HISTORY OF BIOINDICATION

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Abstract: The aim of the present work is to present the history of the bioindication at a glance. The major stages of natural sciences in general and bioindication in detail, starting from the ancient times through middle ages and times of scientific revolution to the present time are shown, as well as the past and present examples of using living organisms (especially lichens) to the indication of environmental pollution. Also current and future tasks of bioindication are specified.

Key words: bioindication, biomonitoring, history, environment, zanieczyszczenie.
Słowa kluczowe: *bioindykacja, biomonitoring, historia, środowisko naturalne, zanieczyszczenie.*

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The history of natural sciences, or indeed all time-dependent phenomena, can be divided into a number of major chronological periods according to the experimental possibilities and intellectual imagination. It seems that from a historic-developmental point of view, the environmental sciences history can be logically divided into five major periods, each of which is initiated (or terminated) by some major „break-through" in scientific thought or through the development of techniques that have permitted the acquisition of a new data.

The first one, logically called „megamorphic", beginning with Aristotle's time and continuing to Leeuwenhoek's invention of the microscope, could be characterized as a terminological-descriptive period of all visible objects. The second one, referred to as „micromorphic", beginning with Leeuwenhoek and continuing to Darwin's views on evolution was connected with the discovery which made possible the recognition of formerly invisible world. The microscope made possible not only the recognition of unknown microorganisms but also the acquisition of new morphological, anatomical and embryological data.

Darwin's evolutionary theory began the third period extending to the rediscovery of Mendel's laws of inheritance. During this period which can be called „evolutionary", Darwin's theory profoundly affected biological thinking. Hereafter the biologists tried to constructed his ideas on a phylogenetic basis. Since the beginning of the twentieth century began the fourth period, commonly referred to as „cytogenetic". This period was characterized by the detail application of cytological and genetic data.

The fifth and last period began with the real progress in two giant field of experimental procedures, i.e. spectroscopy and chromatography. It should be obvious that the second half of twenties century and the first decade of the present century is the period, which can be termed „biochemical". The new instrumental techniques made possible the qualitative and quantitative determination of chemical compound also present as xenobiotics in the environment.

The history of natural environment assessment both

from the chemical and biological point of view can be divided into three main stages connected with the gathering of information and knowledge about the environmental changes caused by natural and anthropological reasons. The first stage, named „old ecology" was a period of observation and description. It comprised the time of first four periods in the history of natural sciences, i.e. „megamorphic", „micromorphic", „evolutionary" and „cytogenetic". The second stage called „new ecology" is more or less equal to the „biochemical" period of the natural sciences history. It was connected with the progress in environmental sciences caused by the development of modern experimental techniques. The „new ecology" is inseparable with the incredible precision of developing spectroscopy and chromatography. In end of the twentieth century and the first decade of the present century we can observe the modern connection of the „old" and „new ecology". This combination using not only chemical methods of assessment but also biological, leads to the sustainable development and environmental protection. The most important biological method of environmental assessment is referred to as bioindication. This explained the classical definition propagated that bioindication is a time-dependent, sensitive registration of anthropogenic or anthropogenically altered environmental factors, by distinguished dimensions of biological objects and biological systems under defined circumstances (Stöcker 1980).

The bioindication has a respectable antiquity. Long ago, before the era of modern chemistry and biology, people observed living organisms under the different conditions and basing on such observations tried to conclude about the environment. One of the first documented use of organisms as indicators for environmental conditions dates back to the days of Aristotle. This famous Greek philosopher, who is credited with dabbling in nearly every known area of modern science, is known to have placed freshwater fish in salt water to observe their reactions (Cairns, Pratt 1993). Farmers have used plants as bio-indicators for thousands of years. Gardeners have known that plants have certain preferences regarding soil, amount of sunlight, and temperature. Since long also scientists have made the observation that many plants rather precise-ly reflect the values of environmental factors (Diekmann 2003).

In the early days of the industrial revolution, canaries were kept in under-ground coal mines.

If a canary showed adverse reactions to conditions in the mine, the miners left (Cairns, Pratt 1993).

In XVIII century Carl Linnaeus who laid the foundations for the modern biological naming scheme and has been known as a father of modern taxonomy, introduced an interesting view to bioindication. He proposed a specific flower clock and called it the Horologium Florae. It was a garden plan that would take advantage of several plants that open or close their flowers at particular times of the day to accurately predict the time. He may never have planted such a garden, but the idea was attempted by several botanical gardens in the early 19th century, with mixed success. Anyway it was an attempt to use the plants for predicting the time in correlation with insolation. The English geologist William Smith (1769–1839) identified strata by fossils of plants and animals. Swiss botanist Alphonse de Candolle (1806–1893) investigated the relations between plants and climatic factors.

The second half of the XIX century was a time of starting bioindication in the modern meaning. William Nylander (1822–1899) a Finnish botanist and entomologist, pioneered the technique of determining the taxonomy of lichens by the use of chemical reagents, such as tinctures of iodine and hypochlorite, still used by lichenologists to this day. Nylander was also the first to realise the effect of atmospheric pollution on the growth of lichens, an important discovery that paved the way for the use of lichens to detect pollution and determine the cleanness of air. In 1866 William Nylander published observations about the lichens in Paris, particularly those of the Jardin du Luxembourg, a large public park. He noted that in general lichens didn't seem to like cities and that urban lichens often showed incomplete development. According to Nylander lichens could give a good indication of the quality of the air and so constituted a very sensitive „health meter" for the surrounding air. Based on his observations about the numbers of lichen species (and numbers of thalli) found in various parts of Paris he concluded that Paris' healthiest area was to be found within the Jardin du Luxembourg (Nylander 1866).

The next stage in lichen's bioindication was developed by the German scientists F. Arnold. In the last decade of the XIX century he introduced the new method – transplantation of the epiphytic lichens from their natural habitats into the city and observation of changes occurred in thalli. The first lichen transplants were performed in the city of Munich (Khaldi i in. 2012). The capital of Sweden, Stockholm, was the first big city in which in 1912 the detail analysis of lichens was carried out (Sernander 1912).

It is not possible to present all investigations using lichens to bioindication in Poland. Probably the first detail lichen-indication map of Polish city was done

by Jan Zurzycki (1950) in Cracow. Sunsequently, the investigations dealing with the lichens in urban areas were carried out (among others) by Rydzak (e.g. 1953, 1956a, 1956b), Kiszka (e.g. 1977, 1986, 1990, 1999), Fałtynowicz (e.g. 1995, 2003) and Matwiejuk (2007a, 2007b). The early and significant investigations in Poland with the lichens transplantation were performed by Świeboda and Kalemba (1978).

Grodzińska began to study heavy metal deposition and heavy metal pollution in national parks (Grodzińska 1980). These were the first studies in Poland to use not only lichens but other plants as bioindicators. These studies were repeated several times; together they provide a picture of successive changes in the environment. They were abundantly cited in the literature. Using mosses as bioindicators, in the 1990s Grodzińska studied heavy metal deposition throughout Poland, under international research programs (Godzik, Zarzycki 2005).

The very important event on the modern history of bioindication was the scientifoc conference in April 1968 in Wageningen, entitled „Air pollution. Proceedings of the first European Congress on the Influence of Air Pollution on Plants and Animals". During the conference scientists from all the world discussed in 10 sections including experimental research, effects of air pollutant on plants, vascular and non-vascular, animals, measurement of air pollution in plants, resistance of plants to air pollution. After the conference the assessment of pollution influence onto living organisms became obvious and common.

On the foundation of above described history of bioindication at a glance, one can say about the presence and future of using organisms for the assessment of the environment. In 1980 Mueller gave a very simple and meaningful definition of bioindication: „Bioindication is the simplification of information from biosystems allowing the assesment of the whole area" (Mueller 1980). Two years later Steubing (1982) defined five levels of bioindicative investigations, i. e. the levels of:
– cells and subcellular organelles,
– tissues and organs,
– organisms,
– populations and biocenoses,
– landscapes.

Obviously the level of organisms is the most common in bioindication investigations.

Modern literature review indicated that most ecological indicators have been developed for ecosystem function, followed by political, regulatory, cost and risk assessment considerations.

There are four main types of indicators, which are not mutually exclusive, including:
– ecosystem health assessment,
– human effects,
– human interventions,
– human health and well-being (Burger 2006).

In the early of nineties of the XXth century can be observed the shaping of the differences between bioindication and biomonitoring. Such division is connected with the qualitative/quantitative approach to the chemical substances in the environment (Markert et al. 1999, Markert et al. 2003). According to Markert's definitions a bioindicatoris an organism (or part of an organism or a community of organisms) that contains information on the quality of the environment (or a part of the environment). A biomonitor, on the other hand, is an organism (or a part of an organism or a community of organisms) that contains information on the quantitative aspects of the quality of the environment. A biomonitor is always a bioindicator as well, but a bioindicator does not necessarily meet the requirements for a biomonitor (Markert et al. 1997, 1999). It seemed clear from the start that bioindication and biomonitoring are promising (and possibly cheap) methods of observing the impact of external factors on ecosystems (Markert 2008). Bioindication can be also used for observation and explaining the relations between more than one pollutant and biotic or abiotic factor influencing the indicative organisms (Markert et al. 2012).

The very big advantage of bioindication is connected with the fact of lack of equipment which is able to measure the toxicity of chemical compounds. The fantastic progress in the development of methods of chemical analysis allows the detection and determination of many compounds but does not answer to questions:
– how the substance could influence on living organisms in the environment?
– how the substance could influence directly or indirectly on human?

New tasks for bioindication appear from these questions, i.e.:
– determination of toxicological characteristics of biologically active substances,
– bioindicative evaluation of different technological procedures,
– current monitoring of sewages and wastes,
– assessment of ecosystems volumes against toxins,
– assessment of interactions between toxins or between toxins and environment,
– protection of water pipes and biological sewage-treatment plant through alarm reaction.The modern

observation of the living organisms under the anthropological factors become more and more dependent from instrumental methods. In research aiming at evaluation of environmental condition and assessment of the reasons for changes in the environment, precise analytical methods are more and more frequently used. the electron microscopy is one of the tools used there among others (Jóźwiak, Jóźwiak 2009). Using a scanning electron microscope with energy Dispersive X-ray spectroscopy (EDS) enables to obtain information on quality concerning morphology and elementary composition of a sample as well as information on quantity concerning concentration of particular elements in a sample during one analysis stage. In bioaccumulators (*Hypogymnia physodes* (L.) Nyl. lichen) transferred to the city, the rate of accumulation of PAH and heavy metals is determined in relation to anthropopressure and the changes in cellular level are analysed with scanning and transmission electron microscope. The tests that have been performed so far, make it possible to conclude that using transmission and scanning electron microscope allows to obtain good assessment of micro changes on the surface of thalli of analysed lichen, and inside the thalli in relation to fungus – photobiont.

One of the example of very recent trends in bioindication was the investigation dealing with factors determining the encroachment of plants into abandoned railway tracks (Galera et al. 2011). Floristic investigation concerned the vascular plants supplemented by determination of basic soil parameters and concentration of heavy metals were carried out in twelve railway areas located in north-eastern Poland (8 areas on tracks withdrawn from exploitation, 4 areas on operating tracks). The selected areas differed with respect to character of the vicinity (forest, grassland or meadow, ruderal). Soil samples demonstrated considerable uniformity with respect to pH and variability in respect to nutrient levels, although concentration of the latter do not seem to be the factor limiting plant growth. The concentration of heavy metals is not dangerous to plant growth. Although chemical features of the soil are within the limits which do not make plant growth difficult, the process of plant regeneration proceeds differently, depending on accessibility of diaspores resulting from surroundings. The decreasing rate of therophytes, especially aliens, manifested stage of succession on abandoned tracks. In the case of ground flora the gradual "preparation" of the habitat (shadow factor on the track), is very important. The degree of advancement of forest regeneration on abandoned tracks is more strongly manifested by the constant return of ground flora species than by trees, as it was commonly thought.

The progress of civilization causing the production and release of different chemical substances into the environment has reached a stage where the control of pollutant's level is very difficult. Huge number of various individual compounds entering the environment have resulted in the necessity of developing new fields of research which combine the ecological, chemical and toxicological approaches (Merian et al. 2008). The classic way in environmental chemistry based on chemical data obtained from procedures used for analysis of biotic and abiotic samples. However, this approach do not provide direct information about "current state of the environment" (Fraenzle, Markert 2007). Hence, the biological methods should be considered for ecological assessment of ecosystems. One of such methods is bioindication.

In its perfect sense, the bioindication is integrated investigation of various biological test systems, which in connection with other environmental factors tend to ascertain the environmental pollution and to foresee its development in the interests of health prophylaxix and environmental protection.

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HISTORIA BIOINDYKACJI

Streszczenie

Celem niniejszej pracy jest zaprezentowanie zarysu historii bioindykacji. Przedstawiono główne etapy rozwoju nauk przyrodniczych ze szczególnym uwzględnieniem bioindykacji, poczynając od starożytności, poprzez średniowiecze i czasy rewolucji naukowej, jak również dawne i obecne przykłady wykorzystania żywych organizmów do określania zanieczyszczenia środowiska. Wyszczególniono również bieżące i przyszłe zadania bioindykacji.