla gimnazjum [Chemistry 1. Lower Secondary School Textbook]	Maria Barbara Szczepaniak, Janina Waszczuk	WSiP
	2.2	Chemia. Podręcznik dla gimnazjum [Chemistry. Lower Secondary School Textbook]	2/3	Chemia 2. Podręcznik dla gimnazjum [Chemistry 1. Lower Secondary School Textbook]	Maria Barbara Szczepaniak, Janina Waszczuk	WSiP
	2.3	Chemia. Podręcznik dla gimnazjum [Chemistry. Lower Secondary School Textbook]	3/3	Chemia 3. Podręcznik dla gimnazjum [Chemistry 1. Lower Secondary School Textbook]	Maria Barbara Szczepaniak, Janina Waszczuk	WSiP
3	3.1	Chemia Nowej Ery [Chemistry for the New Age]	1/3	Chemistry for the New Age. Chemistry 1. Lower Secondary School Textbook	Jan Kulawik, Teresa Kulawik, Maria Litwin	Nowa Era Spółka z o.o.
	3.2	Chemia Nowej Ery [Chemistry for the New Age]	2/3	Chemistry for the New Age. Chemistry 2. Lower Secondary School Textbook	Jan Kulawik, Teresa Kulawik, Maria Litwin	Nowa Era Spółka z o.o.
	3.3	Chemia Nowej Ery [Chemistry for the New Age]	3/3	Chemistry for the New Age. Chemistry 3. Lower Secondary School Textbook	Jan Kulawik, Teresa Kulawik, Maria Litwin	Nowa Era Spółka z o.o.
4	4.1	Chemia dla gimnazjalistów [Chemistry for Lower Secondary School Students]	1/3	Podręcznik. [Textbook]	Krzysztof M. Pazdro, Maria Torbicka	Oficyna Edukacyjna Krzysztof Pazdro Sp. z o.o. (K. Pazdro)
	4.2	Chemia dla gimnazjalistów [Chemistry for Lower Secondary School Students]	2/3	Podręcznik. [Textbook]	Krzysztof M. Pazdro, Maria Torbicka	K. Pazdro
	4.3	Chemia dla gimnazjalistów [Chemistry for Lower Secondary School Students]	3/3	Podręcznik. [Textbook]	Krzysztof M. Pazdro, Maria Torbicka	K. Pazdro
5	5.1	Świat chemii [The World of Chemistry]	1/3	Podręcznik dla uczniów gimnazjum [Lower Secondary School Student Textbook..Part 1. ]	Anny Warchoł (red.)	Wydawnictwo "ZamKor" P. Sagnowski i Wspólnicy Sp. j. S.K.A. (ZamKor)
	5.2	Świat chemii [The World of Chemistry]	2/3	Podręcznik dla uczniów gimnazjum [Lower Secondary School Student Textbook. Part 2.]	Anny Warchoł (red.)	ZamKor
	5.3	Świat chemii [The World of Chemistry]	3/3	Podręcznik dla uczniów gimnazjum [Lower Secondary School Student Textbook.Part 3.]	Anny Warchoł (red.)	ZamKor
6	6.1	Chemia w gimnazjum. [Chemistry – Lower Secondary School Course]	1/1	Chemistry – Lower Secondary School Course	Zofia Kluz, Krystyna Łopata, Ewa Odrowąż, Michał M. Poźniczek	WSiP

Table 2. List of textbooks analyzed within the study

No.	Series No.	Series title	Item within series	Textbook title	Textbook author	Publisher
7	7.1	Chemia dla gimnazjum [Chemistry for Lower Secondary School]	1/4	Chemia. Podręcznik dla gimnazjum, część 1 Chemistr. Lower Secondary School. Textbook. Part 1.	Bożena Kałuża, Andrzej Reych	Wydawnictwo Edukacyjne "Żak" sp. z o.o. sp. k. (Żak)
	7.2	Chemia dla gimnazjum [Chemistry for Lower Secondary School]	2/4	Chemia. Podręcznik dla gimnazjum, część 1 Chemistr. Lower Secondary School. Textbook. Part 2.	Bożena Kałuża, Andrzej Reych	Żak
	7.3	Chemia dla gimnazjum [Chemistry for Lower Secondary School]	3/4	Chemia. Podręcznik dla gimnazjum, część 1 Chemistr. Lower Secondary School. Textbook. Part 3.	Bożena Kałuża, Andrzej Reych	Żak
	7.4	Chemia dla gimnazjum [Chemistry for Lower Secondary School]	4/4	Chemia. Podręcznik dla gimnazjum, część 1 Chemistr. Lower Secondary School. Textbook. Part 4.	Bożena Kałuża, Andrzej Reych	Żak
8	8.1	Moja chemia [My Chemistry]	1/2	Moja chemia dla gimnazjum. [My Chemistry for Lower Secondary School.]	Małgorzata Nodzyńska, Jan Rajmund Paško	Żak
	8.2	Moja chemia [My Chemistry]	2/2	Moja chemia dla gimnazjum. [My Chemistry for Lower Secondary School.]	Jan Rajmund Paško, Małgorzata Nodzyńska	Żak

Table 2. List of textbooks analyzed within the study

- Can the textbook contents help towards effective shaping of the skill of using information contained in the periodic table of elements?
- Do the textbooks offer instructions on how to use the data presented in the periodic table?
- What solutions have the textbook authors adopted to prepare students to efficiently read information contained in the periodic table?

### 3. Methodology

Analyzed have been all chemistry textbooks for lower secondary schools admitted to school use by the Ministry of National Education. Further on in this study, series numbers stated in Table 2 are used.

Left out from the analysis have been educational underpinnings included in almost all textbook series analyzed. The reason is that only the contents of textbooks are subject to mandatory review and approval by MEN, and thus certified as compliant with the core curricu-

lum. Such procedures do not apply to exercise books, task books, materials on CDs attached to the textbooks, and materials for teachers.

Analyzed have been contents relating to the periodic table of chemical elements included in the core curriculum for chemistry within the 3rd level of education and in chemistry textbooks for lower secondary schools. The following elements of the textbook contents have been analyzed:

- position of the periodic table in the textbook (within a chapter, at the end of the textbook, as an insert added to the textbook);
- compliance of information about the periodic table contained in the textbooks with the core chemistry curriculum requirements;
- inclusion in the textbook of a description of the way of reading data contained in the periodic table;
- the color scheme of periodic tables of elements.

It should be stressed that the analysis aimed not at comprehensive assessment of the textbooks but rather

of their selected elements potentially influencing the shaping of the students' competences.

## 4. Findings

### 4.1. The periodic table in the detailed requirements of the core chemistry curriculum for lower secondary schools

The structure of the periodic table and the ability to read the information it contains are described in the core curriculum for the 3rd level of education as five detailed requirements: 2.1; 2.3; 2.4; 2.12 and 4.2. The skills should be developed at the extended 4th level of education (the description is contained mainly in chapters 2 and 3 and in subsection 8.1), and then tested within the secondary school final examination, as since 2015, the tasks contained in the final examination sheet *may refer also to requirements for lower levels, e.g. the 3rd level of education (lower secondary school)*.

#### 4.2. Position of the periodic table in the textbook

The periodic table of chemical elements is a table for frequent use by the student, hence the optimum solution is to add that table to each volume of the series. It also seems a good solution to choose a position where the table would be easy to find quickly. The position and number of periodic tables contained in each volume of the series under analysis is shown in Table 3.

The authors of most of the series added the periodic table to each part of the textbook. The exceptions include series 7 and 8, where periodic tables are only found in some of the textbooks. The textbooks of some series contain 2 or 3 periodic tables each, presenting different chemical elements data. In most cases, the periodic table was a fixed insert or was positioned on the inside cover. An interesting solution is a moving periodic table attached as an insert to the textbook. Such solution was chosen by Publisher 4. All authors added the modern long version of the periodic table, as recommended by the International Union of Pure and Applied Chemistry (IUPAC).

#### 4.3. Compliance with the core curriculum's provisions pertaining to the periodic table

Under the teaching content for chemistry within the 3rd level of education, the core curriculum provides that upon completion of the lower secondary school course in chemistry, the student should be able to perform the following activities based on the periodic table of elements:

- read (...) the basic information about elements (symbol, name, atomic number, atomic mass, element type – metal or non-metal),
- determine the number of protons, electrons and neutrons in the element's atom (...),

Series no.	Item within series	Number of periodic tables	Position in the textbook
1	1/3	2	insert
	2/3	2	insert
	3/3	2	insert
2	1/3	2	insert
	2/3	2	insert
	3/3	2	insert
3	1/3	3	insert
	2/3	2	insert
	3/3	2	insert
4	1/3	3	Inside cover and moving table
	2/3	3	Inside cover and moving table
	3/3	3	Inside cover and moving table
5	1/3	2	insert
	2/3	2	insert
	3/3	2	insert
6	1/1	2	insert
7	1/4	1	Inside cover and moving table
	2/4	0	-
	3/4	0	-
	4/4	1	Inside cover and moving table
8	1/2	1	Inside cover and moving table
	2/2	0	-

Table 3. The position of periodic tables and their number in individual volumes of the series under analysis

The symbol „-“ means that no periodic table has been added.

- explain the relationship between similarity of the properties of elements classified in the same group of the periodic table and the structure of atoms and number of valence electrons,

- (...) read the maximum valence for elements from groups: 1., 2., 13., 14., 15., 16. and 17. (in relation to oxygen and hydrogen),
- (...) read the basic information about nitrogen, oxygen and hydrogen (...).

Table 4 presents information about the periodic table of chemical elements contained in individual textbook series and their compliance with the requirements of the core chemistry curriculum for the 3rd level of education.

#### 4.4. The variety of information included in periodic tables

Within the obligatory course, the students only encounter the periodic table of chemical elements at the lower secondary school level. It seems, therefore, that the periodic tables inserted in textbooks should contain mainly information about the basic properties of the elements, such as: the chemical symbol, name, atomic and mass number, as well as the markings of group numbers and periods. Table 5 summarizes all element data contained in the periodic tables added to individual textbook series.

Each textbook series contained at least one periodic table stating the basic element information (symbol, name, atomic number and group & period number). The exceptions include periodic tables in series 2, where period numbers and element names are missing, and in series 3 and 5, where only the elements' symbols are stated but the names are missing. From one of the periodic tables of series 2, the atomic number is also missing. Not all of the periodic tables state the atomic masses of the elements, but each publisher added at least one table containing that information to its textbook. The division of elements into metals and nonmetals was present in at least one textbook of each series. Additionally, the authors of series 4, 7 and 8 distinguished semimetals. On the other hand, the authors of series 2 divided

Core curriculum chapters and contents	Series no.							
	1	2	3	4	5	6	7	8
<b>Chapter 2. Inner structure of the matter</b>								
2.1 reads basic element information from the periodic table								
- chemical symbol,	+	+	+	+	+	+	+	+
- name,	+	+	+	+	+	+	+	+
- atomic number,	+	+	+	+	+	+	+	+
- atomic mass,	+	+	+	+	+	+	+	+
- element metallicity (metal or nonmetal)	+	+	+	+	+	+	+	+
2.4. explains the relationship between similarity of the properties of elements classified in the same group of the periodic table and the structure of atoms and number of valence electrons;	R	R	R	R	R	Z	R	Z
2.12 (...) reads from the periodic table the maximum valence for elements of groups: 1., 2., 13., 14., 15., 16. and 17:								
- in relation to hydrogen,	I	R	I	I	R	Z	R	R
- in relation to oxygen.	I	R	I	I	R	Z	R	R
<b>Chapter 4. Air and other gases</b>								
4.2 (...) reads from the periodic table of elements and from other sources of knowledge information about								
- nitrogen,	Z	Z	N	N	N	N	R	N
- oxygen,	Z	Z	N	N	N	N	R	N
- hydrogen; (...);	Z	Z	N	N	N	N	Z	N

Table 4. Consistency of information about the periodic table contained in the analyzed textbooks with the core chemistry curriculum requirements for the lower secondary school

Legend: R – the description of the requirement is extended (with examples); Z – the description of the requirement is concise (general trend); N – no description of the requirement; I – other conception has been used for the requirement; „+” – the description of the requirement has been provided.

elements into metals and nonmetals and distinguished noble gases among the nonmetals.

The properties of chemical elements, their ions and compounds are a periodic function of their atomic number, which is why the periodic table is the proper place to present changes in properties of elements from one and the same group or period. In point 2.4, the core curriculum provides that the student should be able to *explain the relationship between similarity of the proper-*

*ties of elements classified in the same group of the periodic table and the structure of atoms and number of valence electrons.* Three publishers provided information about changes of physical properties in at least one of their periodic tables. Publisher 1 noted the state of aggregation of the elements, publisher 3 – the melting and boiling points, and publisher 5 – the density. All data have been presented in units known to the students from the lower secondary school physics course.

The analyzed periodic tables devote little space to information about atomic structure, as e.g.:

- number of electrons in shells – only series 4,
- atomic radius – series 2 and 4 (required at the extended 4<sup>th</sup> level of education),
- ionic radius – series 2 (required at the extended 4<sup>th</sup> level of education),

The authors of series 2 provide a graphic illustration of the length of the elements' atomic and ionic radius together with the relevant numerical values. This way, the student can immediately notice the atomic and ionic radius length trends in individual groups and periods of the periodic table.

The skill of reading *from the periodic table the maximum valence for elements of groups: 1., 2., 13., 14., 15., 16. and 17. (in relation to oxygen and hydrogen)*, described in point 2.12 of the core chemistry curriculum for the 3rd level of education, is required for determination of the molecular and structural formulas of chemical compounds further on within the chemistry course. The students should be able to read that information from the periodic table even if not stated directly. However, the authors of series 1 and 5 textbooks stated the valences of elements directly in the periodic table.

A form of presentation of information that is potentially interesting for the students is addition of photographs or drawings illustrating the elements. The photographs of elements can be found in three textbook series. Stated on the photographs is such information as e.g.: element samples, portraits of their discoverers or the year of discovery (series 5), as well as applications of the elements (series 6). Other additional information provided in the periodic tables included e.g. determination of noble gases (series 2 and 3), trace elements (series 6) and artificially obtained elements (series 3 and 6). Besides, several publishes also quoted the year of discovery of the element in the periodic table (series 1, 4, 5 and 6).

Series no.	Number of periodic tables within the series	Colors used to identify selected properties of the elements													
		Metals		Nonmetals		Semimetals or metalloids		Gases		Liquids		Solid bodies		Noble gases	
		Field background	Fonts	Field background	Fonts	Field background	Fonts	Field background	Fonts	Field background	Fonts	Field background	Fonts	Field background	Fonts
1	2	-	-	-	-	-	-							-	-
2	2	(a)	-	-	-	-	-	-	-	-	-	-	-	-	-
3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	4	(a)	-	-	-	-	-	-	-	-	-	-	-	-	-
5	2	Photo (c)		Photo (c)		-	-	Photo (c) + graphics (d)		Photo (c) + graphics (e)		Photo (c) + graphics (f)		Photo (c) + graphics (d)	
6	2	-	-	-	-	-	-	(g)		(g)		(g)		-	-
7	1														
8	1													(h)	

**Table 6.** Colors used in periodic tables to identify selected properties of the elements

Where:

*a* – Periodic table showing atomic and/or ionic radii of a number of chemical elements; *b* – Lanthanides and actinides shown against a violet background in the textbook series;

*c* – background photograph added; *d* – illustration showing green fog; *e* – illustration showing a bar with a droplet pattern; *f* – illustration showing a uniform bar;

*g* – background illustration added; *h* – elements „not forming chemical compounds” highlighted in yellow in the legend, and other noble gases highlighted in pink as nonmetals; „-” – the specific property of the elements was not distinguished.

#### 4.5. Coloring of the periodic table

Table 6 presents colors used in the analyzed textbook series to distinguish the properties of chemical elements in periodic tables. Also the font and element field background colors within the periodic table were considered.

Almost all authors of the analyzed textbook series used background color for fields of the periodic table to illustrate the elements' chemical character. Metals were most often highlighted in blue (all textbook series except the second table within series 5), and nonmetals – in pink (series 2, 4, 7 and 8), orange (series 3), green (series 1 and 5) or yellow (series 6). Red was also used to highlight nonmetals within series 5, but the authors of that textbook provided red symbols and names of non-metal elements instead of using the red background. On the other hand, the first periodic table within series 6 used red for the symbols of all chemical elements, thus reducing the information value derived from the use of a vivid color. Further, semimetals were shown against a violet (series 7 and 8) or yellow background (series 4). In most cases, the font color strongly contrasted the table field color.

The authors of three textbook series also used colors to identify the state of aggregation of the elements in the periodic table. Thus series 1 and 6 used blue and series 3 – yellow as the background color for elements in the gaseous state. Liquids were identified with a green (series 1 and 6) or orange background (series 3), while beige (series 1), blue (series 3) and yellow (series 6) was used as the background color for solid bodies. The prevalent font color was black, but some authors also used red (series 5 and 6), green and white (series 5). It is only natural that the publishers refrained from experimenting in this respect as black offers the best contrast against a colorful background.

#### 5. Discussion of the findings and conclusions

Mastering of the technique of seeking relevant information needed to solve a problem at the earliest possible level of education is most valuable, and students should be encouraged accordingly as often as possible (Nuffield Science Teaching Project, 1972). The periodic table of chemical elements is among the most important sources of chemical knowledge.

Chemistry focuses on atoms, molecules, ions, electrons and other elementary entities (Burewicz and Gulińska, 1993). To become well acquainted with a phenomenon and to understand it, one has first to experience it with one of the senses. Without such direct interaction, the student lacks active inner participation (Lück, 2010) and is forced incessantly to abstract. The student goes through a sequence of abstraction levels – from sensual perception through recognition of structures and then atomic and subatomic structures to formal abstraction (understanding of symbols and formulas). Thinking and language are inseparable. Becoming acquainted with the world of chemistry with chemical symbols and conceptions as its essence, the students have to use the chemical language practically from the very start (Bogdańska-Zarembina, 1966). In the process of teaching and learning, especially of abstract contents expressed in symbolic language, an extremely important role is played by various graphic materials. Among the graphic materials that are used in chemical education, Soczewka (1988) mentions various tables. They teach students to read *numerical or conceptual data, and thus to give such data a structured content (verbalization)* (Soczewka, 1988). One of such tables is the periodic table of chemical elements. Periodical tables are artifacts designed so as to best arrange the basic chemical knowledge (Marchese, 2008). For the chemist, they pro-

vide the departing point for consideration of the matter. They arrange the branch of knowledge and provide it with a strict framework (Ostrowska and Spalik, 2010). With time, their design underwent various changes due both to gradual supplementation of the knowledge of the elements and the chemists' perception of their organization and conception (for example, „Table des différents rapports” by Étienne-François Geoffroy (1718); Dmitri Mendeleev's table (1869); Charles Janet's table (1927); Bayley-Thomsen-Bohr's table; spiral table developed by Theodore Benfey (1960) (Marchese, 2008). It is hardly an exaggeration to state that the periodic table of elements is the foundation of modern chemistry from both the researcher's and the teacher's viewpoint, hence the great importance of making the student acquainted early with that source of knowledge.

Konieczna (1991) writes that *the extent of utilization of the periodic table as a synthetic and rich source of information depends on the mastered regularities of the theory of constitution of the matter (...). To understand the principles of periodic classification of the elements based on their atomic structure (...) one should use it on an ongoing basis* (Konieczna, 1991). It is stated in the detailed comments on implementation of the core curriculum (1. Lower secondary school – 3rd level of education) that *particular attention should be paid to: (...) efficient reading of element information from the periodic table.*

For the students to become proficient in the use of the periodic table, they should use that source of information as often as possible. Therefore, the good solution is to add the table to each volume within a textbook series. As follows from analysis of Table 3, the authors of all series (except those identified as 7 and 8) added the periodic table to all parts of the textbook. As follows from the findings of a questionnaire survey into

the use of chemistry textbooks by teachers of chemistry at lower secondary schools<sup>1</sup>, carried out by the Science Subjects Laboratory of the Educational Research Institute, teachers consider the periodic table of elements to be the basic tools in the teaching of chemistry. The teachers stated that students should use the periodic table on a regular basis – within each thematic block<sup>2</sup> and during each year of the lower secondary school level chemistry course<sup>3</sup>. This is what makes easy access to the periodic table during all chemistry classes so important. In most of the analyzed textbook series, the periodic table was fixed as an insert or positioned on the inside cover, which seems a good solution as the students can quickly find the table.

The skill of using the periodic table is mentioned directly in four detailed requirements (2.1; 2.4; 2.12; and 4.2), and also assumed in point I. of the general requirements. Provisions of the core curriculum have been treated literally as recommended by MEN (MEN, 2009, p. 150) – only matters mentioned specifically were identified as mandatory and taken into account when assessing compliance of presented contents with the core curriculum (Table 4). However, notions were also analyzed that were not mentioned explicitly in the core curriculum (and therefore the textbooks authors were not obliged to include them in their works), but could be found in the textbooks or the attached periodic tables

of chemical elements<sup>4</sup>. As required by the core curriculum, textbooks (and periodical tables) should contain such information as: the element's symbol, atomic mass, division into metals and nonmetals, group number and period number. The study demonstrated compliance of the textbooks with the core curriculum in this respect (the exception was the reading of information about oxygen, nitrogen and hydrogen). The authors of all series included in their textbooks both the basic information about the periodic table's structure, and information about the elements as such, e.g. about their atomic numbers and masses. The contents of all textbook series describe the method of reading the periodic table to find out which element is a metal or nonmetal. What is worth stressing, the most detailed descriptions contained in all textbook series dealt with the relationship between the element's atom structure and its position in the periodic table. As required by the core curriculum, attention was also paid on similarity of the properties of elements from one and the same group of the table. The reading of valence from the periodic table was discussed in the textbooks of series 2, 5, 6, 7 and 8. Series 1, 3 and 4 proposed a different way of reading the valence – the student may read it from additional tables included in the textbook. This latter approach seems less advantageous as some students may give up looking for information in the periodic table (which is more difficult) and use data shown directly in such additional tables.

The reading of nitrogen, oxygen and hydrogen information from the periodic table was not mentioned within discussion of the gases' properties in all series.

1 Interviewed was a random sample of 160 teachers of chemistry at the 3rd level of education from 16 provinces. Unpublished data

2 The core curriculum for chemistry at the 3rd level of education includes 9 thematic blocks: *Substances and their properties, Inner constitution of the matter, Chemical reactions, Air and other gases, Water and water solutions, Acids and bases, Salts, Carbon and its compounds with hydrogen, Hydrocarbon derivatives.*

3 The biggest proportion of the teachers (over 90%) stated that students should use data from the periodic table when studying constitution of the matter, chemical reactions, the properties of salts and the properties of substances.

4 The commentary to the core chemistry curriculum, subsection 2: *The order of teaching individual thematic blocks and distribution of the material states that: The contents taught do not have to be limited to those included in the core curriculum. The teacher may extend the scope of the curriculum according to specific conditions of work (talented class, increased number of hours, small student groups.).*

The probable reason was that in several cases, the gases were discussed before the description of the periodic table of elements (series 3, 4 and partly 7). In series 5 and 7, no reference was made to the periodic table when describing the properties of gases mentioned in point 4.2 of the core curriculum. It is worth stating here, however, that a student who has mastered the skill of reading, analyzing and interpreting information from the periodic table is certain to also meet the requirement of point 4.2 of the core curriculum and efficiently *read basic information about nitrogen, oxygen and hydrogen.*

The amounts of information provided in the periodic tables attached to the analyzed textbooks varied greatly. Summary information is presented in Table 5. Worth quoting here are the findings of a study into chemistry teachers' expectations – the data have been derived from a questionnaire survey of 160 lower secondary school chemistry teachers<sup>5</sup>. Most teachers argued that the tables should include first of all the information that is directly specified in the core chemistry curriculum for the 3rd level of education. Over 90% of the 160 teachers participating in the survey stated that the periodic table should contain the following information: the element's symbol, name and atomic number, as well as division of the elements into metals and nonmetals. Besides, over 85% of the teachers wanted also group and period number added to the periodic table. Over a half of the teachers mentioned additionally the state of aggregation of the element as the information that should be added to the periodic table. Some teachers participating in the survey wanted also other data added to the tables: for example, every third teacher were for adding information about the elements' electronegativity (not included in the lower secondary school core curriculum), and somewhat less than one-fourth argued that the tables

5 Interviewed was a random sample of 160 teachers of chemistry at the 3rd level of education from 16 provinces. Unpublished data.

should contain relevant photographs. Individual teachers stated that the following should be added to the periodic table: mass numbers of isotopes, melting and boiling points and density of the elements, as well as the oxidation states and valence. It should be stressed that some of the examined periodic tables contained a great variety of data pertaining to an individual chemical element. For example, the periodical table from series 5 included as many as 11 different data for a single element. Such accumulation of information within a single field of the table may make its analysis difficult, especially for students with dysfunctions (as e.g. vision defect, dyslexia, ADHD). It is worth stressing that in the situation of information overload, the students may experience the same problems as adults, e.g. frustration, tension, stress, fury or panic (Akin, 1998). The problem of periodic tables being overloaded with information was discussed by Osorio (Osorio, 1990), who observed that the periodic tables used today contain very big amounts of physical and chemical data. Although such data are of material practical value, they may cause an unintended limitation of the periodical table's educational aspect. What seems a good solution of the problem of information overload affecting the periodic table is inclusion in the textbooks of several tables with different data sets, including at least one containing only the information that is used most often during the course, such as the element's name, symbol, atomic mass and atomic number.

There is also another aspect of the information overload of periodic tables contained in textbooks: the excess of colorful visual stimuli. As follows from research, color is of fundamental importance for perception and serves as a strong stimulus that can either enhance or weaken the message (Zhu and Zhu, 2009). Researchers believe that colors influence cognition and behavior through evolutionary predispositions and acquired asso-

ciations (Elliot and Maier, 2014). It was demonstrated that color is an efficient coding tool making it possible to arrange the visible world through its grouping into similar objects, and that the use of graphics and colors has an impact on the process of memorizing thus presented information (Kuhbandner, Spitzer, Lichtenfeld, Pekrun, 2015). Besides, Kuhbandner et al. (2015) demonstrated that while color does not influence the ability to memorize an object as such, it is of big importance for memorizing the color of the object. For example, warm-colored objects, i.e. red and yellow, are memorized better than cold-colored ones, i.e. blue and (especially) green. Intense colors such as red and yellow attract the viewer's attention as they are deeply rooted in the human subconscious as the colors that signal danger (e.g. from predators). Instead, green and blue are much less effective in attracting the attention, which is due to their prevalence in the natural environment (green plants and blue sky). The human subconscious does not associate those colors with danger but rather with neutral or positive things. According to Bieck (2014), the graphic element that exerts the biggest influence on its perception is the proper choice of the color palette. What is more, a vast majority of graphics *use color improperly, and thus instead of helping towards understanding, the color hinders, disturbs, overwhelms or distorts information derived from data.*

The variety of colors used in the analyzed textbook series to distinguish specific properties of chemical elements in periodic tables is presented in Table 6. As follows from data obtained, colors used most often in the tables were as follows: blue (used 14 times for background or other graphic elements) and red (used 10 times). Used somewhat less often was green and yellow (7 times each) and pink (6 times). What may result from the fact that red (pink) and blue exert a specific impact on the perception of information, and that those two

colors were used most often in the analyzed periodic tables? It should be stressed first of all that the context in which the colors appear greatly affects their perception (Elliot and Maier, 2012) – in the case of metals and nonmetals, the authors of periodic tables chose the “blue-pink” pair obtaining contrast, which is however less intense compared to the “blue-red” pair. Is the use of such colors to identify the element's chemical character in the periodic table beneficial for the memorizing of properties of metal/nonmetal elements? Research shows that blue is among the inferiorly memorized colors, while pink is memorized quite well (Pérez-Carpinell, Baldoví, de Fez, Castro, 1998). Both blue and pink are soothing (Bakhshi and Gilbert, 2015), and thus the student is less likely to focus on them as intensely as would be the case with red or yellow (Zhu and Zhu, 2009; Kuhbandner, Spitzer, Lichtenfeld, Pekrun, 2015). Both colors are more likely to favor conceptual work on solving specific cognitive problems related to analysis of the periodic table than the very formation of the association between the element's color-symbol (name) and property (metal-nonmetal), which is not to say that they would materially reduce the ability to memorize such pairs. It is worth stressing that the authors of series 3 of the textbooks departed from the traditional blue-pink pair identifying the elements' metallicity and replaced pink with orange as identification of nonmetals. Orange is most helpful in the memorizing of contents associated with that color (Perez-Carpinell, Baldoví, de Fez, Castro, 1998), which should yield good results and induce the memorization of nonmetals. Similar advantages could be obtained by the authors of textbook series 6 who identified nonmetals with yellow. In the case of textbook series 1 and 5, instead, the students might have bigger problems memorizing nonmetals as they have been identified with a green background (Kuhbandner, Spitzer, Lichtenfeld, Pekrun, 2015). Only sev-

eral publishers decided to include in their handbooks periodic tables stating the elements' state of aggregation (see Table 6), and in 3 cases color was used to identify only the noble gases. Prevailing colors were: red, yellow and green, whose selection seems to have had little in common with any general associations relating to the state of aggregation (e.g. in series 3, liquids were identified with orange, and solid bodies with blue). Although additional research would be required to find out which of the color combinations is actually the best one for cognitive processes, it is worth stressing that the very use of various colors in the periodic table is reasonable: as follows from extensive research, colorful objects or scenes are memorized better than their equivalents shown in the gray scale (Borges et al., 1977; Wichmann et al., 2002; Spence et al., 2006). Selecting the palette for the periodic table, one should also bear it in mind that red should be used guardedly: although it helps focus on details, it has also been demonstrated to negatively affect the learning efficiency (Gnambs, Appel, Kaspar, 2015).

Several other problems relate to the use of various colors to identify the elements' properties. First, the use of colors in the periodic table may result in emergence and then consolidation of erroneous convictions that are most difficult to eradicate later on in the teaching process (Markowska et al., 2014). For example, intuitive association of blue with a cold object may make the students believe that all metals are cold-colored, which is not true (e.g. gold, copper). Besides, the students may develop an erroneous conviction or consolidate a subjective impression that metals as such are generally "cold", while in fact, due to their very good heat conduction, metals can be both very cold and very hot. What is more, the authors of almost all textbooks (except the second volume of series 5) use blue to identify metals in the periodic table. The situation is similar in the case

of nonmetals where in five of the eight cases, various shades of pink have been used to identify that specific property. Paško (2012) writes that although such (...) *color identification does not disturb the learning process, so-called mental shortcuts can be observed: metals are blue, and nonmetals are pink. This kind of shortage prompted a student (when asked to enumerate the features of metals) to state that „metals are blue”*. Second, the use of the same colors to identify different properties of the elements in separate periodic tables within one textbook series will probably confuse the student. Examples include the use of one and the same color (orange) as identification of nonmetals in one periodic table and of liquids and noble gases in another table in the same textbook (series 3), or the use of a blue background for both metals and nonmetals in one and the same periodic table (series 5).

A separate issue is the use of ingenuous but not too legible and thus inefficient graphics to identify the elements' state of aggregation (see Table 6, series 5 – *d, e* and *f*), which may result in a mistaken reading of the element's properties and in memorization of information that is simply false. One last issue that may cause problems for the students using the periodic tables is the use of complex graphics (e.g. photography) to identify various properties of the elements (series 5). Small graphics with a lot of detail require the students' higher concentration, and may therefore place an excessive burden on the working memory and overload the individual's cognitive resources, leading to the student's discouragement and task evasion (Łompieś, 2015). As Alvin Toffler wrote in his book „Future Shock” (1970), there are limits to the sensory stimuli that we can accept, and also to our ability to receive, process and memorize information. Humans have their limitations, and information overload seriously reduces task performance. Efficient adaptation is only possible if the amount of stimuli is

neither too large nor too small. Besides, it is by no means certain that looking at a photograph of the object (element). the student will indeed memorize the exact information that should be memorized. Although the idea of showing the students the actual elements, whether pure or as object made of a specific element, such illustrations should not serve as the basic form of description of the element in the periodic table. Biecek (2014) writes that *the influence of color may become a problem if the entire graph is dominated by a part of information coded with a color component, or if color carried no information and only plays the part of noise. Bearing the fact in mind that color is the strongest spice, one should dose it with moderation*. Further, Tatarska (2013) argues that *in a visual message, not only color but also contrast is of immense importance*. Although the analyzed periodic tables generally used a strong contrast between the background and the text, contrast and thus also legibility is much lower where photographs are used as the field "filler". This aspect should also be borne in mind when designing a periodic table, as the desire to add esthetic or innovative improvements may compromise clarity, which is of importance at the discussed level of abstraction.

Preparing teaching aids, one should also consider various factors that affect the students' perception of the material, as such perception depends not only on the text itself but also on its presentation (graphics, color scheme). Analysis of data collected within the study does not provide an explicit confirmation of the hypothesis stated in the introduction – that the chemistry textbooks for the 3<sup>rd</sup> level of education insufficiently shape the skills of acquiring and analyzing data from various sources such as tables and graphs, and specifically – the periodic table of chemical elements. Despite the several problematic issues observed in the textbooks (e.g. the overloading of periodic tables with informa-

tion, colors used in the tables to identify the elements' properties, cases of slight inconsistency of the textbook contents with the core curriculum), it has to be stressed that all authors of the analyzed textbooks added a separate chapter or topic dealing with the periodic table. Also all textbook series included at least one volume with contents that can be used to shape the skill of reading information from the periodic table.

What, therefore, is the reason of the students' relatively poor results in tasks involving the obtaining and interpretation of information from the periodic table? Some guesses can be attempted as to the origin of that phenomenon. Even before the new lower secondary school leaving examination formula was introduced (in 2012), two students diagnoses were carried out, accompanying examinations prepared by the Central Examination Board and district examination boards<sup>6</sup>. The Lower Secondary School Student Competence Diagnosis (DKG) sheets<sup>7</sup> included the total of four closed tasks that tested the discussed skills. In the opinion of both teachers and students, tasks relating to the periodic table were the easiest of the entire chemistry part of the lower secondary school leaving examination. This, however, was not reflected in the results of those tasks. The students results (percentages of correct answers) were as follows: task 7.1 – 62%, task 7.2 – 36.7% (IBE, 2012), 7.1 – 44.8%, 7.2 – 36.7% (IBE, 2013). Asked about the students' relatively low scores, the teachers suggested that they probably resulted from a lack of repetition of the material before the examination. Contents relat-

6 <http://eduentuzjasci.pl/badania/110-badanie/412-diagnoza-kompetencji-gimnazjalstow.html>

7 During meetings dealing with DKG four series of workshops for teachers were carried out, which included a detailed discussion of the results of the chemical part of the test. Discussed with the teachers during the meetings were e.g. the issues of difficulty of the tasks, the results achieved by those teachers' students within the diagnosis, and the methodology of work with the students on a specific problem.

ing to the periodic table were usually taught in the first form of the lower secondary school, while the diagnosis took place in the third form. The teachers admitted that they not always revert to the basic issues which they treat as simple and self-evident, especially if they are not required further on within the course. This lack of regular utilization of the periodic table throughout the chemistry course at the lower secondary school is probably the problem. Therefore, irrespective of the chapter, it seems advisable that the textbooks should make regular references to the periodic table of elements, both in the textbook content and as exercises and tasks. To return to cognitive overload, it is worth stressing that it can also be advantageous if it is repeated in a regular and well-conceived manner according to the principles of so-called *deliberate practice* (Łompieś, 2015). Frequent overloading of the cognitive system through regular exercise, optimally repeated every day at close to the maximum intensity, contributes to development of the working memory and stimulates changes in flexibility of the brain that reflect a growth of the person's cognitive potential. According to Freinet, „genuine absorption of knowledge and development of skills occurs when we attempt to create, as this makes our knowledge operative” (Frankiewicz, 1983).

As has been stressed in the Introduction, mere presence of the relevant contents in the analyzed textbooks is not sufficient as the condition of the students' better educational achievements. The textbook as a tool may only lead to good results if used on a regular basis.

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# Ecological awareness of students of life sciences and their choice of the way of transport

Małgorzata Nodzyńska, Paweł Cieśla

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## Summary:

Education for sustainable development ought, inter alia, to shape and strengthen the ability to make judgments and decisions in favor of safer, healthier and more prosperous world, and should develop critical thinking and develop ecological awareness. In this context the aspect of environmental awareness and the related choice of means of transport can be discussed.

This article presents the results of research regarding the choice of means of communication by students. The study was carried out by a questionnaire among students in Krakow. The results of the research are presented in context of available communication possibilities in Krakow, which are also characterized.

Studies have shown that the level of environmental awareness of students is still not satisfactory. Behind their declared concern for the environment do not follow the attitudes and behavior supporting this concern. The most important is their own comfort, even more important than their own health and condition. The care for the environment recedes into the background.

**Key words:** students ecological awareness, means of transport

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## Introduction

Educational goals for sustainable development, as described in the “Education Strategy for Sustainable Development” (2008), state that it should shape and strengthen the capacity to assess reality and make decisions for the sustainable development of individuals, groups, communities, organizations and states. It should change people’s way of thinking, enable them to create a safer, healthier and more prosperous world, shaping critical thinking and developing awareness.

Considering that this strategy was adopted at a high level meeting of the representatives of the Ministry of Environment and Education in Vilnius, on 17-18 March 2005, it seems that the postulates included in the strategy should spread and students of natural sciences should at least have a basic set of information about environmental education.

Students of the Biology faculty at the Pedagogical University of Cracow (UP) have the subject “Education for Sustainable Development” in their program of study and students of the Environmental Protection faculty – the subject “Environmental Education”. Issues related to environmental protection are also discussed during other courses, among others, chemistry, botany, biotechnology. Therefore, a decision was made to verify whether students of life sciences taught at the Pedagogical University of Cracow have a higher ecological awareness than their colleagues from the same acad-



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emy who study exact sciences, engineering, humanities, arts or other fields of study where no such activity is conducted. Especially, whether there is a correlation between environmental awareness declared by the students and consumer attitudes – in this particular case: the choice of a means of commuting to school.

The Ministry of the Environment has been monitoring the environmental awareness of Poles concerning various aspects of the subject since 2011. It may be observed that the subject of the conducted research has not been distributed evenly. The most frequently researched issues were related to power engineering (as many as 29 publications). Quite often research was concerned with: nature conservation, environmental problems, waste management or climate change. Research rarely included: odour and noise, but also CSR, consumer behaviour, air quality, and the Natura 2000 Program. It focused mostly on emotional and cognitive aspects, and less on the behavioural aspect, i.e. the behaviour of the respondents (Fig. 1).

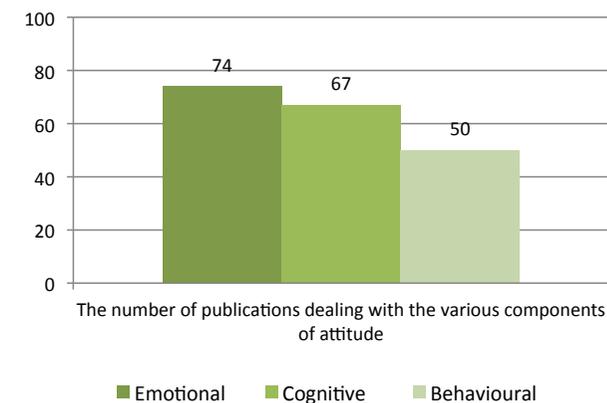


Fig. 1. The number of publications dealing with the various components of attitude

Source: Report on the analysis of the surveys on ecological awareness, attitudes and behaviours © TNS July 2015

The number of projects in selected target groups is presented in Fig. 2. The projects most often focused on one of the mentioned groups.

It can therefore be concluded that our research complements, although to a small extent, the gap concerning the behavioural aspects of the student population).

### Research

The research was conducted over a period of 2 years (from February 2014 to October 2015). The study involved 243 students of the Pedagogical University in Cracow. The study was conducted using the diagnostic survey method, with an online questionnaire. The questionnaire was included as an additional material for remote general university lectures<sup>1</sup> implemented through the Moodle platform.

The survey questionnaire included 18 questions regarding the declared environmental awareness and various behavioural aspects, including:

- choice of the means of transportation;
- segregation of trash;
- consumer preferences;
- environmental behaviour.

This article presents the results of research on the choice of the means of transportation by the surveyed students.

### Hypothesis

The choice of the means of transportation is affected by the environmental awareness of students. Students of

<sup>1</sup> Each student of the first and second degree, within the framework of the curriculum and the program of studies, is obliged to implement the module “general university lectures”. Students from the entire university, not only from the selected unit, may enroll for these lectures. The questionnaire was included in two courses – on-line lectures: “Visualization in chemistry and in teaching chemistry” and “The development of chemical concepts”.

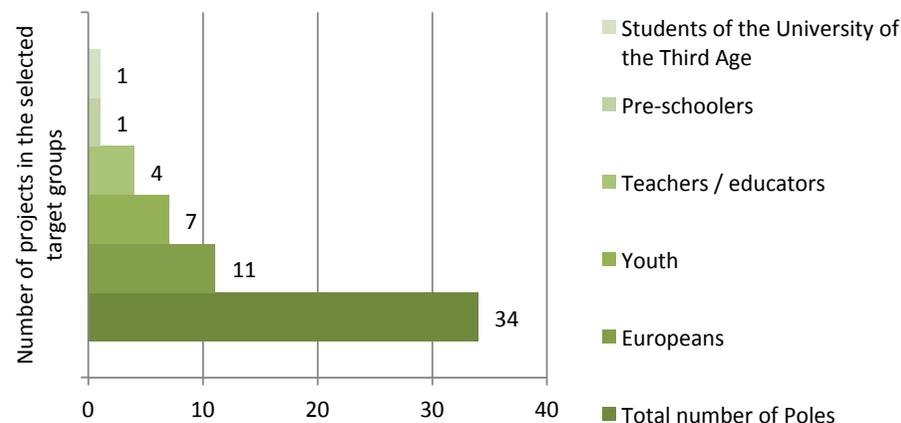


Fig. 2. Number of projects in selected target groups

Source: Report on the analysis of the surveys on ecological awareness, attitudes and behaviours © TNS July 2015

life sciences, who study additional ecological subjects, have a higher environmental awareness than other students, therefore, it would appear that they should choose eco-friendly means of transportation more often than others – as one of the motives for their choice should be environmental care.

### Profile of respondents

The survey was made available to 500 students, and 243 students participated in the study, which is a very high return of completed questionnaires. General return, calculated according to the following formula:

$$r_o = \frac{p}{n} \cdot 100\%$$

where **p** is the number of received completed questionnaires, and **n** the number of subjects in the sample) is  $r_o = 48.6\%$ .

Women constituted a majority of the sample. The proportion of women to men among the respondents who completed the questionnaire was the same as in the group of students attending the general university lectures (Fig. 3).

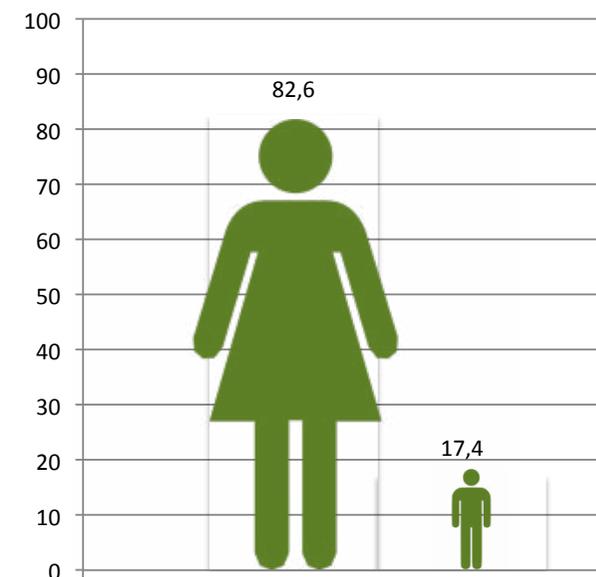


Fig. 3. Percentage of women and men in the tested sample

It is true that all UP students can attend general university lectures, but they are compulsory only for students of first and second degree studies, so naturally these students were the main group of participants in the lectures and therefore respondents to the questionnaire. The smallest number of students were postgraduate students (Fig.4).

The age of the respondents (Fig. 5) corresponded to the degree of study of the persons surveyed (a significant proportion of the students were those who started studying earlier in another field of study and then stopped and continued on another field of study at UP, therefore the age of the students is slightly higher than it would appear from the level of studies).

Students attending general university lectures represented all faculties of UP. Bearing in mind a higher clarity of the results, students' education was assigned to 4 groups (Fig. 6): natural sciences, humanities, technical/exact sciences, others.

**Local Context – organization of transportation in Cracow**

The area of Cracow is 327 km<sup>2</sup> (which gives Cracow 2<sup>nd</sup> place in Poland, after Warsaw). Cracow is inhabited by about 762 000 inhabitants, during the academic year this number is increased by students of Cracow universities (approx. 180 000<sup>2</sup>). In such a large city the organization of public transport is of great importance.

In Cracow there operates the Municipal Communications Company (MPK) with trams and buses. There

are also private carriers, but their role is limited mainly to the transportation of residents from the suburbs to the centre.

In 2015 there were 194 km of tram tracks in Cracow, and the total length of MPK bus lines was 2170 km (157 lines: 70 urban, 65 agglomeration, 15 night and 7 fast).

Cycling has also developed in Cracow – at the end of 2012 there were 145 km of cycle paths and pedestrian trails, and in 2013 – 3.9 km of new lanes were created.

The following maps (Fig. 7 and Fig. 8) show the location of the main UP building in relation to the MPK transport network and cycle paths. As can be seen, the building is located near the city centre and well connected by trams and buses. There is also a cycling path which goes through the UP area.

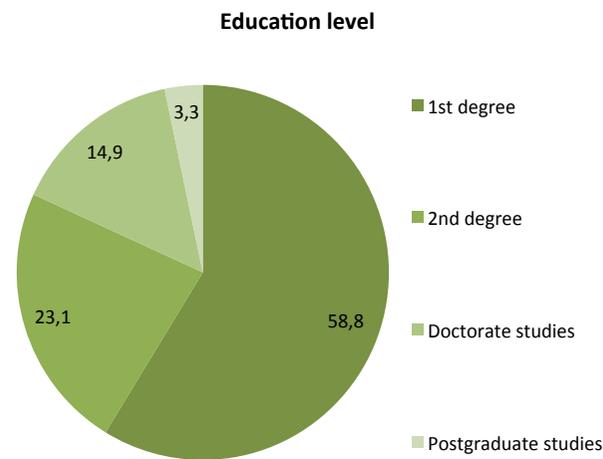


Fig. 4. Percentage of students at different stages of education in the tested sample

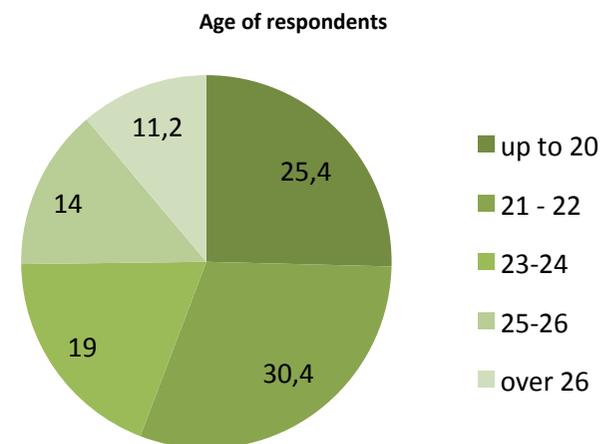


Fig. 5. Percentage of students in individual age groups in the tested sample

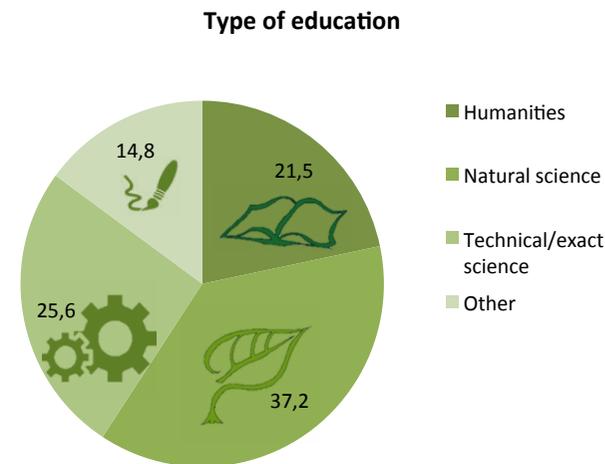


Fig. 6. Percentage of students in particular types of education in the tested sample

2 As of 31.12.2014 – Central Statistical Office data (<http://stat.gov.pl>)

The walk from the nearer dormitory to the UP building on foot takes up to 14 minutes (on the map of public transport UP dormitories are highlighted with red circles) and the walk from the further dormitory takes 54 minutes (more than half of the route runs through

green areas: the Vistula boulevards, Planty). From the dormitory at Piekarska Street (Fig. 9) it is possible to go by bike (using only cycling paths and green areas it takes 21 minutes, while driving through the city using cycling lanes it takes 17 min) or by tram (26 min) or

bus (38 min). Access by car (due to the exclusion of cars from the centre of Cracow is comparable to the bus or longer due to traffic jams).

The use of cycling routes from the dormitory to the university should also be encouraged by the “City Bike –

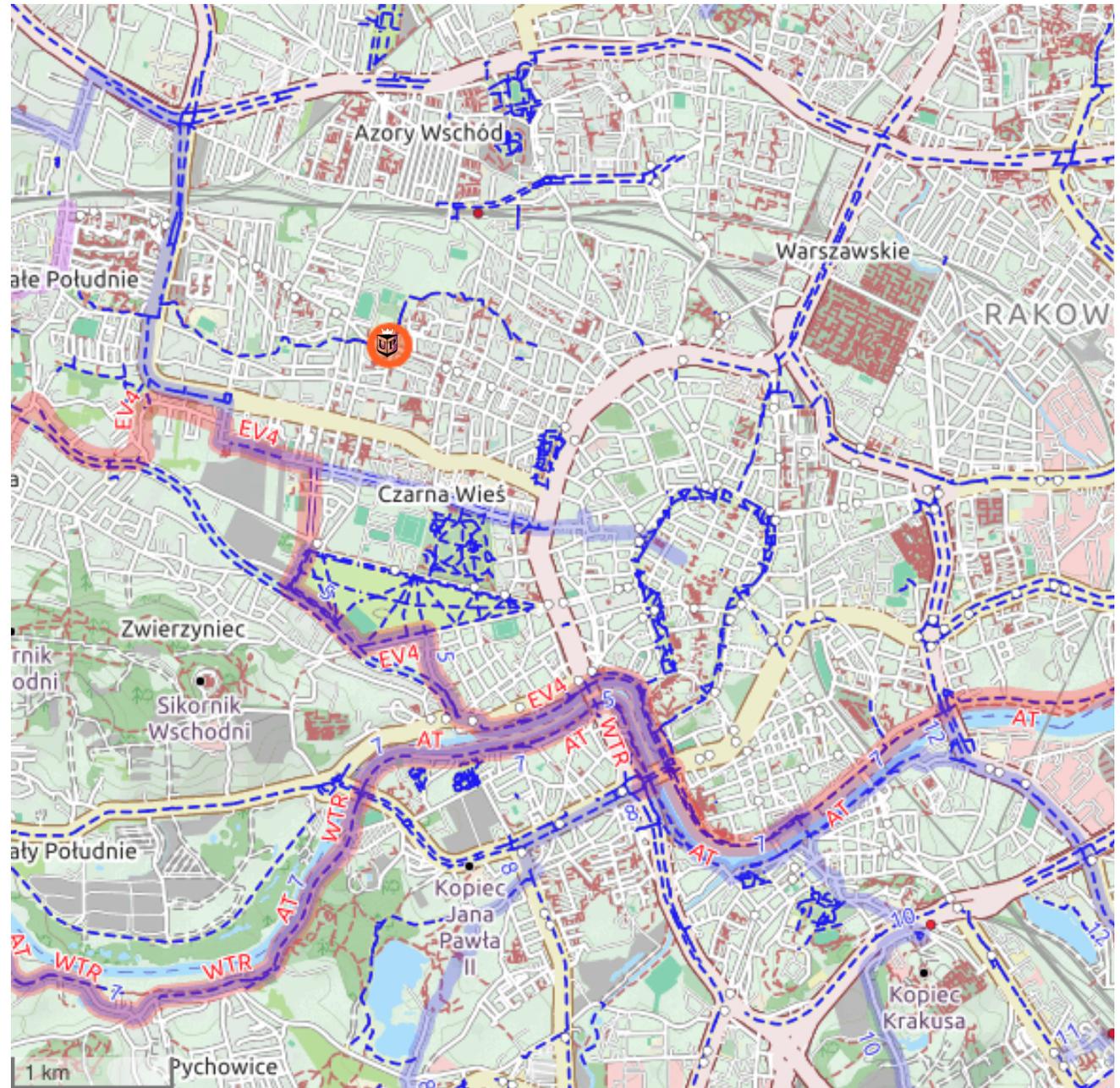


Fig. 7. Map of public transport in Cracow. The map shows the main building of the UP, the railway station, UP dormitories

Source: <http://kmlkrakow.atlaskolejowy.pl>

Fig. 8. Map of the bicycle paths in Cracow.  
The map shows the main UP building

Source: <https://www.openstreetmap.org/node/2984351165#map=13/50.0620/19.9501&layers=C;>  
CC-BY-SA 2.0.



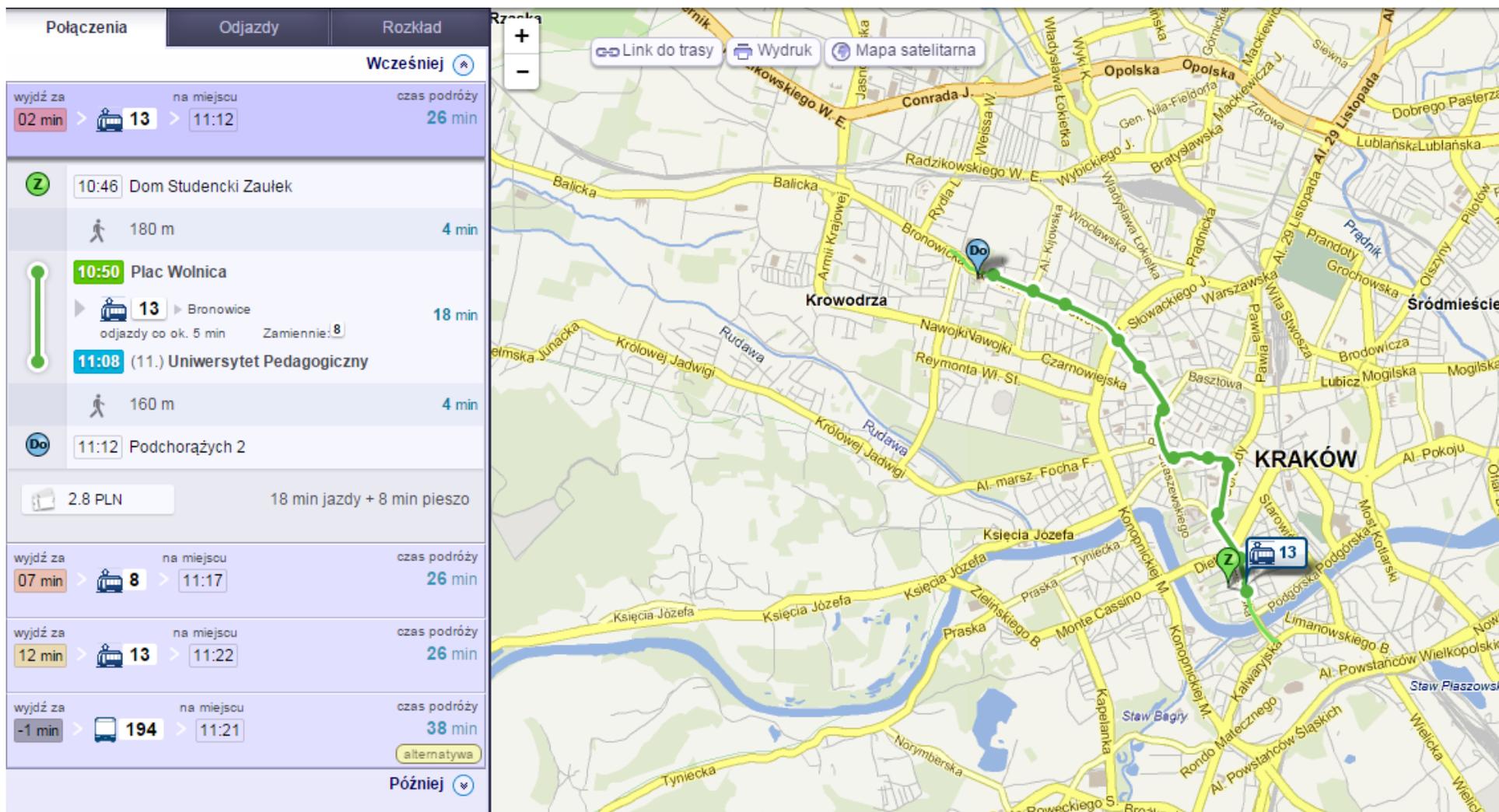
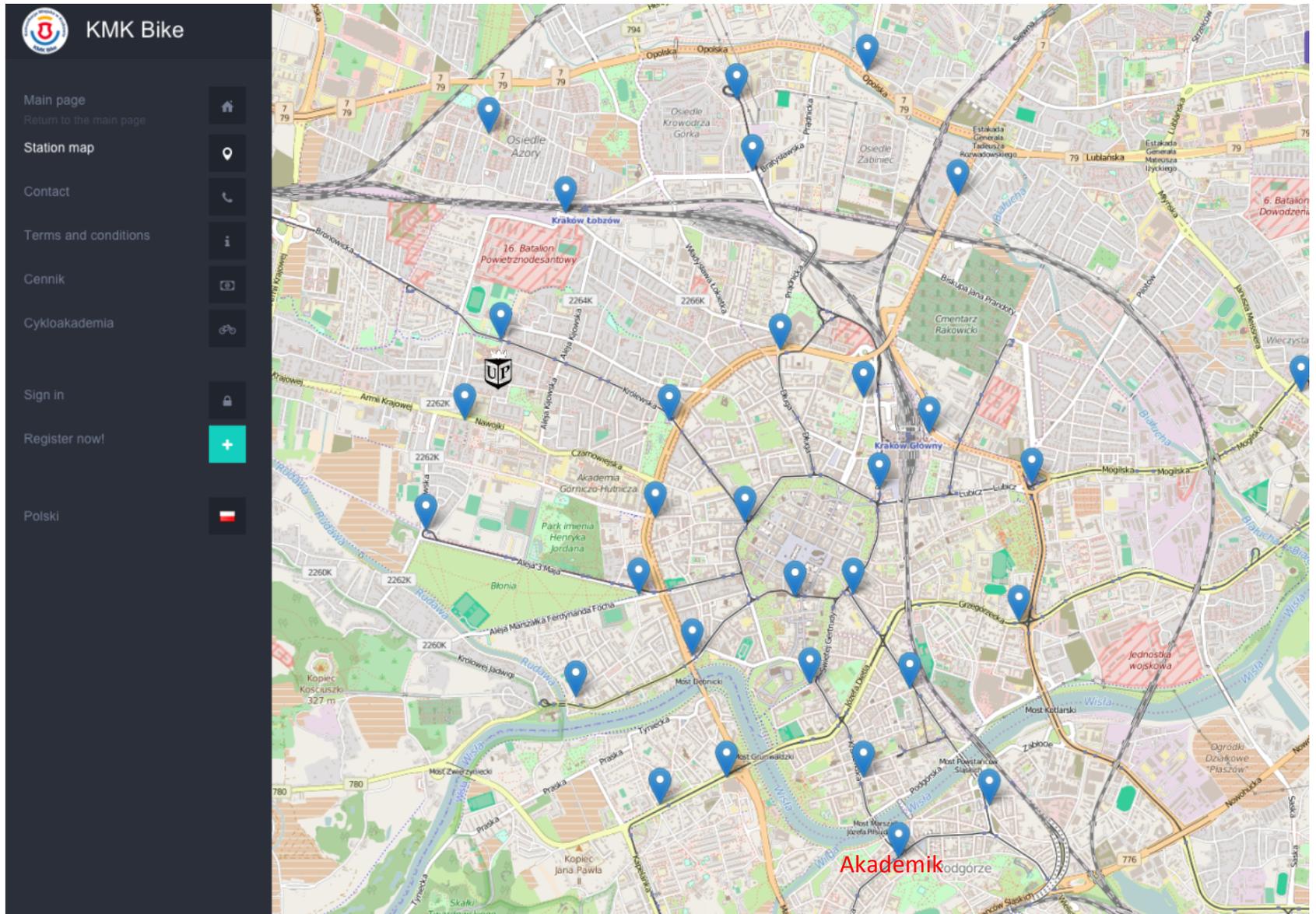


Fig. 9. Commuting time of trams and buses from the dormitory at Piekarska Street to the main building

Source: <http://krakow.jakdojade.pl>

Fig. 10. Map of bike rental stations in Cracow. The map shows the main UP building and the further dormitory

Source: <https://kmbike.pl/panel/station-map/#>



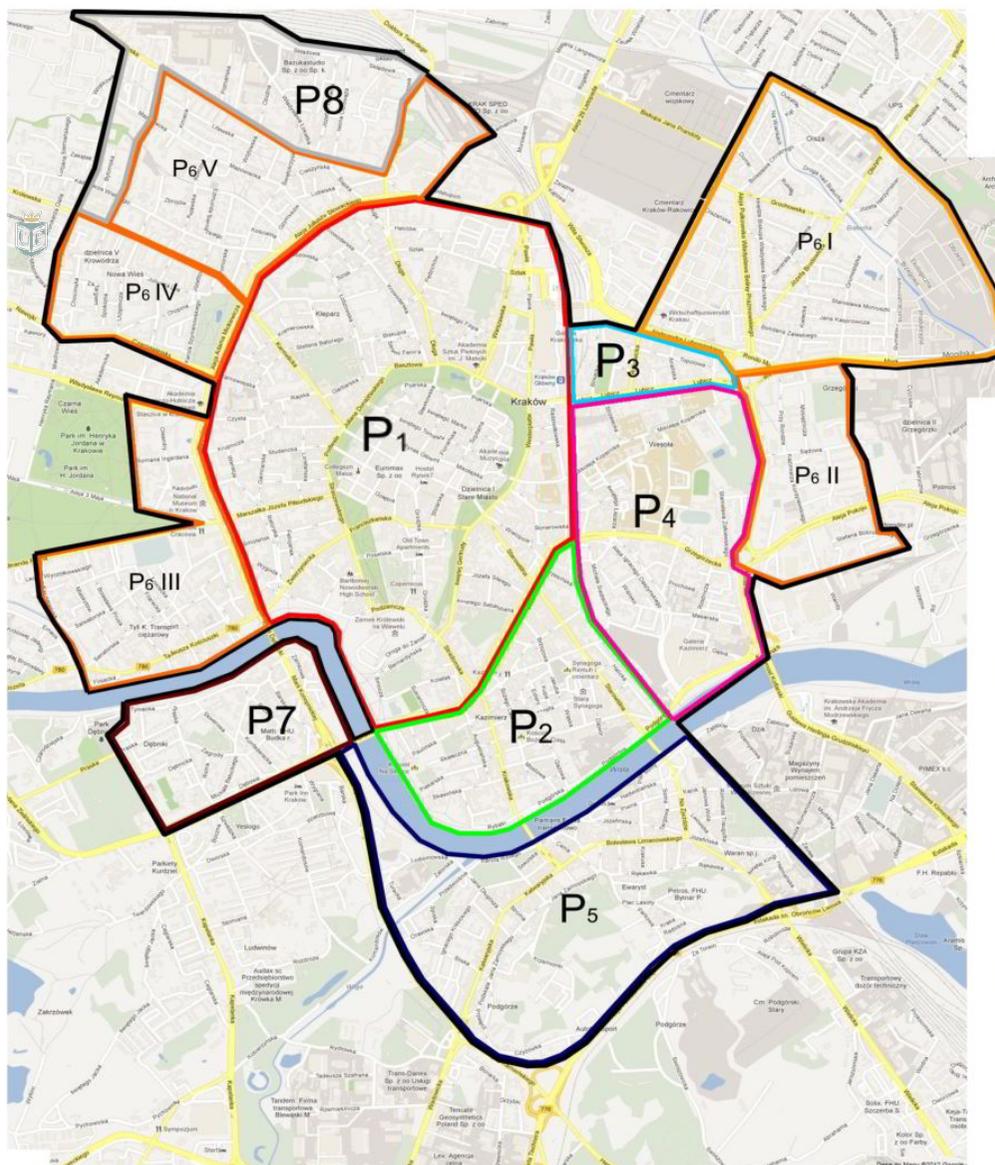
SCIENCE

SCHOOL

IN SHORT

Fig. 11. Map of paid parking zones in Cracow. The map shows the main UP building

Source: <http://mi.krakow.pl/strefa-platnego-parkowania/mapa-strefy>



Bike KMM.” Residents of Cracow have at their disposal 300 bicycles in 34 stations (Fig. 10). In this system, the first 30-minutes of the bicycle ride is free which allows to access the university from the dormitory (the bicycle station is next to the university and near the further dormitory).

It should therefore seem that the location of the university building should promote the use of environmentally friendly means of transportation, especially that in the close vicinity of the UP there are paid parking zones for cars and during the day it is difficult to find a free parking space (cf. arrangement of parking zones in Fig. 11).

The choice of public transport should also be encouraged by the fact that Cracow offers a variety of amenities for people traveling by public transport.

The most important include the so-called MPK dedicated lanes (Fig. 12 and Fig. 13). They were adopted by a resolution of the City Council on 8 January 1993, which was based on the principles of sustainable development in the field of the public transport system. The priority was to separate the traffic from the tram and bus traffic (to this end some tram tracks were used as bus lanes) and create traffic lights that would react to the emergence of public transport vehicles.

Dedicated MPK lanes allow buses and trams for a quick passage through the city, even during traffic jams, significantly reducing the travel time by tram or bus in comparison to the car.

Subsequent improvements for passengers include the so-called Viennese stops (Fig. 14). These are built when the track does not stick to the pavement and between there is a lane for traffic – the Viennese stop is characterized by the fact that the street level is elevated to the level of the sidewalk at the entire length of the stop. This makes it easier for the passengers to board and disembark the vehicle (especially in the case of

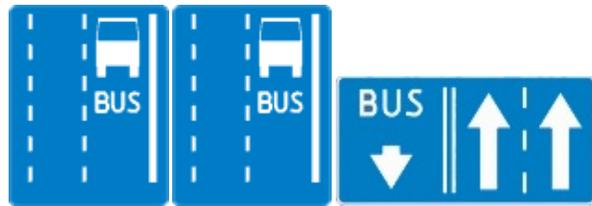


Fig. 12. The separation of MPK lanes by painting stripes – advantages: easy to introduce, the traffic organization design is enough, some horizontal signs and paint

the elderly, the disabled or, for example, mothers with prams). Secondly, it calms down the traffic in the vicinity of the stop (a natural obstacle for the driver in the form of a Viennese stop, which acts as a speed bump and the driver is forced to slow down in its vicinity). Additionally, such stops have been equipped with warning elements designed for the visually impaired, and reflective elements installed in the road before the arrival on the platform and marked with vertical marking (Fig. 15). Therefore, they are a great amenity for people using public transport.

Another amenity for people using public transport are electronic boards (Fig. 16)<sup>3</sup>. More than 250 boards are now installed at all tram stops in the city (with the exception of routes to Walcownia and Pleszów, where such boards occur only on the final stops).

To encourage residents of Cracow to stop driving in the city centre there are two more facilities. The first is a “Park and Ride” car park – parking lots located near the peripheral stops (Czerwone Maki, Giełda Balicka) designed for drivers leaving their cars in P+R parking lots and transferring to public transport. Two years ago, the first K+R “Kiss and Ride” car parks appeared on the streets of Cracow, now there are 4 car parks of this kind (Fig. 17). They are intended for drivers giving a lift to other persons who then switch to public transport.

<sup>3</sup> The first electronic boards in Cracow appeared in 2008 on Line 50.

Fig. 13. The separation of MPK lanes through the use of separators. Cracow was the first city in Poland (in the second half of the 1990's) to use concrete separators at Westerplatte Street to physically separate the tramway on the road from other lanes

Source: [http://kmmkrakow.pl/attachments/article/79/3037\\_197.JPG](http://kmmkrakow.pl/attachments/article/79/3037_197.JPG)



Fig. 14. Viennese stop – the amenities previously described in the text

Source: <http://kmmkrakow.pl/informacje-o-systemie-kmk/infrastruktura/80-przystanki-wiedenskie.html>





Fig. 15. Marking of Viennese stops for car drivers

Elevated platforms at the entrances and exits are marked with a horizontal sign P-25 "speed bump" and at the entire length of the stop there is a horizontal sign P-17 "line of stop." Additionally, the elevation of the road is preceded by a vertical sign in the form of A-11 signs "speed bump" (+ board with the distance) and the B-33 sign "speed limit"

Source: <http://kmmkrakow.pl/informacje-o-systemie-kmk/infrastruktura/80-przystanki-wiedenskie.html>



Fig. 16. The oldest type of boards provide information only about the nearest departures of trams

More modern ones also provide information on the adaptation of vehicles for disabled persons, include a button activating a voice announcement concerning the next departure designed for the visually impaired, provide data on air pollution in Cracow. The most recent ones include a map of the region with the location of other stops including line numbers, the weather forecast for the next few days and the news presented on the screens. Additionally, the boards can be used to convey information about road difficulties (scheduled and extraordinary).

In addition, driving through the city centre is more difficult due to the one-way street system, which forces drivers to make major detours and discourages them from driving around the city centre.

#### Research results and conclusions

The survey contains 18 questions about environmental awareness in relation to various aspects of daily life. Below are the obtained results of selected aspects, primarily concerning the choice of the means of transportation in the city traffic. One of the questions contained



Fig. 17. K+R car park at Pawia Street

K+R car parks are marked with the sign B-35 "No parking" with a possible indication "above 1 minute (3 minutes)", a board "Refers to K+R parking spaces" and an information sign "K+R Kiss and Ride. Kissing permitted up to 1 minute (3 minutes)", as well as a painted horizontal sign in the form of the letters "K+R" together with the designated parking places or parking lanes.

in the survey related to the declared environmental awareness. The figure shows data which indicates that 45.1% of the respondents determines their awareness as good or very good, 43% as average, and only 9.9% as very poor or poor. Therefore, it would seem that such a high declared awareness and the public transport system in Cracow will affect the choice of environmentally friendly means of transportation.

The distribution of the declared level of environmental awareness among students is not homogeneous. Students of individual fields of study differed in assessing their knowledge of environmental issues.

It can be observed (Fig. 19) that among the students of humanities there are no people who declared that

they have no knowledge about the environment, and only individual persons assess their environmental awareness at level 2. However, most of the students do not consider themselves as professionals in this field – therefore, out of all the compared groups, respondents in this group identified their environmental awareness at level 3. The results for students of natural and technical sciences are similar. Approx. 10% of students of natural and technical sciences define their environmental awareness as poor (2) or very poor (1), and about 10% as very good (5). Students of natural science most often defined their environmental awareness at level 4 (among all the surveyed groups, this was the highest percentage of choices at that level), while students of mathematical-technical studies assessed themselves slightly lower (the most common indication was level 3). Students of other fields of study assessed their knowledge more critically – as much as 25% of them defined their environmental awareness as poor (2) or very poor (1). However, many of them (approx. 18%) determined their knowledge as very high (5) – this is the highest percentage in the surveyed population.

The analysis of the raw data from students' responses to the question concerning the choice of the means of transportation seems to confirm this relationship (Fig. 20 and Fig. 21). Less than 20% of the respondents go to university by car, and the vast majority (over 63%) use public transport. The obtained data is coherent with nationwide surveys, where 57% of respondents declared that, whenever possible, they choose public transport or the bicycle, instead of a car<sup>4</sup>.

The first criterion that was examined was the gender criterion. It was examined whether the choice of the means of transportation depends on the sex of the surveyed person, as shown in Figures 22-25.

<sup>4</sup> [https://www.mos.gov.pl/g2/big/2014\\_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf](https://www.mos.gov.pl/g2/big/2014_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf)

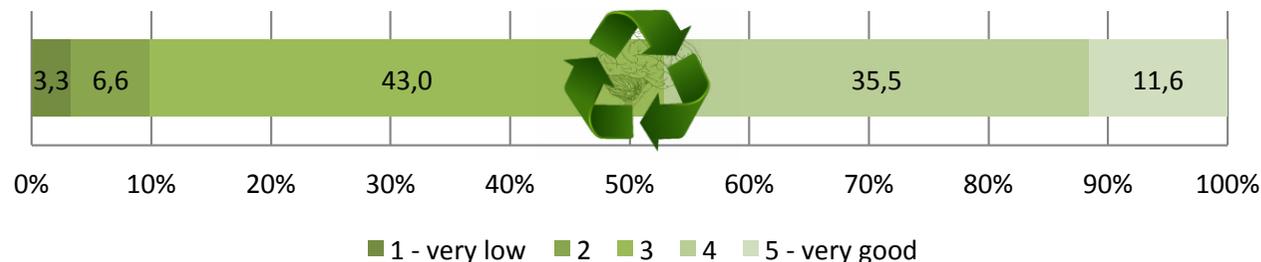


Fig. 18. Declared level of environmental awareness among the surveyed students

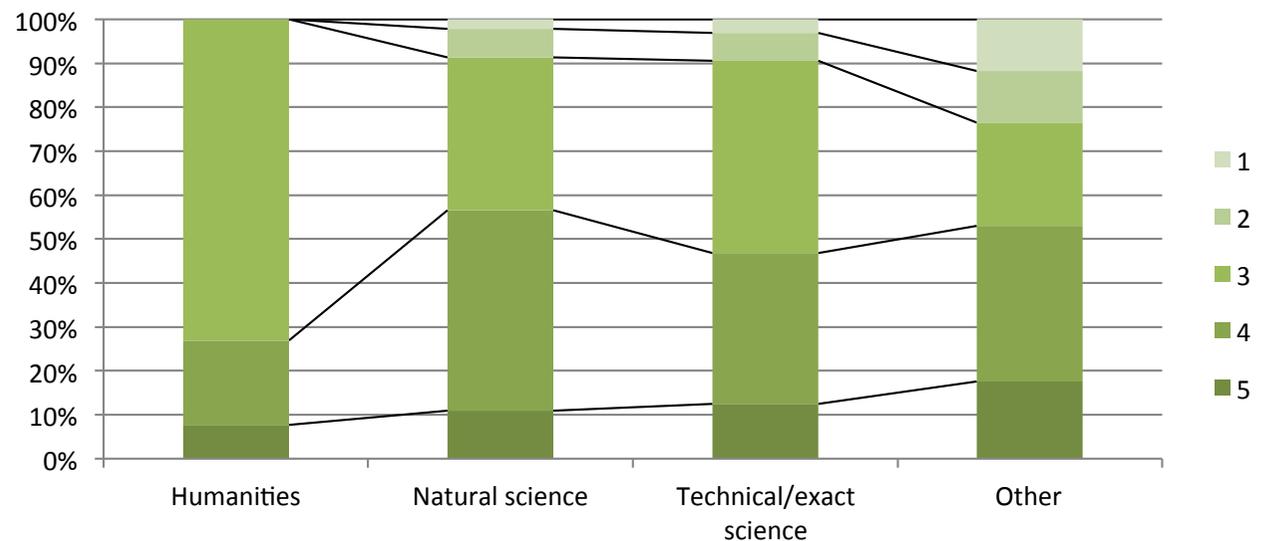


Fig. 19. Declared level of environmental awareness among the surveyed students depending on the field of study, while calculating the group sample at 100%

Fig. 20. Percentage of indications about the type of transport chosen by students to go to university (the sum of responses is greater than 100 because it was possible to choose several answers)

Further analysis will be based on the above chart.

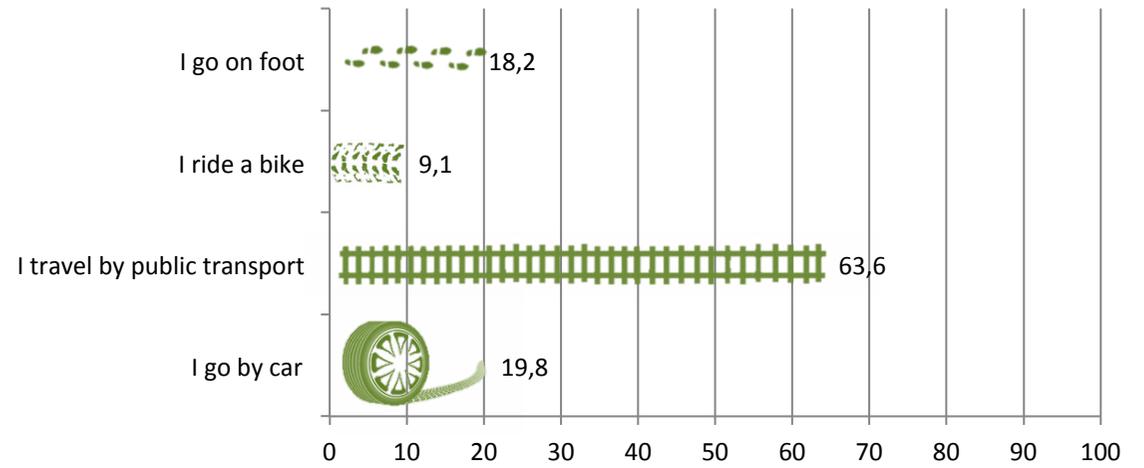
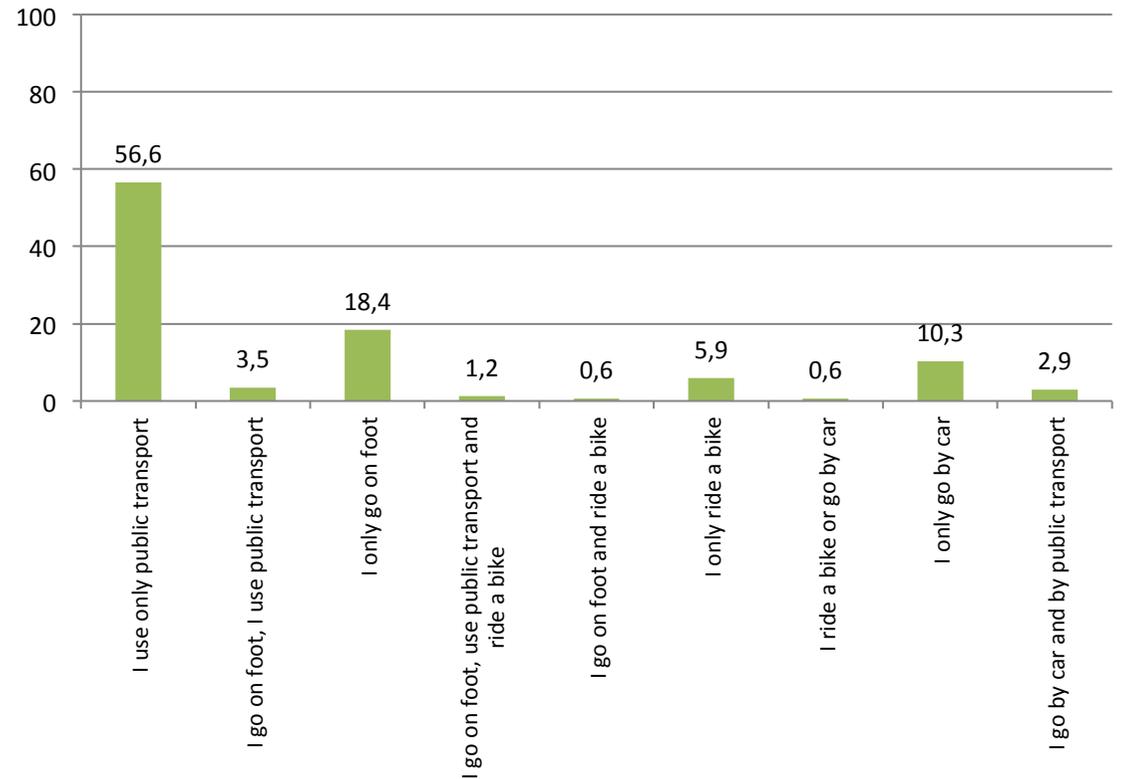


Fig. 21. The percentage of indications about the type of transport chosen by students to go to university – detailed student choices



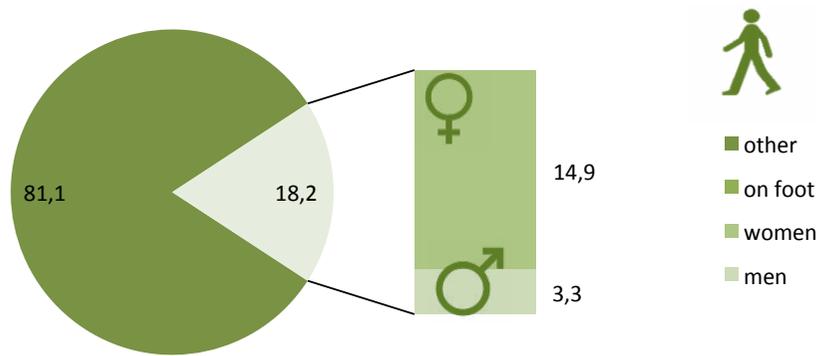


Fig. 22. Percentage of persons going to university on foot by gender

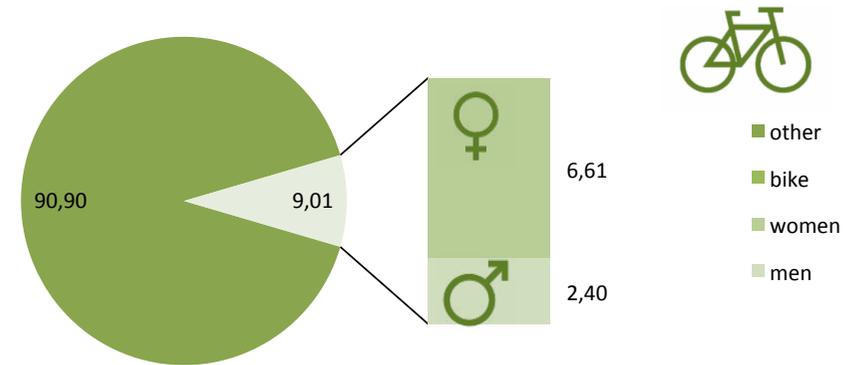


Fig. 23. Percentage of persons going to university by bike by gender

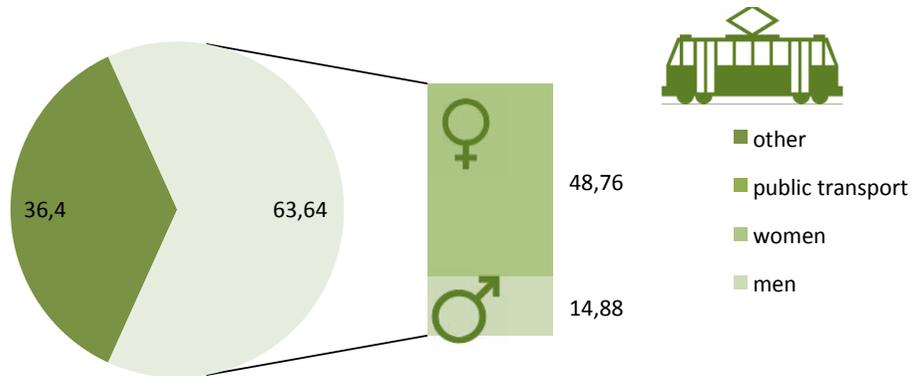


Fig. 24. Percentage of persons commuting by public transport by gender

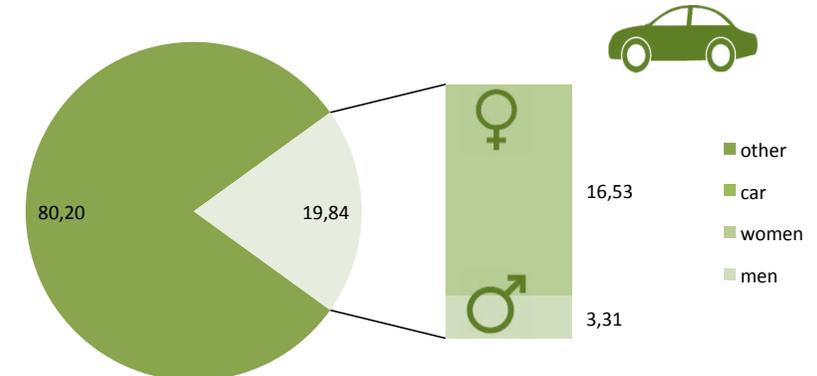


Fig. 25. Percentage of persons commuting by car by gender

However, raw data did not provide the answer to the question whether women or men are more likely to choose more ecological means of transport. To verify this, the received data was compared to the percentage of men and women in the study population (Figure 26).

A comparison of the percentage of women and men in the surveyed population and their choice of means of transport indicates that men are more likely, than their share in the study population, to drive a bicycle and use public transport. Conclusion: this seems to deny the widespread belief that men are more likely to drive a car than women, and that women are more likely to travel by public transport – but it should be remembered that the research concerned young people.

The second criterion that was examined was the field of study. It was compared whether the choice of means of transport depends on the field of study (and conducted courses, for example, on the environment). The results are shown in Figures 27-30.

After equating the obtained results to the percentage of students in different fields of study in the surveyed population (Fig. 31, Table 1), it can be observed that students of natural sciences, more often than their representation in the student population, choose public transport and walking. They rarely drive.

Leaving the analysis of the received data at this level would undoubtedly demonstrate the influence of the environmental attitudes of students on the choice of means of transport. However, if we observe how the choice of the means of transport changes with the level of studies (Fig. 32) and the age of students (Fig. 33), we notice a disturbing tendency: the older the students are and the better educated, their declared interest in environmental protection and the type of education has less influence on their pro-ecological choices.

Conclusion: It seems that the lack of a car or lack of funds for its maintenance decides about the preferences

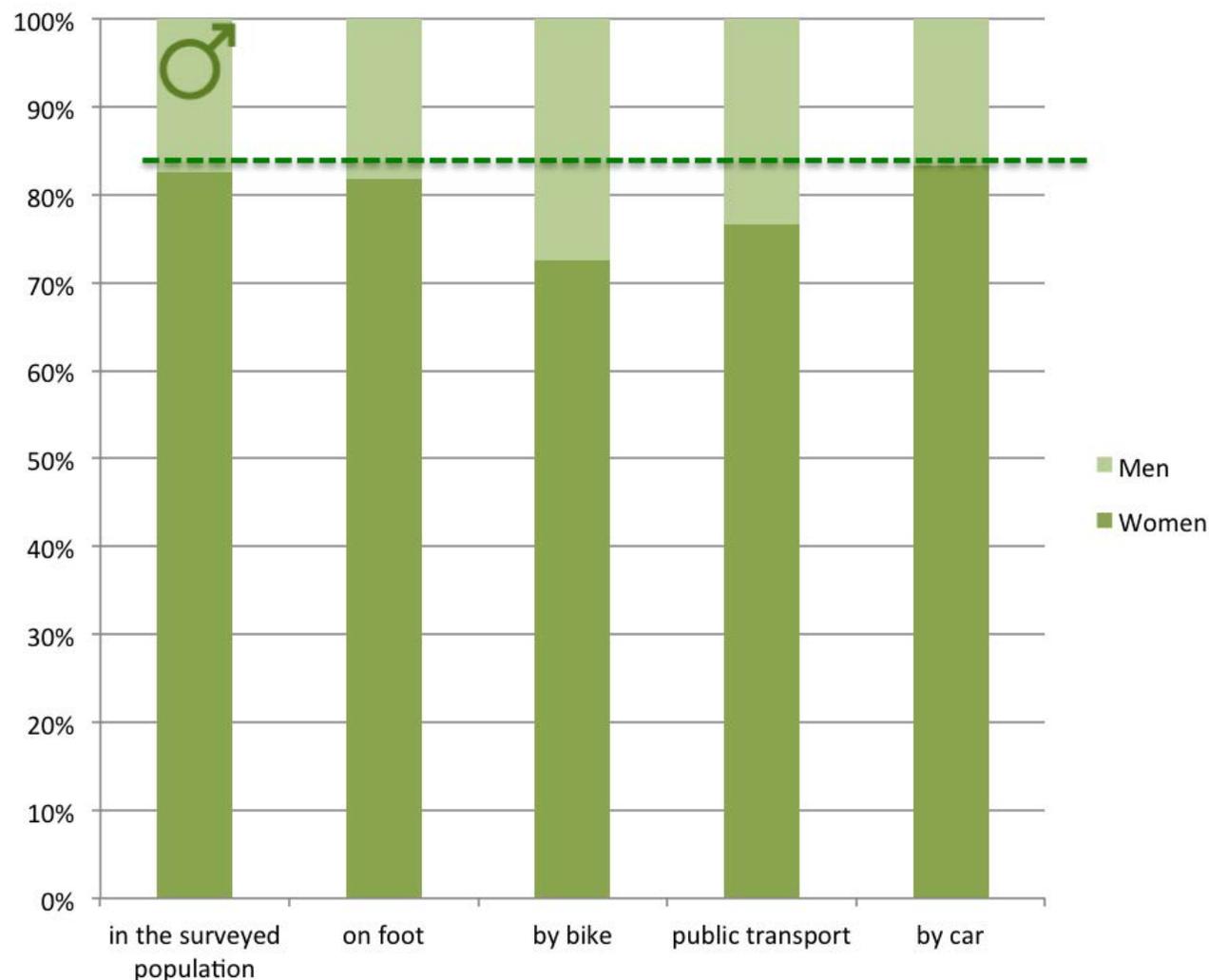


Fig. 26. Alignment of the results to the percentage of men and women in the study population

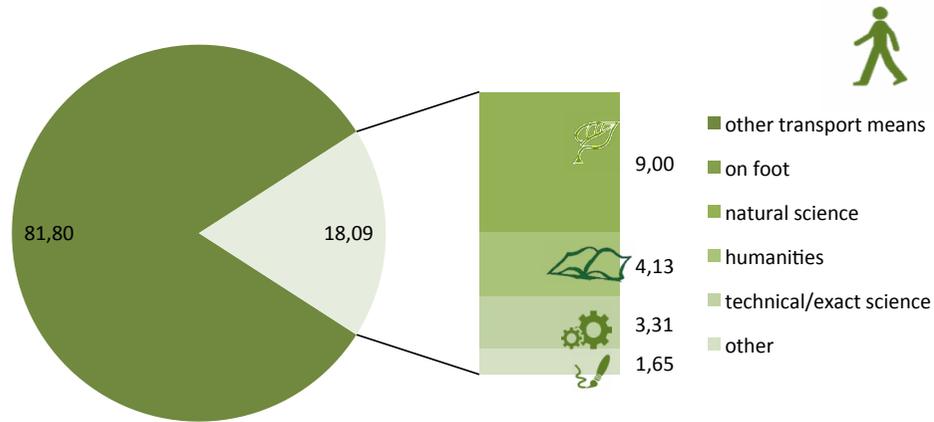


Fig. 27. Percentage of people going to university on foot with regard to their studies

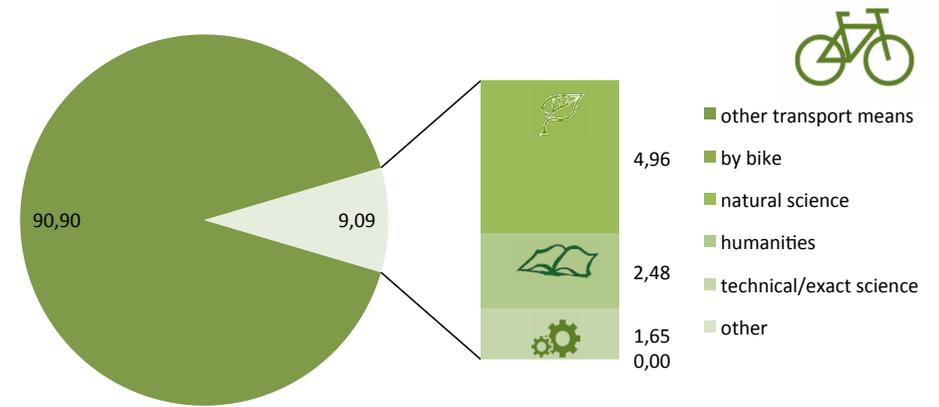


Fig. 28. Percentage of people riding a bike to university with regard to their studies

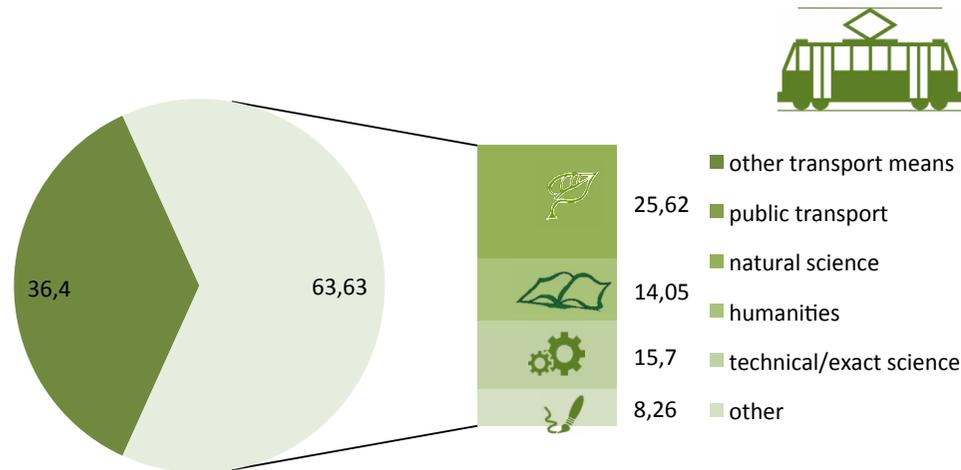


Fig. 29. Percentage of people commuting to university with regard to their studies

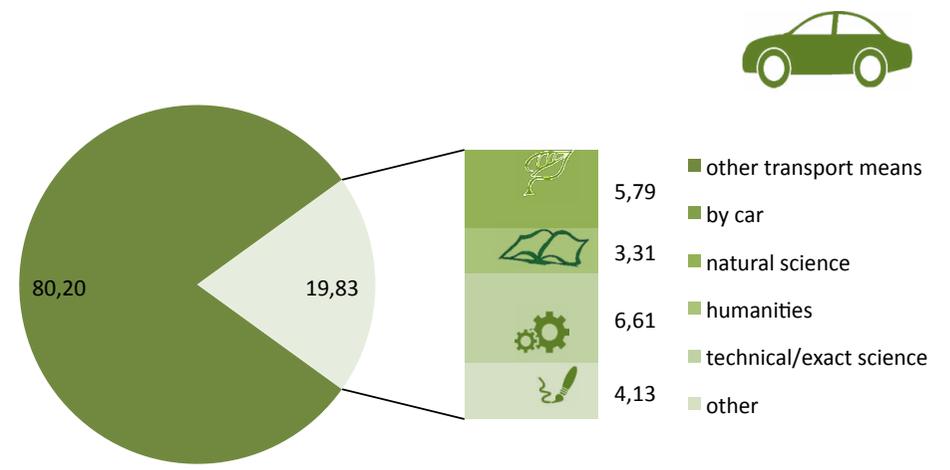


Fig. 30. Percentage of people driving to university with regard to their studies

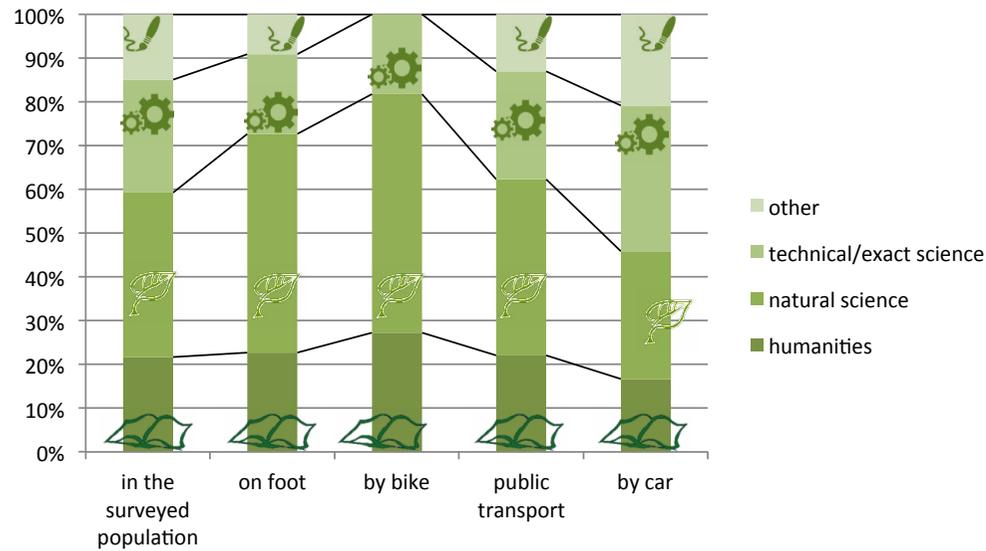


Fig. 31. Alignment of the obtained results to the percentage of students of particular fields of study in the studied population

	Humanities	Natural science	Technical/exact	Other
On foot	≈	↑↑	↓	↓
Bike	↑	↑↑	↓	↓
Public transport	≈	=	≈	≈
Car	↓	↓	↑↑	↑

Symbols used in the table:

- ↑↑ much more than the average in the surveyed population
- ↑ more than the average in the surveyed population
- = the average in the surveyed population
- ≈ nearly as the average in the surveyed population
- ↓ less than the average in the surveyed population

Table 1. Comparison of the obtained results of individual groups with the mean in the population

Based on Fig. 31.

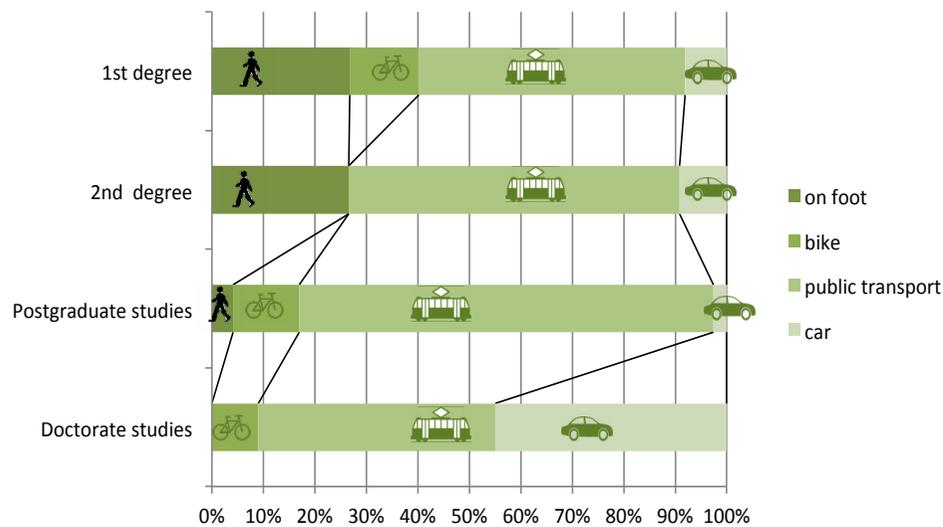


Fig. 32. Alignment of the obtained results to the percentage of students at a given level of study in the studied population

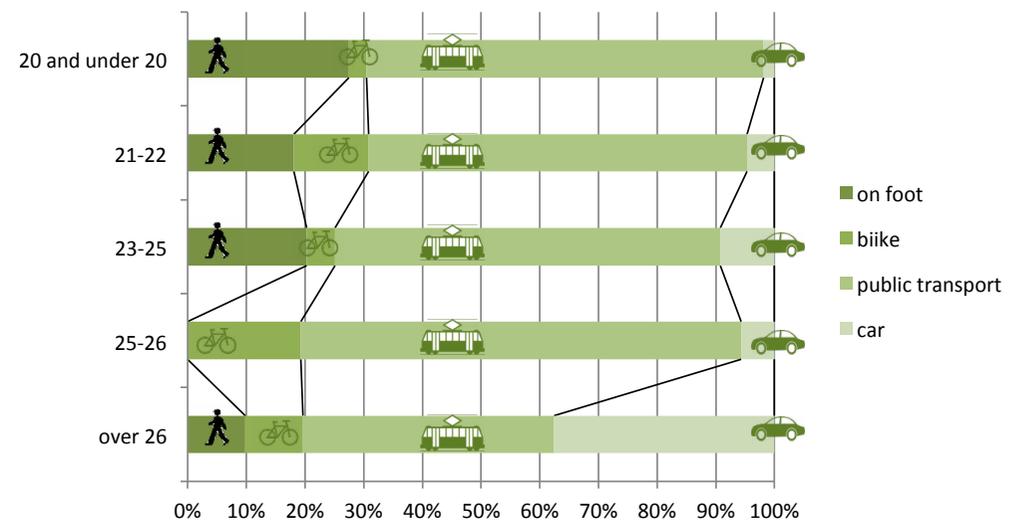


Fig. 33. Alignment of the obtained results to the percentage of students of a given age in the studied population

of environmental means of transport among students. This concept is supported by the motivations of choosing the means of transport.

In the remainder of the survey, students were asked to provide, in an open question, three expressions to justify their choice of a particular means of transportation.

Students choosing to walk to university on foot (Fig. 34) most frequently mentioned the following advantages of walking: it's close, healthy, fast, cheap, comfortable, they like sport / fitness / physical activity, safety.

The provided expressions may be grouped into three categories. One of the dimensions of motivation is the broadly understood concept of comfort – this may include the following: it's close, fast, cheap, comfortable (highlighted in blue in the chart). The second dimension of motivation has a pro-health / pro-ecological aspect – it is represented by: health, I like sport, physical activity, fitness (highlighted in green in the chart); the third is safety (highlighted in red in the chart). If we segregate the data in this way we will observe (Fig. 35) that pedestrian communication as a method of reaching the university is chosen because of comfort (64% of indications). The pro-health aspect amounts to only 34% of responses (Safety 2%).

Students choosing a bike to go to university mentioned the same eight advantages of this type of transportation (it's close, healthy, fast, cheap, comfortable, I like sport / fitness / physical activity, safety).

Identically as in the previous example, the expressions provided by students were grouped into three categories (Fig. 37). And as in the previous example, students choose cycling as a means of transport to get to university mainly because of comfort (62% of indications). The pro-health aspect amounts to only 31% of responses (Safety 8%).

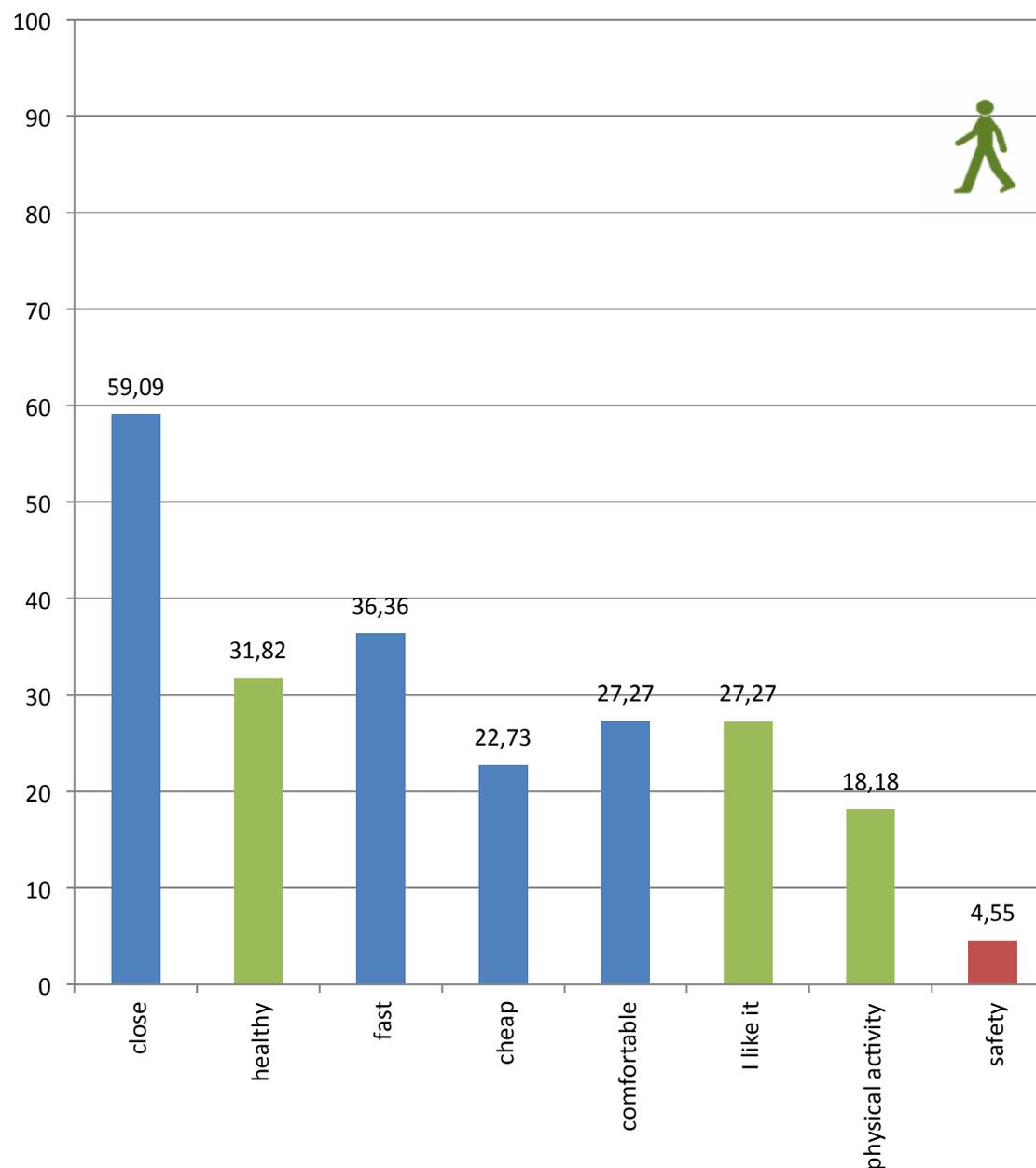


Fig. 34. Expressions used by students to justify walking on foot

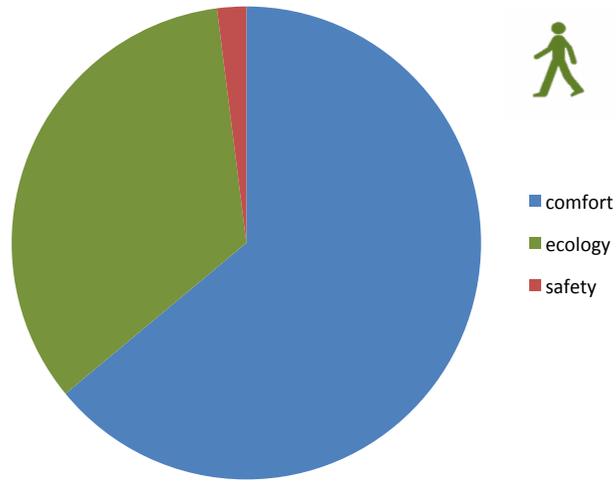


Fig. 35. Expressions listed by the student to justify walking on foot, grouped into 3 categories

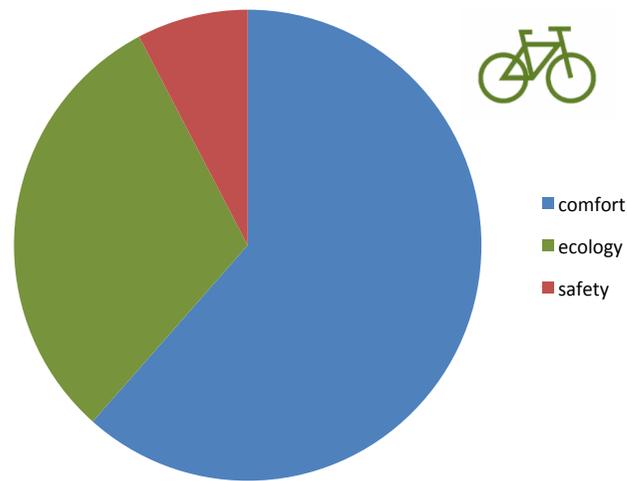


Fig. 37. Expressions listed by the students to justify reasons for cycling, grouped into 3 categories

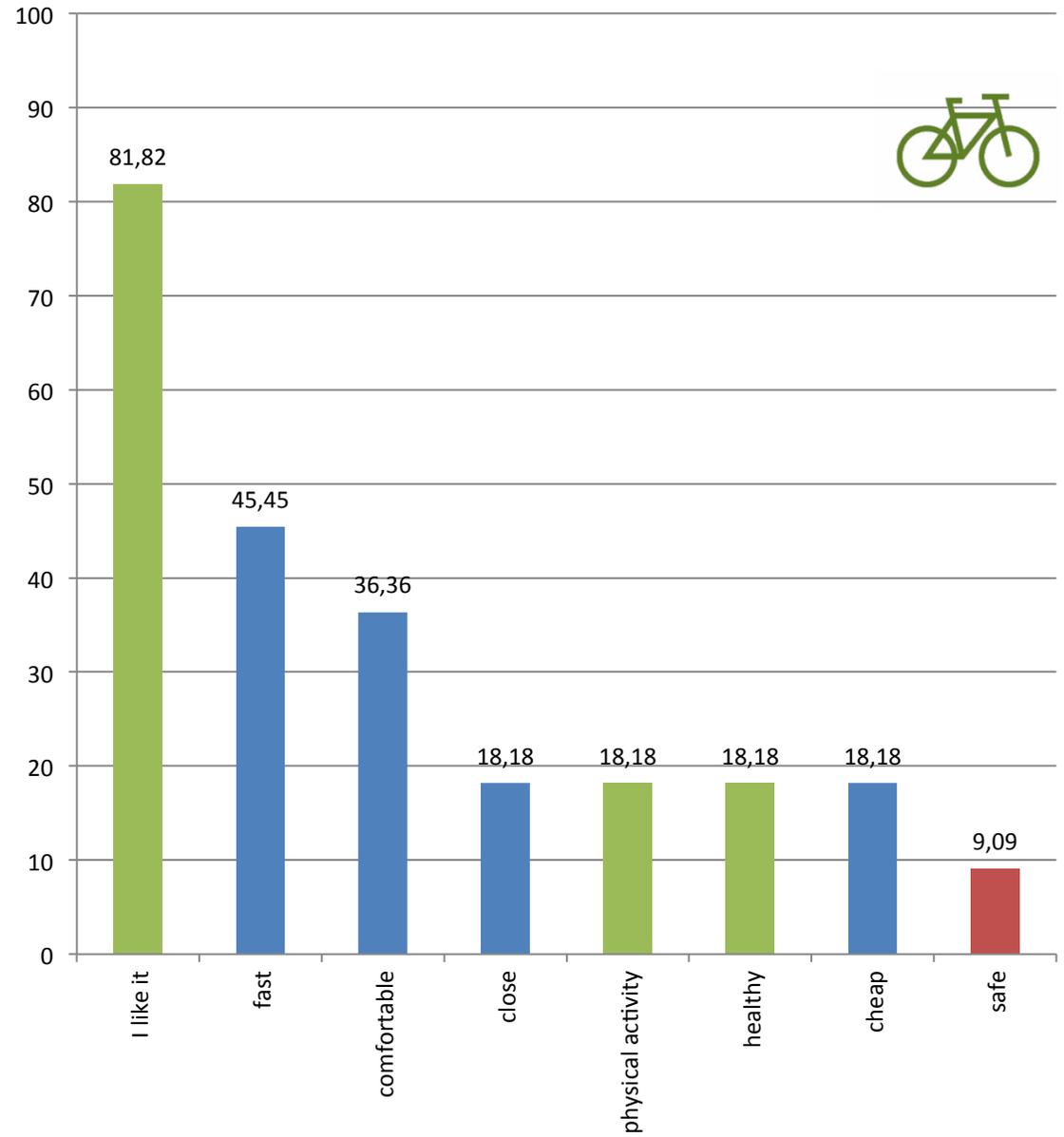


Fig. 36. Expressions listed by students to justify the reasons for cycling

Students who choose public transport as a way of commuting to university mentioned as many as 28 different expressions motivating their choice (Fig. 38): fast, cheap, convenient, it's far away, no car, safe, it's close, the only possible means of transport, accessible, ecological, traffic jams, direct access, problems with parking, it's packed, without stress, because I can, frequency, necessity, I like it, I do not have a driving licence, I do not have a bike, straight, friendly, no choice, punctual, relaxing, efficient, healthy, I'm cold.

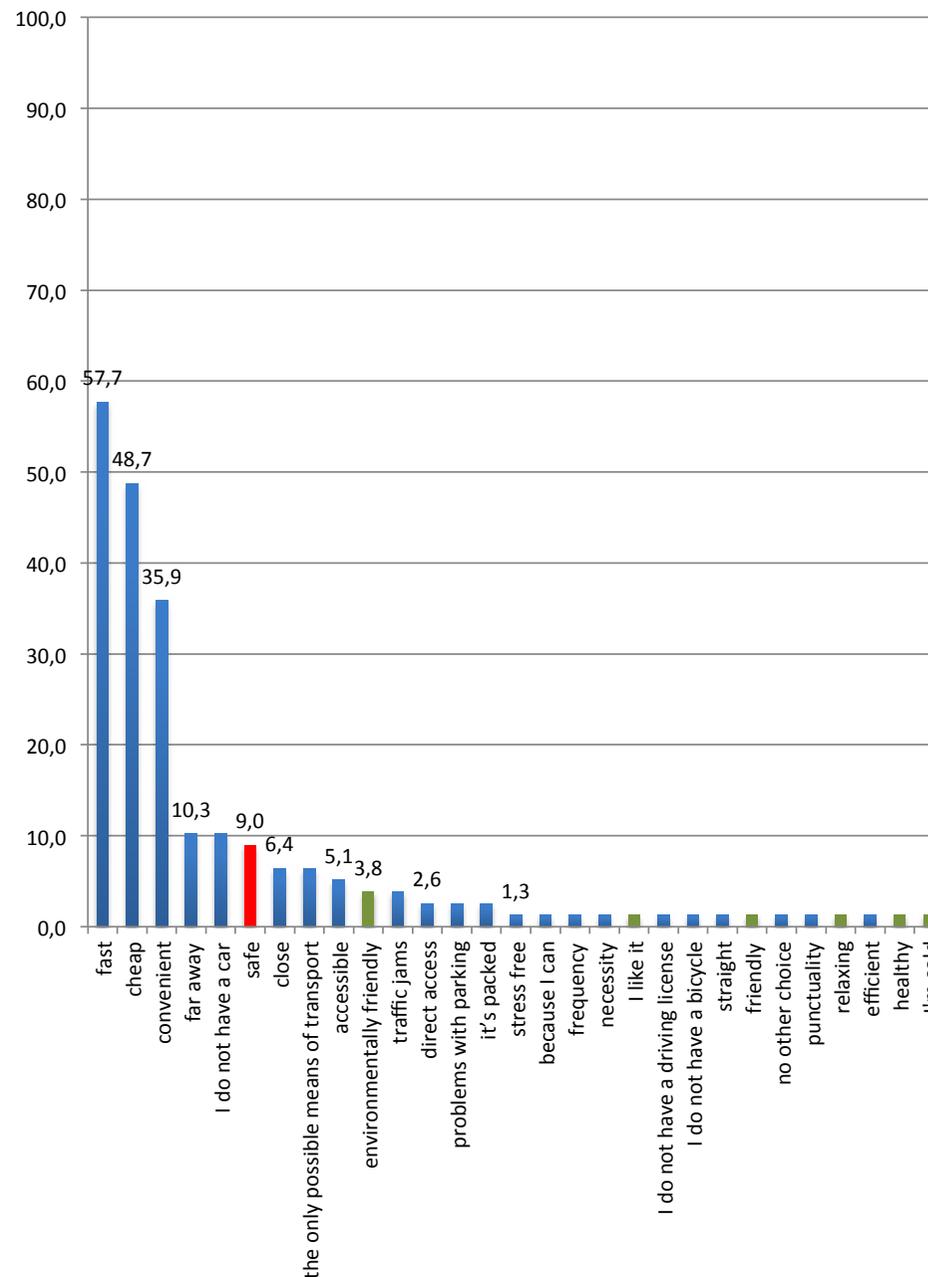
Conclusions: It is difficult to agree with some of these expressions (e.g. relaxation, stress free), other motivations are not fully understood (e.g. healthy, friendly), still other reveal personal preferences of the respondents (e.g. it's packed). Sometimes the choice of public transport is a necessity or the only possibility (e.g. lack of bike, driving license, car). Some of the opinions of the surveyed students confirm the earlier analysis of the authors about the ways of moving around Cracow (e.g. traffic jams, parking problems, punctuality, efficiency, comfort).

Students who chose public transport were the only ones to point directly to the ecological aspect of the choice of means of transport (3.8%). It is worth noticing that some student responses are contradictory (e.g. 6.4% of students argue that they use public transport because their destination is close, and 10.3% that it is far away).

Expressions listed by students were grouped into three categories (Fig. 39). Like in the earlier cases, the choice of public transport as a method of commuting to university was due to comfort reasons, but in this case it amounted to as much as 91% of indications. The health / environmental aspect amounts to only 5% of the responses and safety 4%.

Students who chose the car as a means of transportation to go to university listed 11 different motivational choices (Fig. 40): fast, convenient, it's far, independ-

Fig. 38. Expressions listed by students justifying the use of public transport



ence, children to be transported, better, more efficient, direct access to the place of destination, safe, economical, laziness. Conclusions: This is the only group which mentions “children” (which in Cracow is not quite true given the number of parents with children on buses or trams and children travelling with cyclists), and the only one where people admit to laziness. The responses concerning “independence” and “direct access to the place of destination” – are somewhat stretched because of the parking difficulties in Cracow, usually the only available parking place is located far away from the destination. Also, the economic aspect in this case seems unlikely.

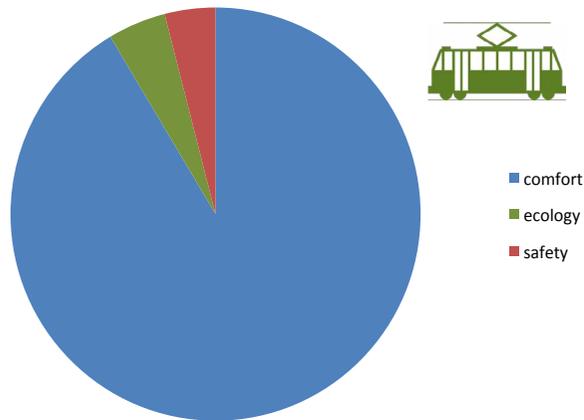
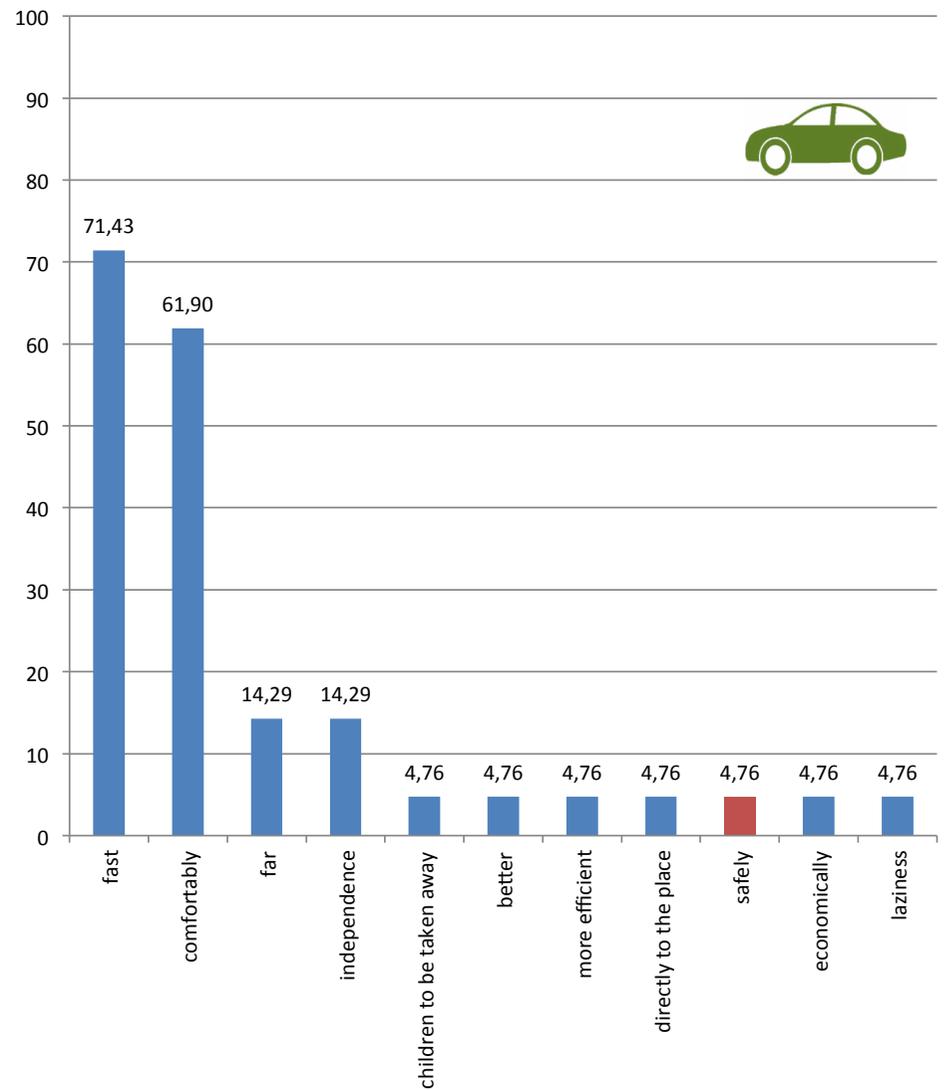


Fig. 39. Expressions listed by students justifying the use of public transport, grouped into 3 categories

Fig. 40. Expressions listed by students justify driving a car



Expressions listed by students were grouped into two categories (Fig. 41). There is no pro-health / environmentally friendly aspect here. Convenience amounts to 92% of responses, and safety to only 8%.

The summary of the results presented in one graph (Fig. 42) leads to the following conclusions:

- on foot: close and healthy,
- the bike is used by people who like it,
- public transport is cheap and ecologically sound,
- the car is fast and convenient

The grouping of the results into 3 categories (Fig. 43): convenience, ecology, safe shows that the convenience of walking and cycling is comparable for the respondents (slightly more than 60%) and similarly, the convenience of using public transportation and the car is also comparable (just over 90%). The pro-health/ecological aspect is demonstrated by slightly more than 30% of respondents riding a bicycle or walking on foot.

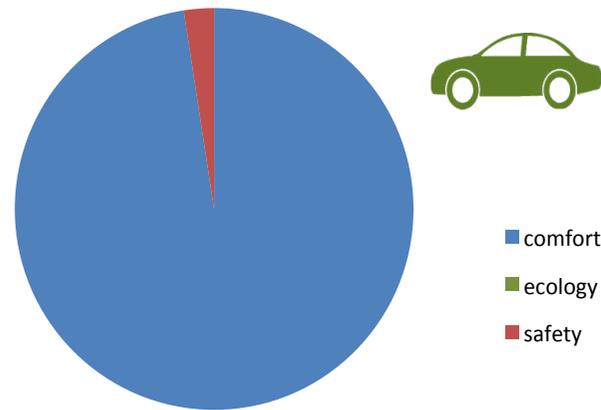


Fig. 41. Expressions listed by students justifying the use of a car, grouped into 3 categories

Fig. 42. Comparison of the motivations when using different means of transportation

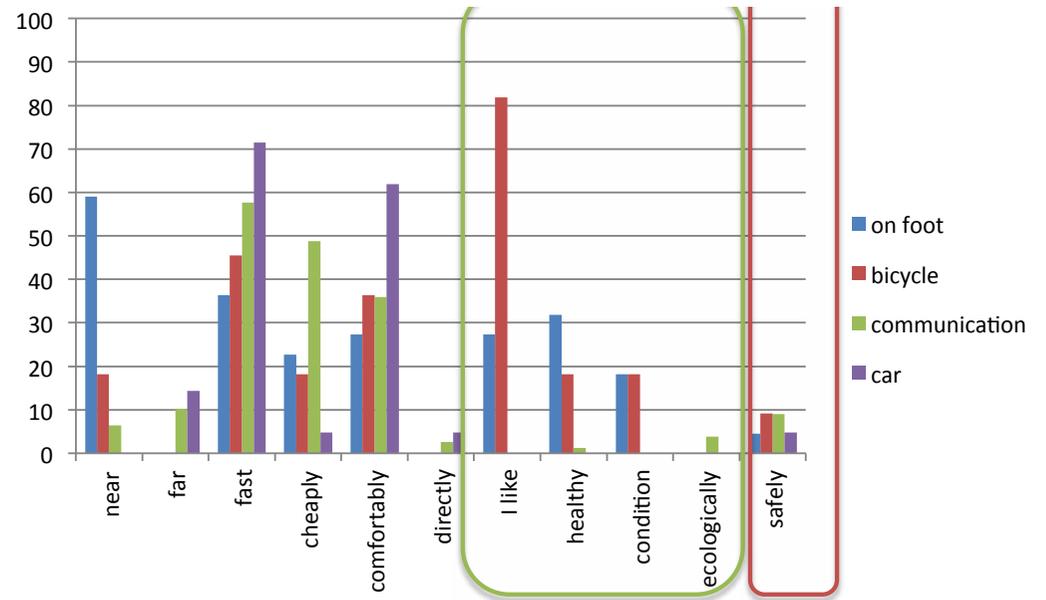
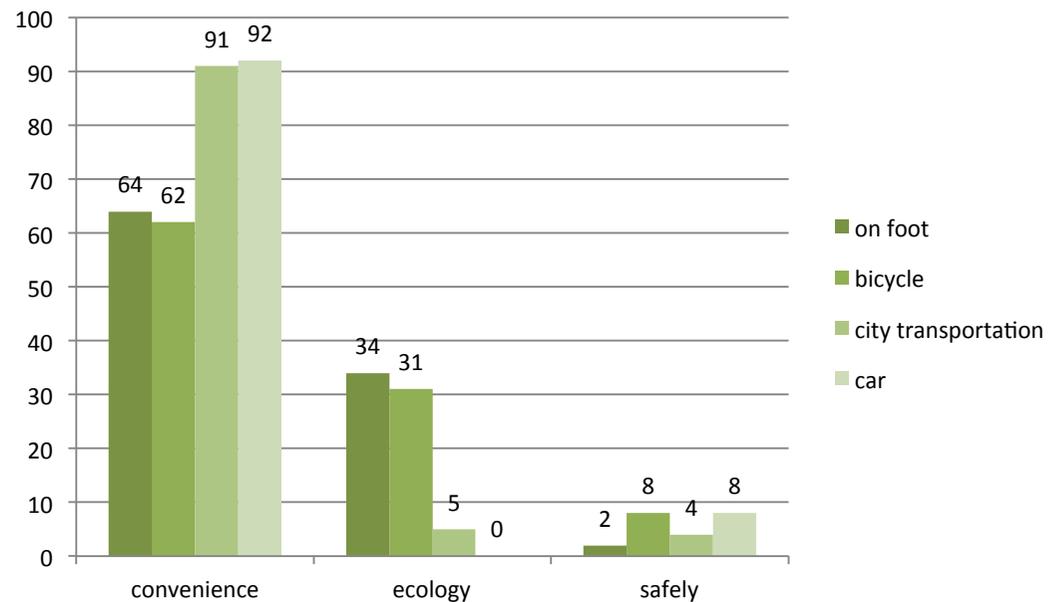


Fig. 43. Comparison of the grouped motivations when using different means of transportation



Safety, as a motivating factor for the choice of the means of transport, is the lowest (below 10%) – the highest in the case of the car and bike<sup>5</sup> (8%).

In a local referendum, held on 25 May 2014, 85% of Cracow residents were in favour of the construction of bicycle paths. Whereas students were asked the following question: *If there were good and safe bicycle paths in your area, would you ride a bike to work / school?* More than half of the respondents answered NO (Fig. 44). Therefore, it is not the lack of safe bicycle paths that affects the use of the bicycle as a means of transportation.

As a justification of the answer “NO” (Fig. 45), students mentioned the following reasons: far away (18%), I do not like it (12%), I do not have a bike (9%), no stamina (3%), I prefer to walk (3%) and I can’t ride a bike, I prefer to drive a car, I prefer to ride a bike on the street than on a bicycle path, when cycling I cannot dress elegantly, I do not have time, I have to take children to the kindergarten (about 1%).

As justification for answer “YES” (Fig. 46), students mentioned the following reasons: it’s healthy (17%), I like it (11%), fast (5%), cheap, pleasant, safe, comfortable (2%), its’ close, ecological, independence (1% each). Other justifications (fear of cycling, the road, no traffic, far away, well-being, oxygenation, it’s easy, fitness, contact with nature, relaxation, movement, training, less traffic in the city) were below 1%. It can therefore be said that the motivations for “Yes” are more diverse. However, both in the case of the reasons for “YES” and “NO”, there appears the justification: I like it/ I do not like it, so it seems that people have to get to like riding a bike... maybe the school, maybe some actions...

<sup>5</sup> Wydaje się, że jednak ścieżki rowerowe w Krakowie spełniają swoją rolę i rowerzyści czują się na nich bezpiecznie. It seems that bicycle paths in Cracow fulfil their role and cyclists using them feel safe.

Fig. 44. *If there were good and safe bicycle paths in your area, would you ride a bike to work / school?*

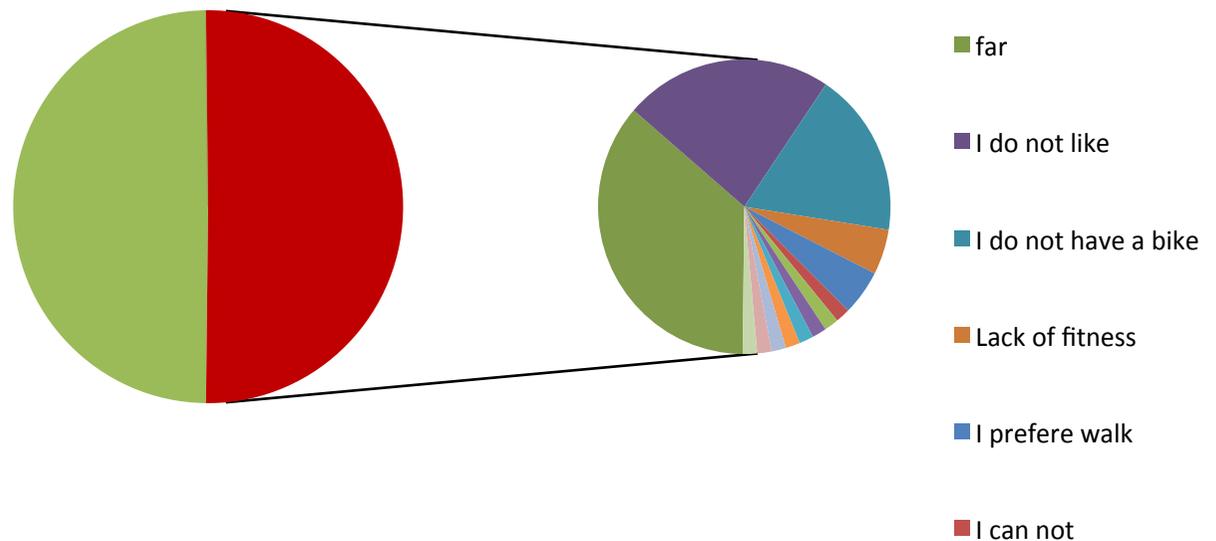
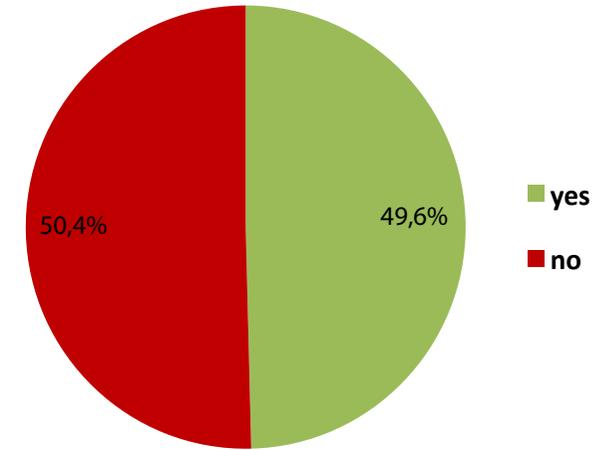


Fig. 45. *If there were good and safe cycling paths in your area, would you go to work / school?* Justification for choosing answer “No”

## Conclusion

Based on the above findings, it can be stated that the level of ecological awareness among students is still not satisfactory and the declared care for the environment is not supported by attitudes and behaviours. Students of natural sciences have identified their ecological awareness as one of the highest, but although students of this particular field of study, more often than it would appear from their representation in the student population, choose public transport and walking, and less frequently the car, their own comfort is most important to them, even more than health and stamina, and not care for the environment. In situations where they have the choice of convenience or care for the environment, they choose their own comfort. Also, in situations where they have the choice of saving money or engage in pro-ecological actions which involve increased spending, saving money is also a priority. As the study shows<sup>6</sup>, only one in three Poles (36%) is willing to spend more money on ecological solutions.

As concerns education for sustainable development more emphasis should be placed on the ability of students to properly assess the reality and make decisions that enable them to take care of their health and the environment.

Research also shows that without changing the students' attitudes, further development of cycling networks in Cracow will not affect more frequent use of bicycles as a means of transportation. It seems, therefore, that the construction of bicycle paths postulated by the inhabitants of Cracow has a recreational purpose rather than a communication purpose.

Research also shows that men are more likely to ride a bicycle and use public transport than women. This

<sup>6</sup> [https://www.mos.gov.pl/g2/big/2014\\_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf](https://www.mos.gov.pl/g2/big/2014_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf)

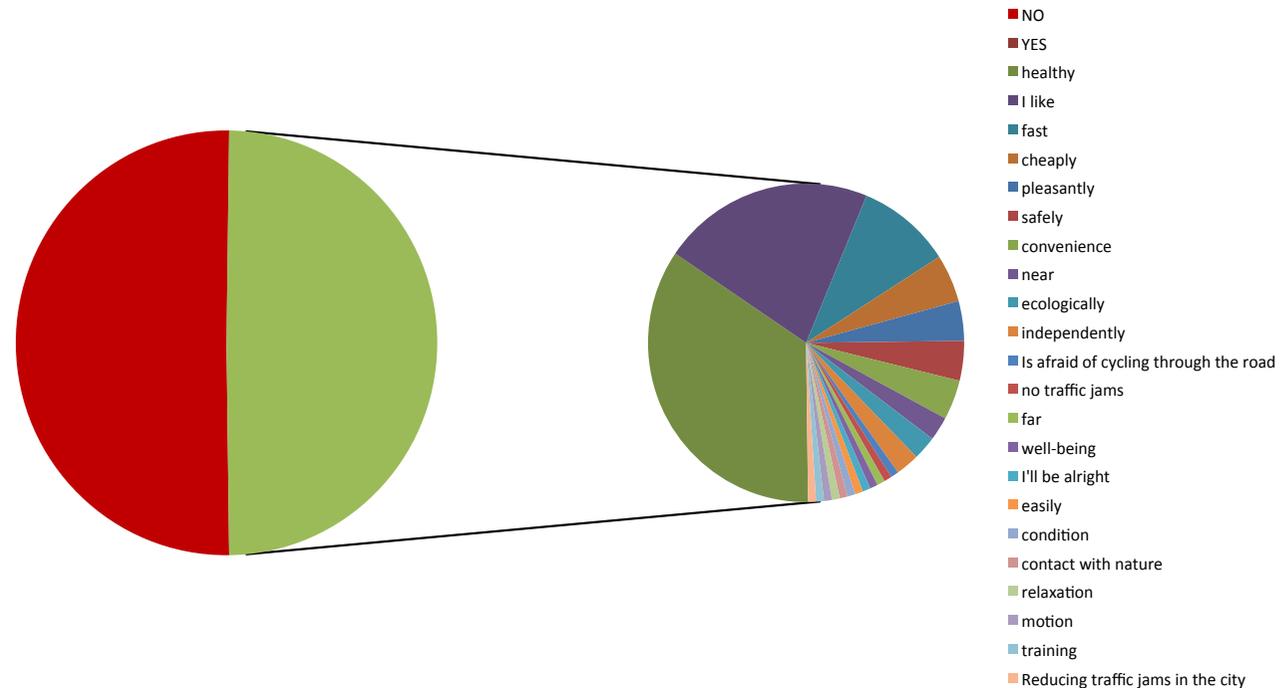


Fig. 46. If there were good and safe cycling paths in your area, would you go to work / school? Justification for choosing answer "Yes"

contradicts the general belief that men are more likely to drive a car than women and that women are more likely to travel by public transport – but we must remember that the study concerned young people.

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- The report on the analysis of the surveys on ecological awareness, attitudes and behaviour of Poles conducted in Poland in 2009-2015 was prepared for the Ministry of the Environment by the Social Research Team at TNS Polska. The project was financed from the National Fund for Environmental Protection and Water Management

[https://www.mos.gov.pl/fileadmin/user\\_upload/Raport\\_z\\_analzy\\_badan\\_swiadomosci\\_postaw\\_i\\_zachowan\\_ekologicznych\\_Polakow\\_przeprowadzonych\\_w\\_Polsce\\_w\\_latach\\_2009-2015.pdf](https://www.mos.gov.pl/fileadmin/user_upload/Raport_z_analzy_badan_swiadomosci_postaw_i_zachowan_ekologicznych_Polakow_przeprowadzonych_w_Polsce_w_latach_2009-2015.pdf), dostęp 11 lipca 2016r.

(Raport z analizy badań świadomości, postaw i zachowań ekologicznych Polaków przeprowadzonych w Polsce w latach 2009-2015 przygotowany został na zlecenie Ministerstwa Środowiska przez Zespół Badań Społecznych w TNS Polska. Projekt sfinansowany został ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej.)

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<http://kmmkrakow.pl/informacje-o-systemie-kmk/infrastruktura.html>

[https://www.mos.gov.pl/g2/big/2014\\_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf](https://www.mos.gov.pl/g2/big/2014_12/3cd08e737106bd35c7a6e3128e9abbbd.pdf)

# Plants growing on wastes? Classes scenario based on household wastes

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„Responsible consumption and production”, „climatic action”, „life below water” and „life on land” – these four issues are only few examples of the sustainable development goals [Sustainable Development – Knowledge Platform] (<https://sustainabledevelopment.un.org>). To achieve them, however, one should take into consideration another goal – this is namely „quality education”. There is no doubt that the earlier the environmental education begins, the higher chances for building the society aware of the environmental issues. Many authors emphasize the need of promotion pro-environmental attitudes among children at the kindergarten and primary school level (Falkiewicz-Szult, 2014, Lelonek, 1984, Męczkowska and Rychterówna, 1923). It is very significant nowadays, while we are facing unmeasurable consumption and waste production which



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cannot be biodegraded in majority. The Statistical Office in Katowice (Poland) published in 2015 „Wskaźniki zrównoważonego rozwoju Polski” (Sustainable Development Indicators of Poland). Among other things, the authors analyzed data concerning waste management. Table 1 shows a few categories of waste management and production with data for the last year presented in the publication.

Waste management is crucial for environmental protection and conservation. Waste production utilizes energy and resources, thus improving the waste management technology, including recycling, should be a desired course. In 2015 the production of plastics and other similar polymers reached 58 mln tons in the European Union, Norway and Switzerland (circa 18% world production) (PlasticsEurope, 2016). In 2015 Poland took sixth place in the ranking of plastics demand in Europe (6.3%) (PlasticsEurope, 2016). The highest use of plastics

Category	Year of data	Value	Trend
Non-mineral waste generated per capita	2012	1883 kg	Fluctuations with increase
Municipal waste generated per capita	2013	297 kg	Decrease
Municipal waste treated by landfilling per capita	2013	157 kg	Decrease
Municipal waste collected selectively in relation to total municipal waste	2014	19.8%	Increase
Recycling of packaging waste	2012	41.4%	Fluctuations

Tab. 1. Data on the waste production and management published in „Wskaźniki zrównoważonego rozwoju Polski” (*Sustainable Development Indicators of Poland*) (2015).

Non-mineral waste: construction waste, soils, various mineral waste, dredged material. Municipal waste: mainly generated in the households. Source of data: Eurostat, GUS.

in Europe concerns packaging and building materials (respectively: 39.9% and 19.7% in 2015) (PlasticsEurope, 2016). Despite the need of the waste recycling, people exhibit various attitudes toward waste sorting. The low level of awareness reflects in ignoring the rules of waste segregation in Poland (for example: putting different types of rubbish in wrong bins and containers, disposing of unsqueezed bottles), developing of wild garbage dumps or burning garbage to heat homes.

Wastes represent a great threat to ecosystems and organisms which inhabit them. Studies conducted in two forest stands near Ostrów Wielkopolski (Poland) proved that waste disposed in forest pose a great threat to life of invertebrates and small vertebrates (Kolenda et al., 2015). Among 254 collected pieces of rubbish 102 did not contain any animals, however 111 of them became graves for animals and there were alive animals in 76. Invertebrates outnumbered vertebrates, nonetheless dead rodents (4 species, 5 specimens) and shrews (2 species, 5 specimens) were found. Jambeck et al. (2015) estimated that 192 coastal countries produced 275 million metric tons of plastic and 4.8-12.7 million metric tons entered the ocean waters in 2010. These wastes are dangerous for the marine life. Probably the most popular example are sea turtles confusing plastic bags with jellyfish. Furthermore the plastic trash is commonly found in stomachs of birds, e.g. the Magellanic penguins (*Spheniscus magellanicus*) (Pinto et al., 2007). But what is even worse, Wilcox et al. (2015) estimate that till 2050, 99% of sea birds will „feed” on plastics. Plastic products do not degrade easily or they do not degrade at all and they lead to death of lots of birds nowadays. The mass production and disposing of plastics in environment induce changes in ecosystems – the nature tries to respond to a new factor. It can be seen in behavior of many animals. Hermit crabs (*Coenobita purpureus*) use plastic wastes the same way they use seashells – as shel-

ters (<http://okinawanaturephotography.com/>). Birds use rubbish to decorate their nests, e.g. the black kite (*Milvus migrans*) (Sergio et al., 2011). Moreover two species of solitary bees representing the genus *Megachille* use plastic materials to build their nests (Maclvor and Moore, 2013).

To reduce the amount of wastes on dumps and contribute to protection of the natural resources, we should convert and recover waste if it is possible. Such materials as paper, glass, plastics and metals can be recycled. Various biodegradable waste can be composted at large scale or in the households. Composting is a degradation of biodegradable products due to the activity of microorganisms in proper thermal, humidity and oxygen conditions. Compost may be used as a soil and fertilizer (Möller, 2016). However, one should remember that the properties of compost depend on the material which was composted (Möller, 2016, Prasad, 2013.). Biowaste generated in city may be called „urban organic wastes”. It can be broken down into several categories, for example household biowaste, green waste from gardens or organic waste from food processing (Möller, 2016). Knowing the source of waste is important due to presence and amount of various chemical elements in them. To simplify, probably the most crucial are phosphorus and heavy metals. While phosphorus is playing a significant role in growth and development of plants, heavy metals are toxic to organisms (Möller, 2016). Due to numerous applications of compost which production is connected with chemical cycling and energy flow in nature, compost can be defined as renewable natural resource.

Recently, an idea of creating urban composters has emerged. Everybody would have access to these composters and the compost produced there would be used according to planned earlier purposes. The Social Initiative „I hand over waste” (Oddam Odpady) runs the campaign „Open composters” („Otwarte Kom-

postowniki”) which aims to gather data about public, accessible for everyone urban composters. Furthermore the authors provide information about location of the open composters by showing them on a map (<http://mapa.oddamodpady.pl/>, access 25.02.2017).

It is estimated that until 2020 the mass of all types of waste per capita will reach 680 kg (Pawul and Soczyk, 2011).

Shaping pro-environmental attitudes in kids and youths by teachers requires long-term nurturing of students with paying attention to the educational content and ways of acquiring the ecological knowledge. Such knowledge should stimulate exploration and constant curiosity of the surrounding reality, thus it should also be applicable outside the school and in free time. ([http://www.pdg.ug.edu.pl/studenci/edukacja\\_ekologiczna.pdf](http://www.pdg.ug.edu.pl/studenci/edukacja_ekologiczna.pdf) after Klus-Stańska, 2000). (Męczkowska and Rychterówna) already shared that opinion in 1923. The conclusion is obvious: the theory provided in the classroom is not enough to deal with waste sorting and recycling issues. There is a need to support the process of teaching with practical experiences to awaken the curiosity.

In the face of great anthropopression, here we suggest a classes scenario for the primary school students. The core curriculum, indeed, requires realization of lessons concerning waste management, but especially during the first level of education (I-III primary school classes). The school subject Nature which is realised in IV class of the primary school was given an aim „*Acceptance of the responsibility for the condition of the natural environment (...)*” which allows to remember students the significance and rules of waste management. Moreover it is possible to connect the waste management issues with at least two of the points which are meant to be realized during V-VIII classes of the primary school: „*VII. Ecology and environmental protection. The stu-*

*dent: 9) presents renewable and non-renewable natural resources and suggests ways of rational management of these resources in compliance with points of the sustainable development” and „VIII. Threats to biodiversity. The student: 4) justifies the need of the biodiversity protection”.* However, it is possible only when realization of the point VII. 9) will be based on the rational waste management in compliance with sustainable development. Otherwise it will be meaningless to find an educational aim on that school level which could be connected with waste issues. It seems to be logical to integrate the point VII. 9) with VIII. 4) from the point of view of threats which mass waste production poses to environment. Furthermore there is a suggestion in the core curriculum that realization of both sections (VII and VIII) as well as V and VI should be done in the last class of the primary school. This raises doubts about carrying out reliable lessons concerning such issues, when we take into consideration that there is so much material and so little time to teach and to prepare for the final exam of the VIII class. Here, provided by us school scenario may be used as a variety of an ordinary lesson or after-school activity.

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## Scenario

**Target group:** 10-15 years old.

**Form of activities:** group work, individual work.

**Methods:** scientific, laboratory, verbal, project.

**Time:** at least 3 weeks (including two lesson units – 45 min).

**Materials:**

- Garbage collected by students in their households, according to the scenario.
- Garden soil (5-10 litre).
- Seeds of rapidly sprouting plants: bittercress, tomato, lettuce, fenugreek, radish.
- 20 pieces of 0.5 litre glass jars in reserve.
- 10 litre or 20 litre wastebags may be also helpful.

**Aim:** Due to analyzing the problem of waste mass production and management, the classes are meant to stimulate pro-environmental attitudes in students who will spread them further in future in the society. It is in agreement with expected effects of implementation of the project method (Stawiński, 2000).

## Core curriculum

(new version which will take effect on 1.09.2017) (Dz.U. 2017 poz. 356):

**Primary school, IV class, school subject: Nature.**

**Aims of education – general requirements**

III. Shaping the attitudes upbringing.

7. Acceptance of the responsibility for the condition of the natural environment through:
  - 1) proper behavior in the natural environment,
  - 2) social responsibility for the condition of the neighbourhood,

- 3) the activities for the local environment,
- 5) conscious activities for natural environment protection and conservation.

**Educational contents – detailed requirements**

VII. The anthropogenic environment and the landscape near school. The student:

- 3) determines relationships between elements of the natural and anthropogenic environment.

**Primary school, V-VIII classes, school subject: Biology.**

**Aims of education – general requirements.**

II. Planning and conducting of observations and experiments; concluding. The student:

- 1) determines the research problem and hypotheses, plans and conducts simple, biological experiments, and documents observations;
- 2) determines conditions of the experiment, distinguishes control from experimental variants;

VI. The attitude toward nature and environment. The student:

- 1) explains the necessity of conservation;
- 2) presents an attitude full of respect toward himself and alive organisms;

**Educational contents – detailed requirements**

VII. Ecology and environmental protection. The student:

- 9) presents renewable and non-renewable natural resources and suggests ways of rational management of these resources in compliance with points of **the sustainable development.**

VIII. Threats to biodiversity. The student :

- 4) justifies the need of the biodiversity protection.

## Description of classes

1. Students are divided into four teams by the teacher.
2. Each team is given a task to collect one type of wastes in the households: I. Plastic products – plastic bags, packaging products, bottles, II. Paper – cartons, journals, III. Glass – jars, bottles (**unbroken**), IV. Biowaste (preferably food waste) – egg shells, peelings, green waste. Plastic and glass waste should be rinsed with water to avoid unpleasant odour and development of fungi.
3. After one week of collection students bring wastes to school and notice the diversity of wastes generated in the households. Basing on the observations of students, the teacher estimates with them the amount of wastes per capita, generated during one week and then during one year. The wastes can be measured with a tape measure to estimate the volume they occupy by comparing them mathematically to a cuboid, or by putting them in wastebags with known volume. The calculations are made by the teacher or students dependably of the educational level.
4. Students prepare the material: they count 200 seeds of the chosen plant and then pour them with water and leave for 15 min.
5. If there is insufficient amount of 0.5 litre glass jars, students will use prepared earlier jars. Prepare the experiment in well-lighted place. Each variant prepare in two repetitions:
  - Jar I. Fill it with the garden soil almost to the top.
  - Jar II. Cut and shred the plastic wastes to pieces. Place them on the bottom of the jar. Then coat it with a layer of the garden soil. Repeat the pattern two more times (in total six layers).
  - Jar III. Similar to Jar II, however replace the plastic wastes with biowastes.

- Jar IV. Similar to Jar II, however replace the plastic wastes with paper.
  - Jar V. Cut and shred the plastic wastes to pieces. Fill the jar with them almost to the top.
6. The teacher asks students to point the control variant (Jar I) and experimental variants (Jars II-V). Students pour each jar with the same volume of water – 100 millilitres. They sow 20 seeds on the top layer of each jar (they use seeds poured with water in point 4.).
  7. Students observe germination and growth of plants. Whenever needed, they water the plants to enable germination. Students take notes how many plants germinated and how many of them survived after two weeks. It is possible to measure the length of seedlings and roots. After two weeks the students remove the content from all jars and evaluate the state of wastes. The observations of the state of glass degradation can be performed as evaluation of the state of glass jars. All material must be gently removed from jars if the shoots and roots of seedlings are planned to be measured. Otherwise they may be damaged. Finally, the students state their conclusions.
  8. Results and conclusions of the experiment can be presented in a form of a note in the notebook, classroom exhibition, photo reportage, blog in the internet and others, as suggested in Pilichowski and Tokarska-Osyczka (2016).

### Examples of the research problems formulated by the students:

- Influence of soil organisms for decomposition of waste.
- Influence of water for decomposition of waste.
- Influence of waste for a plant growing.

### Examples of the questions formulated by the students:

- Is the glass decomposed due to the activity of water and soil microorganisms?
- Is the plastic decomposed due to the activity of water and soil microorganisms?
- Are the paper waste decomposed due to the activity of water and soil microorganisms?
- Are the kitchen biowaste decomposed due to the activity of water and soil microorganisms?
- Does the plastic provide conditions for life of plants?
- Does the soil enriched with kitchen garbage provide better conditions for plant development?\* (in order to obtain more reliable results we recommend to cultivate the plants longer than two weeks).

### Examples of the hypotheses which can be formulated by the students:

- Glass is water resistant.
- The plants are not able to grow on a substrate solely consisting of the plastic.
- Plastic is resistant to soil microorganisms.
- Kitchen waste can be composted.

### Examples of the conclusions formulated by the students:

- Plastic does not dissolve and degrade in water (Jar V).
- The plastic is not biodegradable. Mechanical shredding of the plastic wastes by soil organisms and plant roots can occur in nature (Jar II).
- The plastic does not provide nutrients for plants, unless it is contaminated with organic and inorganic matter (for example: food leftovers). However, these are limited resources (Jar V).

- Waste paper is decomposed in the soil as a result of activity of microorganisms and invertebrates (Jar IV).
- Bio waste can be successfully composted and used as a fertilizer after processing or substrate for sowing plants (Jar III). The teacher should consequently explain that the process of degradation of organic matter takes several weeks to several years, depending on the type of material and processing conditions.
- Glass is not degraded by water and soil microorganisms.
- Plants need substrate to root in and uptake minerals, and water to develop and grow correctly.
- Non-biodegradable wastes, such as glass and plastic, discarded into the environment pose a threat to the fauna (look at the source text). Thus, it is essential to throw waste in accordance with the principles of segregation and storage and with respect to the surroundings, environment and nature.

If the lengths of shoots and roots were measured, they can be compared between control and experimental variants. Calculate the average length of shoots and roots of both repetitions. If the repetition failed (low level of germination, drying the variant), discard it in the analysis.

## Appendix I. Material for the student

Human produces unimaginable amount of waste that can pollute and damage the environment. Apparently, it may not be a dangerous plastic bag which becomes a great threat to sea turtles confusing it with a jellyfish and after swallowing the bag they suffocate and die. Waste disposed into the environment can become a death trap for many small animals, e.g. insects, arachnids, small rodents and shrews. Unfortunately,

plastic and other materials are difficult or non-degradable in the environment, contaminating them for years. Similarly, glass cannot be biodegraded. However, there are types of waste that decompose in the environment. These are green waste we produce practically every day in the households, for example: peels from vegetables, grass mowed in a front of the house or dry leaves falling from the trees in autumn. There are other waste which we can manage: eggshells, old fruit etc. If there



Fig. 1. Wild wastedumps pose a risk to animals and plants, especially when they are the source of chemical contamination. Moreover bottles, plastic bags and all containers can be deadly traps for small fauna.

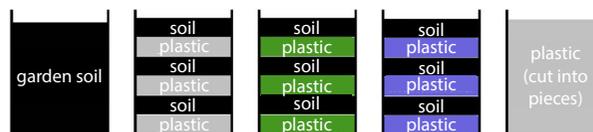


Fig. 2. The experimental schema. Five jars in five variants (control and four research variants).

is enough space, one might think of building a small composter, where all waste could be converted into a high-quality substrate for plants or fertilizer. Another interesting solution are urban composters with access for everyone. Maybe in your city it would be possible to build it?

Run an experiment in accordance with instructions provided by the teacher:

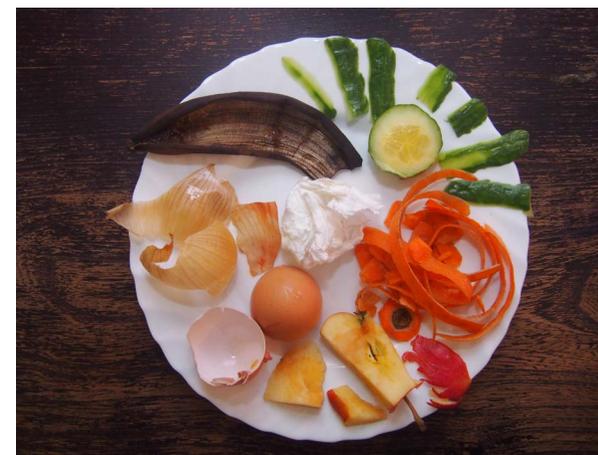


Fig. 3. An example of bio waste which may be material for composting.



Fig. 4. Preparing jar V filled with plastic and similar polymers. 1. Collect garbage, wash it in water. 2. Cut into small pieces. 3. Fill the jar tightly with them.

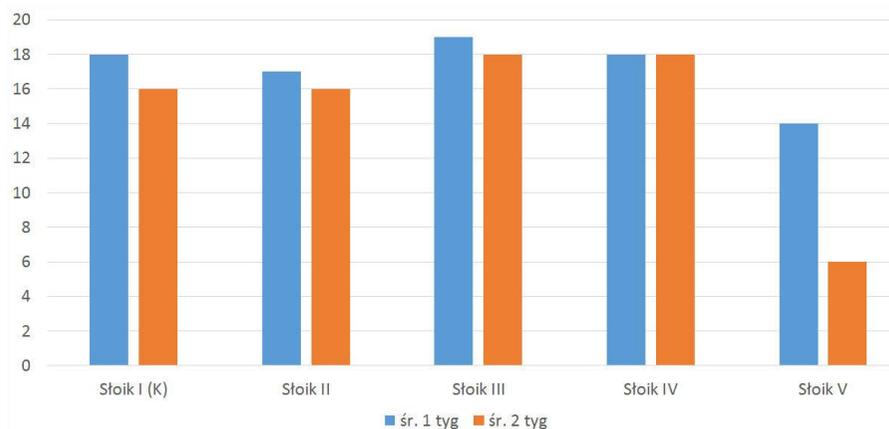
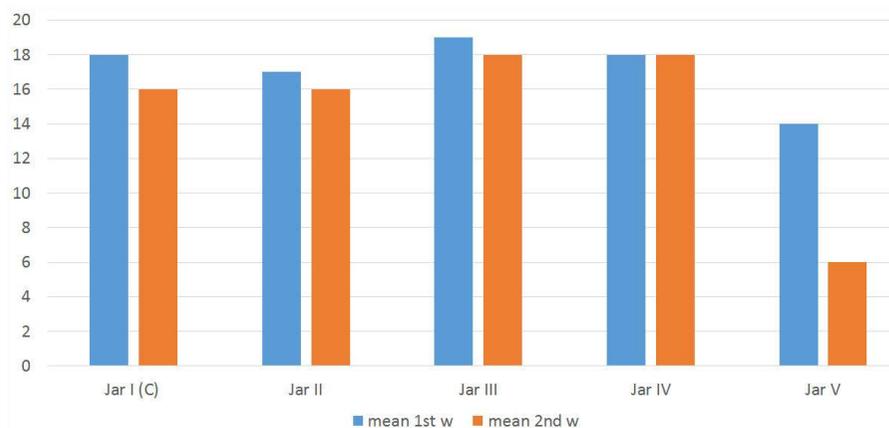
## Appendix II. Observation card.

- Before setting the experiment formulate:
  - The research problems.
  - The research questions.
  - The research hypotheses.
- After finishing the experiment formulate conclusions.
- Complete the table by writing the number of germinating seeds after two weeks of observation.

Number of germinating seeds		
Replication	I	II
Jar I		
Jar II		
Jar III		
Jar IV		
Jar V		

- Complete the table by writing the number of living plants after first and second week of observation. Calculate the average number of plants of two repetitions of the same variant (jars I–V). Show the results on the bar graph prepared in Excel/OpenOffice Calc (see example).

Number of alive plants		
After	I week	II week
Jar I		
Jar II		
Jar III		
Jar IV		
Jar V		



- Take photographs of the material used in five research variants (jars I–V) in the first day of observation before you put the material in the jars and in the last day after you remove it from the jars. Compare the photos (state of the content of the jar I in

the first day with the content in the jar I in 14th day etc.). Note your observations. Answer the question: Whether and in which jar the waste decomposition occurred? (see example)

Fig. 5. An example of a bar graph showing a comparison of mean values of alive plants after first and second week of the experiment  
Jar I (C) – the control variant.,  
*mean 1st w* – the mean value of the number of living plants after the first week of experiment,  
*mean 2nd w* – the mean value after two weeks of experiment.

**Appendix III. Table of measurements of the length of sprouts and roots.**

Task 1. Measure the length of sprouts and roots. Numbers 1-20 represent plants from jars I-V.

Task 2. Calculate the average length of shoots and roots of the two repetitions. If the repetition was failed (low level of germination of plants, dried variant), discard it in the analysis.

plant name: .....											
the number of jar	I	II	III	IV	V	I	II	III	IV	V	
repetitions	I					II					
the length of sprouts [mm]	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										
	17										
	18										
	19										
	20										
average											

SCIENCE

SCHOOL

IN SHORT

the length of roots [mm]	1																			
	2																			
	3																			
	4																			
	5																			
	6																			
	7																			
	8																			
	9																			
	10																			
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average																				

## Links

- <https://sustainabledevelopment.un.org/?menu=1300> (access 22.02.2017)
- <http://okinawanaturephotography.com/tag/hermit-crabs-in-plastic/> (access 22.02.2017)
- <http://oddamodpady.pl/gdzie-sa-otwarte-kompostowniki/> (access 25.02.2017)

# A new era of Polish Biological Olympiad

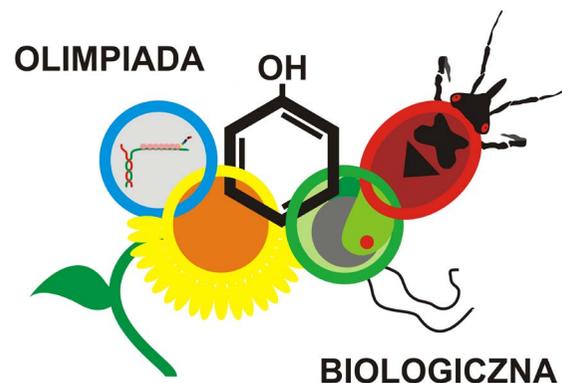
Editorial board

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On April 21-24, 2017, at the Faculty of Biology, University of Warsaw, the final stage of 46th Polish Biological Olympiad will take place. This year, there are 99 high school students that were qualified. They were the best at solving two previous exams; one held at their schools, and another one organised at every voivodeship in Poland.

Although the history of Polish Biological Olympiad is fairly long, this edition will be somewhat exceptional. For the first time, organisers decided to introduce practical exams to the final stage.

On 22 of April, every participant will be asked to go through four different laboratories. High school students will spend 90 minutes at each laboratory to solve practical problems of biochemistry, zoology, botany and mycology, and statistics and phylogenetics. It will be the first attempt to evaluate practical skills of participants. One of the reasons to do so is the ranking of Polish students at International Biological Olympiad (IBO). Although students with the best results of theoretical exam have been chosen to represent Poland at previous IBOs, it was a challenge for them to mark high scores because IBO requires practical knowledge of biology. Organisers of Polish Biological Olympiad believe that by introducing practical exams resembling that of IBO to the final stage of Polish Biological Olympiad, they will be able to choose the best students not only with theoretical knowledge, but also capable of solving



practical problems of biology and eligible to interpret biological data.

The following day will also be the hard day for the participants. In the morning, students will solve theoretical exam, but not traditional one, in which precise knowledge of textbooks was tested. In present edition of Polish Biological Olympiad, the exam will be primarily focused on the interpretation of real experimental data published in scientific journals. In the afternoon, students will talk to the committee to discuss major and minor points of their scientific project that they should have prepared before the final stage of the Olympiad.

Practical skills, theoretical knowledge, and the scientific value of their project as well as its presentation to the members of the committee will be evaluated. This will enable to select the best of the best. Keep your fingers crossed for every participant of the final stage of Biological Olympiad and visit [www.olimpbiol.pl](http://www.olimpbiol.pl) to follow fascinating intellectual competition of motivated young people.