Int. J. of Sustainable Water and Environmental Systems
Volume 6, No. 1 (2014) 17- 26

International, transdiciplinary and intercultural cooperation in bioindication and biomonitoring studies (B&B technologies)

– with specific consideration of plant organisms and chemical elements[1]

Markert, Bernd[a*], Wuenschmann, Simone[a], Baltrėnaitė, Edita[b], Chudzińska, Ewa[c], De Marco, Silvia[d], Diatta, Jean[e], Ghaffari, Zahra[f], Gorelova, Svetlana[g], Marcovecchio, Jorge[h], Tabors, Guntis[i], Yousef, Naglaa[j], Wang, Meie[k], Fraenzle, Stefan[l], Kumari, Alka[m]

[a] Environmental Institute of Scientific Networks (EISN-Institute); Fliederweg 17,D-49733 Haren-Erika, Germany
[b] Vilnius Gediminas Technical University; Saulėtekio al. 11, LT–10223 Vilnius, Lithuania
[c] Adam Mickiewicz University, Institute of Experimental Biology, Department of Genetics, ul. Umultowska 89, 61-614 Poznan, Poland
[d] Faculty of Exact and Natural Sciences, Department for Biology, Universidad Nacional de Mar del Plata; 25 de Mayo 2855, Mar del Plata, Argentina
[e] Department of Agricultural Chemistry and Environmental Biogeochemistry, Poznań University of Life Sciences; Wojska Polskiego 28 60-637, Poznań, Poland
[f] Faculty of Environment and Energy, Science and Research Branch, Islamic Azad University; Hesarak, Tehran, I.R.Iran
[g] Department of Botany and Plant Growing, L.N. Tolstoy Tula State, Pedagogical University; 125 Lenin Avenue, 300026 Tula, Russian Federation
[h] Instituto Argentino de Oceanografia; Camino La Carrindanga km 7, Bahia Blanca, Argentina
[i] Faculty of Biology, University of Latvia. Raiņa bulvāris 19 Riga, LV-1050, Latvia
[j] Faculty of Science, Department of Ecology, Sohag University; 82524 Sohag, Egypt
[k] State Key Laboratory of Urban and Regional Ecology, Research Centre for Eco-environmental Sciences, Chinese Academy of Sciences; 52 Sanlihe Rd., 100864 Beijing, China
[l] International Graduate School, Markt 23, D-02763 Zittau, Germany
[m] Biodiversity Division, CSIR – Institute of Himalayan Bioresource Technology, Palampur-176001, H.P., India

[1] This article is a composition of lectures given by the first author at UEP in Boston, USA, 2010, at ICHMET 15 in Gdansk, Poland, 2010, at STT 37 in Bangkok, Thailand, 2011, at BIOMAP 6 in Cesme, Turkey, 2012 and in Bareilly, India, 2012.

Corresponding Author: Prof. Dr. Bernd Markert,
markert@eisn-institute.de, www.eisn-instiute.de

DOI: 10.5383/swes.06.01.0002

Abstract

Bioindication and biomonitoring methods (B & B technologies) have been used in environmental quality assessments for many decades. The international cooperation in between various scientific teams throughout the world has produced common ideas, highly innovative results and common scientific definitions. Bioindicators (**biomonitors**) are organisms or communities of organisms whose content of certain chemical elements or compounds and/or whose morphological, histological or cellular structure, metabolic-biochemical processes, behaviour or population structure(s), including changes in these parameters, supply (**quantitative**) information on the quality of the environment or the nature of environmental changes. Bioindication compares relative (**absolute**) data of information (e.g. contamination) to each other. In this article, clear cut definitions of terms relevant for the practical use of B & B technologies are presented. Additionally, different uptake activities in living organisms as a function of substrate concentration are given. Physiological functions are compared by effects of acute and chronic doses of toxic substances on living systems. Future work should and must be focused on integrative B & B technologies because a) contamination can entail a large number of inorganic and organic chemicals, b) a large number of environmental monitoring problems, and c) a single bioindicator / biomonitor will not provide any meaningful information. Integrative and transdisciplinary concepts such as the Multi-Markered-Bioindication-Concept (MMBC) provide basic means to get into precautionary environmental protection effects. For further development of B & B methods, highest personal energy has to be given by teachers of universities and other institutions to students and to convince (strategically) decision makers as politicians to invest (financially) in the development of education and research of this innovative technique. Young people have to be intensively convinced on the “meaning” of our scientific doing, e.g. by extended forms of education. One example of multilingual education of students on a global scale and perspective is given here, meeting their emotional and rational intelligence. So, young people can find innovative scientific ideas by a strong international relevance to get mentally convinced by a profitable “biological green” technique. Students will be motivated to move scientifically and professionally into our international working field. In addition to this form of international scientific exchange we find an excellent side-effect pertinent to intercultural exchange.

Keywords: bioindication, biomonitoring, B & B technologies, definition, globalisation, transdisciplinarity, (multilingual) international education

1. Introduction

The environmental compartments - air, water, soil and the biocoenoses associated with them are considerably influenced by a larger number of both biotic and abiotic factors [1-4]. Owing to an increasing extent of industrial activities, the environment is also influenced by chemical pollutants. This diverse group of potentially hazardous substances contains a larger number of organic compounds, as well as heavy metals (e.g. mercury and tin), metalloids (e.g., arsenic and antimony), and organometal compounds (like tributyl tin). Once they accumulate in soil, ground water or organisms, drawbacks for certain members of a trophic chain may become unpredictable yet grave [5-11].

Already, ancient high cultures used metals to measure the extent of their emissions, which can be detected globally by corresponding depositions e.g. in Greenlandic ice cores. During the last 150 years, however, anthropogenic emissions have become extensive and as a result their negative effects on man and his environment were no longer restricted to the regional surroundings of emission sites.

Accumulation, being a slow, inconspicuous process which, however causes a likewise slow damage to living organisms, requires a meticulous and constant surveillance of deposition of heavy metals and organic compounds and of their impacts on living nature. Emissions into the atmosphere are often monitored by means of deposition collectors whereas in aquatic monitoring a non continuous but intermittent sampling of water is usually employed.

There are elegant though indirect methods to obtain data on existence, distribution and effects of pollutants, namely, bioindication and biomonitoring. These methods make use of the capacity of organisms to signify presence of pollutants over either short or longer periods of time [12-35].

Because bioindicators or biomonitors integrate environmental burdens (of chemicals) over time of experiment at their sites, short-term variations are cancelled out. As compared to “conventional” means of measuring emissions, bioindication or –monitoring takes much less expenditures in both personnel and apparatus than e.g. running a deposition sampler. Hence bioindicators can be employed throughout large areas provided the organisms are sufficiently far-spread and abundant, enabling investigations which cover entire countries or even continents which could be done otherwise only if accepting very high demands of work and money [36, 37].

Using one or several (different) organisms for the purposes of estimating environmental burdens brings about yet another advantage: beyond statements on the very organism which is embedded in some ecological niche within an ecosystem, hence analytical data obtained on it can be integrated into a more comprehensive biological system. Thus beyond the very bioindicator ecologically relevant inferences are possible on larger parts of the biocoenosis due to the biotic interactions which interconnect them, unlike when using direct physico-chemical methods [38].

2 Material and Methods

2.1 Definitions

Markert et al. (1997) and Markert (2007) gave an exact and meanwhile generally valid definition to discern among bioindication and biomonitoring:

- **Bioindicators** are organisms or communities of organisms whose content of certain elements or compounds and/or whose morphological, histological or cellular structure, metabolic-biochemical processes, behavior or population structure(s), including changes in these parameters, supply information on the **quality** of the environment or the nature of environment changes. Bioindication compares **relative data** (e.g. on contamination) to each other.

- **Biomonitors** are organisms or communities of organisms whose content of certain elements or compounds and/or whose morphological, histological or cellular structure, metabolic-biochemical processes, behavior or population structure(s), including changes in these parameters, supply information on the **quantitative aspects** of the quality of the environment or the nature of environment changes. Biomonitoring compares **absolute data** (e.g. on contamination) to each other.

We speak of **active** bioindication (biomonitoring) when bioindicators (biomonitors) bred in laboratories are exposed in a standardized form in the field for a defined period of time. At the end of this exposure time the reactions provoked are recorded or the pollutants taken up by the organism are analyzed. In the case of **passive** biomonitoring, organisms already occurring naturally in the ecosystem are examined for their reactions. This classification of organisms (or their communities is according to their "origin".

A classification of organisms (or their communities) according to their "mode of action" is as follows (Fig. 1): **Accumulation** indicators / monitors are organisms that accumulate one or more elements and/or compounds from their environment. **Effect** or **impact indicators / monitors** are organisms that demonstrate specific or unspecific effects in response to exposure to a certain element or compound or a number of substances. Such effects may include changes in their morphological, histological or cellular structure, their metabolic-biochemical processes, their behavior or their population structure. In general, the term “reaction indicator” also includes accumulation indicators/monitors and effect or impact indicators/monitors as described above.

When studying accumulation processes it would seem useful to distinguish between the paths by which organisms are exposed to elements/compounds. Various mechanisms contribute to overall accumulation (**bioaccumulation**), depending on the species-related interactions between the indicators / monitors and their biotic and abiotic environment [39]:

- **Biomagnification** is the term used for absorption of the substances from nutrients via the epithelia of the intestines. It is therefore limited to heterotrophic organisms and is the most significant contamination pathway for many land animals except in the case of metals that form highly volatile compounds (e.g. Hg, As) and are taken up through the respiratory organs, (e.g. trachea, lungs).

- **Bioconcentration** means the direct uptake of the substances concerned from the surrounding media, i.e. the physical environment, through tissues or organs (including the respiratory organs). Besides plants, that can only take up substances in this way (mainly through roots or leaves), bioconcentration plays a major role in aquatic animals. The same may also apply to soil invertebrates with a low degree of solarization when they come into contact with the water in the soil.

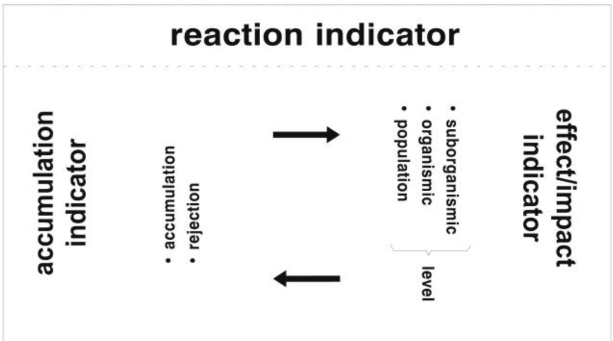

Fig. 1. Illustration of the terms reaction, accumulation and effect / impact indicator [39].

Besides the classic floristic, faunal and biocoenotic investigations, which primarily record rather unspecific reactions to pollutant exposure at higher organizational levels of the biological system, various newer methods have been introduced as instruments of bioindication. Most of these are biomarkers and biosensors (according to [39]):

- **Biomarkers** are measurable biological parameters at the suborganismic (genetic, enzymatic, physiological, morphological) level in which structural or functional changes indicate environmental influences in general and the action of pollutants in particular in qualitative and sometimes also in quantitative terms. Examples: enzyme or substrate induction of cytochrome P-450 and other Phase I enzymes by various halogenated hydrocarbons; the incidence of forms of industrial melanism as markers for air pollution; tanning of the human skin caused by UV radiation; changes in the morphological, histological or ultra-structure of organisms or monitor organs (e.g. liver, thymus, testicles) following exposure to pollutants.
- A **biosensor** is a measuring device that produces a signal in proportion to the concentration of a defined group of substances through a suitable combination of a selective biological system, e.g. enzyme, antibody, membrane, organelle, cell or tissue, and a physical transmission device (e.g. potentiometric or amperometric electrode, optical or optoelectronic receiver). Examples: toxiguard bacterial toximeter; EuCyano bacterial electrode. Biotest (bioassay): routine toxicological-pharmacological procedure for testing the effects of agents (environmental chemicals, pharmaceuticals) on organisms, usually in the laboratory but occasionally in the field, under standardized conditions (with respect to biotic or abiotic factors. In the broader sense this definition covers cell and tissue cultures when used for testing purposes, enzyme tests and tests using microorganisms, plants and animals in the form of single-species or multi-species procedures in model ecological systems (e.g. microcosms and mesocosms). In the narrower sense the term only covers

single-species and model system tests, while the other procedures may be called suborganismic tests. Bioassays use certain biomarkers or – less often – specific biosensors and can be used in bioindication or biomonitoring.

With regard to genetic and non-genetic adaptation of organisms and communities to environmental stress we have to differentiate between the terms tolerance, resistance and sensitivity:

- **Tolerance** [41] means a desired resistance of an organism or community to unfavorable abiotic (climate, radiation, pollutants) or biotic factors (parasites, pathogens), where adaptive physiological changes (e.g. enzyme induction, immune response) can be observed.
- **Resistance,** unlike tolerance, is a genetically derived ability to withstand stress [41].This means that all tolerant organisms are resistant, but not all resistant organisms are tolerant. However, in ecotoxicology the dividing line between tolerance and resistance is not always so clear. For example, the phenomenon of PICT (pollution induced community tolerance) is described as the phenomenon of community shifts towards more tolerant communities when contaminants are present. It can occur as a result of genetic or physiological adaptation within species or populations, or through the replacement of sensitive organisms by more resistant organisms.
- **Sensitivity** of an organism or a community means its susceptibility to biotic or abiotic change. Sensitivity is low if the tolerance or resistance to an environmental stressor is high, and sensitivity is high if the tolerance or resistance is low.

2.2 Using plants as bioindicators/biomonitors

Because of unfavourable locations, many plants have developed the ability to enrich high concentrations of individual elements, often regardless of whether these elements are physiologically useful or not. These plants are called accumulators. With respect to biomonitoring, there should be a correlation between the environmental concentration of a pollutant to be observed and the content in the organism proper. A linear, indicative interrelation of both measure values has not been found so far for any organism. The concentration ranges which might be interesting for bioindication and biomonitoring showed very small 'measuring ranges' (black bars) in accumulator and excluder organisms (Fig. 2).

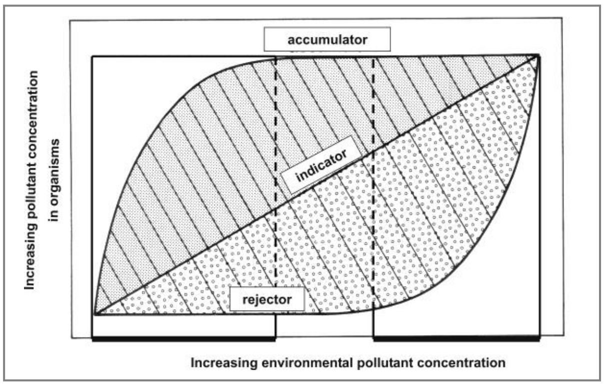

Fig. 2. Differing uptake activities in living organisms as a function of the substrate concentration ([39], according to [42]).

For example, regardless of the amount of element in the soil, some Ericaceae have a high concentration of manganese, and beeches have a high amount of zinc. The accumulative behaviour, which may have genetically predetermined origins rather than ones determined by locations, makes it possible to chemically fingerprint a very wide variety of types of plant. In the future, this might lead to the chemical characterization, and therefore to the systematization, of individual plant types, which could provide information about evolutionary connections on a phytosociological level. A rejection, or reduced uptake of individual elements, occurs less frequently than does an accumulation of elements, but rejection behaviour has been demonstrated for numerous plant species. The reduction in concentration of an element in an organism can be the result of a complete or a partial exclusion. For example, bacteria, algae, and higher plants contain populations which are resistant to heavy metals and which can reduce considerably the uptake of heavy metals by excreting mucilagenous substances or by changing their cell walls [37].

In the context of activity studies, and especially in toxicity monitoring, generally one must differentiate between acute and chronic working models. As is shown in Fig. 3, the acute delivery of a substance is usually followed by a direct, short-term effect on the organism or the population.

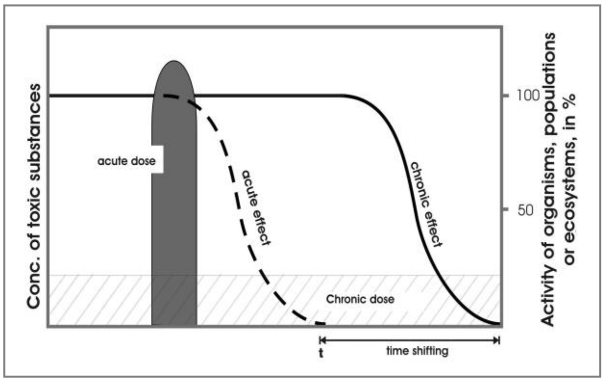

Fig. 3. Comparison of effect of acute and chronic doses of toxic substances on living systems [43].

These types of toxic effects are relatively easy to generate experimentally in the laboratory by adding different substances to the test organisms. However, it is more difficult to investigate chronic effects of a substance, meaning the subthreshold, long-term application of a substance which only shows an effect (usually a toxic one) after lengthy constant uptake. These mechanisms of chronic activities are considerably more difficult to study because all other values and parameters which could influence the test organism have to be kept constant over a considerable period of time. Often the chronic effect of substance differs from an acute effect only by its chronologically displaced occurrence. Thus, the chronic effect usually only creeps along, and so in reality it is often recognized too late [37].

2.3 Integrative B & B concepts

In addition to microorganisms, fungi, algae, mosses, lichens, ferns and higher plants (e.g. 44-56 further examples are . described in [8] animals can be used as bioindicators and biomonitors. In comparison to plants, animals have generally developed a greater arsenal of stress coping mechanisms; in addition, non sessile animals can avoid a certain number of threatening environmental or anthropogenic stressors by virtue of their mobility or motility [57]. Owing to the generally higher sensitivity of aquatic animals to xenobiotics in comparison to that of terrestrial organisms they play a major role in acute, subchronic and chronic tests. Under field conditions inquiries into distribution patterns and the different organotropic accumulation of xenobiotics are the major fields of interest in various bioindicative / biomonitoric approaches [57]. Some animal groups representing indicative qualities are given in [8]. The possible integrative relation of atmospheric element pollution, soil samples, stomach content and tissue and organs of rats in a specific study area is given by [58, 59]. The results of bioindicative studies of humans are manifold, e.g. Wuenschmann et al. (2008) gave impressive results on the relation of chemical elements to nutritional intake, human milk and transfer of the milk to babies. In these investigations it could clearly be demonstrated that human milk cannot be used as bioindicator / biomonitor for the heavy metal pollution status of the environment [60]. Other stimulating examples of bioindication and biomonitoring studies for controlling organic pollutants are given amongst others in [61].

With bioindicative methods being used for monitoring release, distribution, effects and control of pollutants an integrative approach towards monitoring on larger spatial scales – as well as including quite diverse sets and sources of information – is suggested (Multi-Markered-Bioindication-Concept, MMBC, Fig. 4), meant to be eventually used for preventive healthcare on the scale of counties. Fig. 4 represents only one proposal of a complete dynamics environmental monitoring system supported by bioindication to integrate human and ecotoxicological approaches. It can recombine its measurements parameters according to the particular system to be monitored or the scientific frame of reference. Therefore it seems to have good chances to being transferred into use for the pollution control observation in megacities.

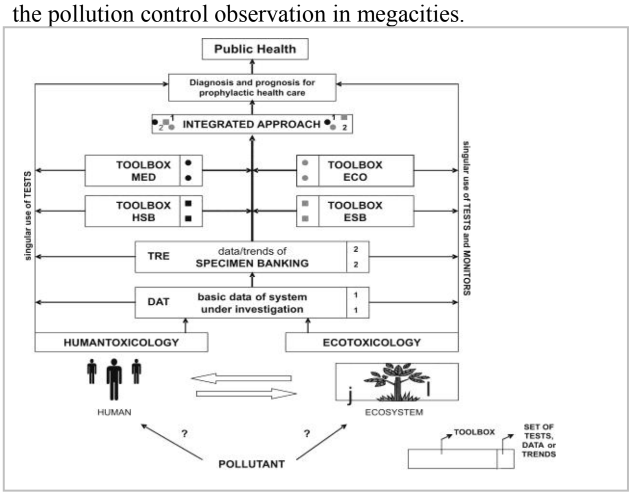

Fig. 4. Multi-Markered Bioindication Concept (MMBC), an integrative approach on human health care which draws upon a multidisciplinary input organized along several integrated and functional "windows". MMBC is one way how bioindicative toolboxes may be organized in a hierarchical framework for purposes of human and ecotoxicology. In toolboxes MED and ECO there are single sets of tests for functional combination in order to obtain an integrated approach towards some specified scientific problem. Toolboxes HSB (Human Specimen Banking) and ESB (environmental specimen banking) derive from years of research using sample banks for both human and environmental toxicology; thus they can supplement MED and ECO by important information on toxicological and ecotoxicological features of environmental chemicals. This integrated approach is not only to link all the results but to corroborate them by data already available from (eco-)systems research, toxicology, environmental monitoring and specimen banks. Toolboxes TRE and DAT provide parameters required to accomplish this [25].

To come closer to a prophylactic healthcare system (independent of population size as in megacities or in smaller cities or rural areas) we should come to a more integrated understanding on an international, interdisciplinary and intercultural level [62]. For overcoming existing gaps during the international education of pupils and students and for getting common research projects financially sponsored, the public must be convinced by day by day activities [63-65].

3 Conclusions

Future education for catalyzing an increase on global use of B & B technologies

Besides doing first-class research on bioindication and biomonitoring, utmost energy must be given by us as teachers of Universities and other institutions to educate young students in a way that they are strongly motivated to move into our specific working field. Psychologically, does it mean not only to act as a professional teacher by giving information on the scientific topic itself, but to convince students mentally, for instance by oral and written information transfer by communication which occurs during delivering a lecture? This happens, for example, in extant use of a so-called Dialogic Education Process (DEP; [37]).

A German will commonly speak to another German in German, but normally not in English, independent of whether this German is able to speak English. At an international conference English as the "first language of the world" is normally used as conference language, in order to balance the language barrier of participants from non native speaking countries taking part. In such an international conference, the German scientist will probably give his/her presentation in English.

The same behaviour in using languages is typically developed in between talks of students to students or students to teachers and vice versa. The use of the mother language is often preferred in the own nation. Translated into conditions set by the mental motivation of students the use of their own mother language shall give them the psychologically very important feeling to be "at home" and be satisfied with their elected scientific field, especially when they are starting their scientific career. A proper command of multiple languages belongs to the key factors for being successful.

Therefore we have developed a project of multilingual education of students on a global scale and perspective which is briefly summarized in Table 1 and which has been started about three years ago. International colleagues have translated a general paper on bioindication and biomonitoring, which had been published in the English language before. The languages included are for example Arabic, Chinese, French, Latvian, Lithuanian, Persian, Polish, Russian, and Spanish (more languages are in the concrete planning stage, as for instance Indian, Turkey and Portuguese). In addition to the translation the participating scientists include special case studies on bioindication and biomonitoring (from now on, B & B) technologies carried out in their own country. The translated papers have been finally published in national journals or books. Some already available publications are given, for example in [66-70].

Tab. 1. Multilingual publications on bioindication and biomonitoring issues in chronological order. Additional translations planned for the future are not given here yet.

Language	Authors	Title	Published in
German	Markert, B.	**Einsatz der Bioindikation und des Biomonitorings zur Umweltüberwachung, Definitionen, generelle Aspekte und Anwendungen**	Markert, B., **2001**, MS version, unpublished.
English	Markert B., Breure T., Zechmeister H	**Definitions, strategies and principles for bioindication / biomonitoring of the environment**	Markert B, Breure T, Zechmeister H , eds., **2003**. Bioindicators & Biomonitors. Elsevier, Amsterdam.
French	Markert, B., Wünschmann, S., Herzig, R., Quevauviller, P.	**Bioindicateurs et biomoniteurs; Définitions, stratégies et applications**	Techniques de I´Ingenieur, **2010**, P 4170, 1-16.
Lithuanian	Markert B., Wünschmann S., Baltrėnaitė E.	**Aplinkos stebėjimo naujovės. Bioindikatoriai ir Biomonitoriai: Apibrėžtys, Strategijos ir Taikymas**	Environmental Engineering and Landscape Management, **2012**, 20, 3, 221-239.
Polish	Markert, B., Wünschmann, S., Diatta, J., Chudzińska, E.	**Innowacyjna Obserwacja Środowiska: Bioindykatory i Biomonitory: Definicje, Strategie i Zastosowania**	Environmental Protection and Natural Resources, **2012**, 53, 115-152.
Chinese	Markert B., Wang, M., Wünschmann, S., Chen, W.	生态环境生物指示与生物监测技术研究进展 (Bioindicators and Biomonitors in Environmental Quality Assessment)	Acta Ecologica Sinica, Elsevier, **2013**, 33, 1, 33-44.
Spanish	Markert, B., Wünschmann, S., Marcovecchio, J., De Marco, S.	**Bioindicadores y Biomonitores: Definiciones, Estrategias y Aplicaciones**	Marcovecchio, J., Freije, R., eds., **2013**. Bioindicadores y Biomonitores Procesos Químicos en Estuarios, in press.
Persian	Markert B., Wünschmann S., Ghaffari Z	ها و ناظران¬ی محیط زیست؛ شناساگر¬ی نوآورانه¬مشاهده تعاریف، راهبردها و کاربردها :زیستی اصلی مقاله مشخصات:	**2013**, in press.
Latvian	Markert B., Wünschmann S., Tabors, G.	Inovatīvie vides novērtējumi. **Bioindikatori un biomonitoringi: definīcijas, stratēģijas un programmas**	**2013**, in prep.
Russian	Markert, B., Wünschmann S, Gorelova S	**Биоиндикаторы и биомониторы: определение, стратегии и применение. Использование древесных растений для биомониторинга и биоиндикации окружающей среды.**	**2013**, in prep.
Arabic	Markert, B., Wünschmann S, **Youssef, N.**	التعاريف :المراقبة البيئية المبتكرة المؤشرات و الرواصد الحيوية والاستراتيجيات والتطبيقات	**2013**, in prep.

Students (and all other individuals) interested in B & B technologies can find by this translated article innovative scientific motivation in their own mother language with a strong international relevance. They get mentally convinced and thus more easily convinced of these elegant and profitable "green" techniques, because we meet by the use of appropriate teaching and lecturing methods the rational AND EMOTIONAL intelligence of an audience and motivate them to move into our international working field [71].

In addition to this form of international scientific exchange, individuals can be motivated to deal with bioindication and biomonitoring by easily observable side-effect pertinent to intercultural exchange (Fig. 5, exchange of information and knowledge between and among students and scientists e.g.. at conferences).

This means, B & B technologies are moving people, from continent to continent, from one organismic species to another, transdisciplinary from one scientific field to the other, from rational to emotional intelligence and back, from culture to culture or simply in having scientific interest and fun on internationally connected ways and habits of thinking.

Fig. 5. Conference & Workshop on "Metals and Gases in Plants with Special Reference to Bryophyte Physiology & Climate Change" from 17th to 20th of December 2012 at Bareilly, India.

Therefore and as a conclusion, bioindication and biomonitoring methods will stay as multi marked bioindication concept (MMBC). Further information on MMBC is available in [25].

Acknowledgements

We would like to thank the Organizers of the International Conference & Workshop on "Metals and Gases in Plants with Special Reference to Bryophyte Physiology & Climate Change" from 17th to 20th of December 2012 at Bareilly, India. The Department of Botany of Bareilly College gave us a scientifically and from human point of view very interesting stay in India. Thank you!

References

[1] Ellenberg H, Mayer R, Schauermann J. Ökosystemforschung. Ergebnisse des Solling Projektes. Ulmer, Stuttgart, 1986.

[2] Haber W. Nachhaltige Entwicklung unter humanökologischen Perspektiven im globalen Wandel. Erste Hans Carl von Carlowitz-Vorlesung des Rats für Nachhaltige Entwicklung anlässlich seiner 9. Jahreskonferenz am 23. November 2009 in Berlin.

[3] World Health Organization (WHO). Biological monitoring of chemical exposure in the workplace. Guidelines, Vol.1 & Vol.2, Geneva 1996.

[4] Zhu YG, Jones KC. Urbanisation and health in China. Lancet, 2010, 376, 232-233.

[5] Adriano DC, ed. Biogeochemistry of Trace Metals. Lewis, Boca Raton, 1992.

[6] França E, De Nadai Fernandes E. Biomonitoring of the Atlantic Forest in biodiversity conservation: native tree species as accumulators of chemical elements. Biotaneotropica, 2007, Vol. 7, No. 1.

[7] Kashulina G, de Caritat P, Reimann C. Acidity ststus mobility of Al in podzols near SO_2 emission sources on the Kola Penisula, NW Russia. Applied Geochemistry, 1998, 13, 391-402.

[8] Markert B, Breure A, Zechmeister H. eds. Bioindicators & Biomonitors, Principles, Concepts and Applications: Elsevier, Amsterdam, Boston. London, New York, Paris, San Diego, San Franzisco, Singapore, Sydney, Tokyo, 997 pp, 2003.

[9] Reimann C, Halleraker Jo H, Kashulina G, Bogatyrev I Comparison of plant and precipitation chemistry in catchments with different levels of pollution on the Kola Peninsula, Russia, Science of the Total Environment, 1999, 243, 244, 169-191.

[10] Hooda P, ed. Trace elements in soils, John Wiley and Sons, New York, 596p, 2010.

[11] Wang M, Markert B, Shen S, Chen W, Peng C, Ouyang Z. Microbial Biomass Carbon and Enzyme Activities of Urban Soils in Beijing. Envin Sci Pollut Res, 2011,18, 958-67.

[12] Bargagli R, Monaci F, Borghini F, Bravi F, Agnorelli C Mosses and lichens as biomonitors of trace metals. A comparison study on Hypnum cupressiforme and Parmelia caperata in a former mining district in Italy. Environmental Pollution, 2002, 116, 279-287.

[13] Freitas MC, Pacheco AMG, Vieira BJ, Rodrigues AF. Neutron activation analysis of atmospheric biomonitors from the Azores: a comparative study of lower and higher plants. Radioanalytical and Nuclear Chemistry, 2006, 270, 21-27.

[14] Freitas MC, Pacheco AMG, Baptista MS, Dionísio I, Vasconcelos MTSD, Cabral JP. Response of exposed detached lichens to atmospheric elemental deposition. Ecological Chemistry and Engineering, 2007, 14(7), 631-644.

[15] Freitas MC, Pacheco AMG, Baptista MS, Dionísio I, Vasconcelos MTSD, Cabral JP. Response of exposed detached lichens to atmospheric elemental deposition. Proceedings of ECOpole, 2007, 1(1/2), 15-21.

[16] Frontasyeva MV, Smirnov LI, Steinnes E, Lyapunov SM, Cherkintsev VD. Heavy metal atmospheric deposition study in the South Ural Mountains,

Journal of Radioanalytical and Nuclear Chemistry, 2004, 259, 19-26.

[17] Gorelova, S.V., Lyapunov, S.M., Gorbunov, A.V., Okina, O.I., Frontasyeva, M.V., 2010. The possibility of using woody plants for bioindication and biomonitoring emissions of metallurgical industry. Problems of Biogeochemistry and Geochemical Ecology, 1(12), 155-163

[18] Gorelova, S.V., Frontasyeva, M.V., Lyapunov, S.M., Gorbunov, A.V., Okina, O.I., 2011. Woody plants in passive biomonitoring and bioremediation of urban ecosystems. Aspect of heavy metal accumulation, 2011. Neutron Spectroscopy, Nuclear Structure, Related Topics: Abstr. of the XIX Intern. Seminar on Interactioon of Neutrons with Nuclei (Dubna, May 25-28, 2011). – Dubna, JINR, P. 29

[19] Haas JR, Bailey EH, Purvis OW. Bioaccumulation of metals by lichens: Uptake of aqueous uranium by Peltigera membranacea as o function of time and pH, American Mineralogist, 1998, 83, 1494-1502.

[20] Lee JA, Tallis JH. Regional and historical aspects of lead pollution in Britain. Nature, 19973, 245:216-218.

[21] Klos A, Rajfur M, Waclawek M, Waclawek W, Wuenschmann S, Markert B. Quantitative relations between different concentrations of micro- and macroelements in mosses and lichens: the region of Opole (Poland) as an environmental interface in between Eastern and Western Europe, Int. J. Environment and Health, 2010, Vol. 4, No. 2/3, 98-119.

[22] Loppi S, Bonini I. Lichens and mosses as biomonitors of trace elements in areas with thermal springs and fumarole activity (Mt. Amiata, central Italy). Chemosphere, 2000, 41, 1333-1336.

[23] Loppi S, Giomarelli N, Bargagli R. Lichens and mosses as biomonitors of trace elements in a geothermal area (Mt. Amiata, central Italy), Cryptogamic Mycoloie, 1999, 20, 119-126.

[24] Marchevecchio JE, Ferrer L. Distribution and geochemical partitioning of heavy metals in sediments of the Bahia Blanca Estuary, Argentina. J. Coast Res., 2005, 21, 826-834.

[25] Markert B, Breure T, Zechmeister H. Definitions, strategies and principles for bioindication / biomonitoring of the environment. In: Markert B, Breure T, Zechmeister H. eds. Bioindicators & Biomonitors. Principles, Concepts and Applications. Elsevier, Amsterdam, 2003, 3-39.

[26] Markert B, Wuenschmann S, Fraenzle S, Figueiredo A, Ribeiro AP, Wang M. Bioindication of trace metals – with special reference to megacities. Environmental Pollution, 2011, 159, 1991-1995.

[27] Ozturk M, Yucel E, Gucel S, Serdal S, Aksoy A. Plants as biomonitors of trace elements pollution in soil. In: Prasad, M.N.V., ed., Trace elements – Nutritional Benefits, Environmental Contamination, and Health Implications. Wiley, 2008, 721-742.

[28] Pesch R, Schmidt G, Schroeder W. Changing Plant Pheology in Germany. Lecture given at the 5th International Workshop on Biomonitoring of Atmospheric Pollution (BIOMAP). 20-24 Sept. 2009, Buenos Aires, Argentina.

[29] Pignata ML, Gudifio GL, Wannaz ED, Pla RR, Gonzalez CM, Carreras HA, Orellana L. Atmospheric quality and distribution of heavy metals in Argentina employing Tillandsia capillaries as a biomonitor. Environ. Pollution, 2002, 120, 59-68.

[30] Pla R, Pignata ML, Carreras H, Gonzalez C, eds. 5th International Workshop on Biomonitoring of Atmospheric Pollution, 20th to 24th of Sept. 2009, Buenos Aires, Argentina.

[31] Saiki M, Jaluul O, Sumita N, Vasconcellos M, Filho W. Trace element contents in serum of healthy elderly population of metropolitan São Paulo area in Brazil. Journal of Trace Elements in Medicine and Biology, 2007, Vol. 21, 70-73.

[32] Smodis B, Pignata ML, Saiki M, Cortes E, Bangfa N, Markert B, Nyarko B, Arunchalan J, Garty J, Vutchkov M, Wolterbeek HT, Steiness E, Freitas NC, Lucaciu A, Frontayeva. Validation and application of plants as biomonitors of trace athmospheric pollution – a co-ordinated effort in 14 countries, Journal of Atmospheric Chemistry, 2004, Vol., 49, 3-13.

[33] Steinnes E, Rühling A, Lippo H, Makinen A. Reference materials for large scale metal deposition surveys, Accreditation and Quality Assurance, 1997, 2, 243-249.

[34] Zechmeister H.G, Hagendorfer H, Hohenwallner D, Hanus-Illnar A, Riss A. Analyses of platinum group elements in mosses as indicators of road traffic emissions in Austria. Atmospheric Environment, 2006, 40, 7720-7732.

[35] Wolterbeek B, Sarmento S, Verburg T. Is there a future for biomonitoring of element air pollution? A review focussed on a larger-scaled health-related (epidemiological) context. Journal of Radioanalytical and Nuclear Chemistry, 2010, 24, 926-934.

[36] Berg T, Steinnes E. Is it possible to estimate atmospheric deposition of heavy metals by analysis of terrestrial mosses? 24th TFM ICP Vegetation, Rapperswil, Switzerland, 2011.

http://icpvegetation.ceh.ac.uk/events/documents/Steinnesetal_000.pdf,

[37] Fraenzle S, Markert B, Wuenschmann S. Introduction to Environmental Engineering, Wiley-VCH, Weinheim, 420 pp., 2012.

[38] Markert B, Baltrėnaitė E, Chudzińska E, De Marco S, Diatta J, Ghaffari Z, Gorelova S. Marcovecchio J, Tabors G, Wang M, Yousef N, Fränzle S, Wünschmann S. Global and Transdisciplinary Networking in Bioindication and Biomonitoring Studies – Past, Present and Future Approaches; 2013, submitted.

[39] Markert B, Oehlmann J, Roth M. General aspects of heavy metal monitoring by plants and animals, in : Subramanian, K.S. and Iyengar, G.V., eds., Environmental Biomonitoring – Exposure Assessment and Specimen Banking, American Chemical Society Symposium Series, 1997, 654, 19-29, Washington DC.

[40] Markert B. Definitions and principles for bioindication and biomonitoring of trace metals in the environment, Journal of Trace Elements in Medicine and Biology, 2007, 21, 77-82.

[41] Oehlmann J, Markert B. Humantoxikologie, eine Einführung für Apotheker, Ärzte, Natur- und Ingenieurwissenschaftler, Wissenschaftliche Verlags-gesellschaft mbH, Stuttgart, 1997.

[42] Baker AJM. Accumulators and excluders - strategies in the response of plants to heavy metals. Journal of Plant Nutrition, 3, 643-654, 1981.

[43] Markert B. Instrumental Element and Multi-Element Analysis of Plant Samples, Methods and Application: John Wiley and Sons, Chichester, New York, Brisbane, Toronto, Singapore, 296 pp, 1996.

[44] Harmens H, Norris D, Steinnes E, Kubin K, Piispanen J, Alber R, Aleksiayenak Y, Blum O, Coşkun M, Dam M, De Temmerman L, Fernández J. Mosses as biomonitors of atmospheric heavy metal deposition: Spatial patterns and temporal trends in Europe. Environmental Pollution, 2010, Vol. 158, 10, 3144-3156.

[45] Jeran Z, Freitas C, Wolterbeek H, eds. Assessment of levels and sources of trace element air pollution: the biomonitoring approach. Kluwer, Dordrecht, 2004.

[46] Kalaji H, Saxena D, Bosa K. Chlorophyll fluorescence: A trustable bioindicator for ecological studies under climate change conditions, lecture given at The International Conference on Monitoring of Metals and Gases in Plants with Special Reference to Bryophyte Physiology & Climate Change, Bareilly, India, 17-18th of Dec., 2012, Abstract, 11-12.

[47] Kumari A, Lal B, Pakade Y, Chand P. Assessment of bioaccumulation of heavy metal by Pterris Vittata L. Growing in the vicinity of fly ash, International Journal of Phytoremediation, 2011, 13, 8, 779-787.

[48] Kumari A., Upendra NR. Biomonitoring of atmospheric pollution levels with Ricca gangetica in the vicinity of fly ash near National Thermal Power Corporation (NTPC), Kahalgaon, Bhagalpur, India, lecture given at The International Conference on Monitoring of Metals and Gases in Plants with Special Reference to Bryophyte Physiology & climate Change, Bareilly, India, 17-18th of Dec., 2012, abstract, p. 41-42.

[49] Loppi S, Chiti F, Corsini A, Bernardi L. Lichen biomonitoring of trace metals in the Pistoia area (central northern Italy). Environmental Monitoring and Assessment, 1994, V. 29, 1, 17-27.

[50] Nriagu J, Pacyna J, Szefer P, Markert B, Wuenschmann, S, Namiesnik J. eds. Heavy Metals in the Environment – Selected papers of the ICH Met 15 Conference, Maralte Publisher, Leiden, The Netherlands, 336 pp, 2012.

[51] Poli DB. Polar Auxin Transport in Moss: Clues for Climate Change, lecture given at The International Conference on Monitoring of Metals and Gases in Plants with Special Reference to Bryophyte Physiology & climate Change, Bareilly, India, 17-18th of Dec., 2012, Abstract p. 33.

[52] Ribeiro AP, Figueiredo AMG, Sarkis JES, Hortellani MA, Markert B. Pt, Pd and Rh Levels in soils of São Paulo City, Brazil: Assessment of automobile catalytic converter pollution. Environmental Monitoring and Assessment, 2012, 184, 12, 7373-7382.

[53] Saxena D, Srivastaval K, Singh S. Assessment of metal accumulation in moss in relation to atmospheric emission source in Uttrakhand, india, 24th Task Force meeting, 31st – 2nd of Feb., ICP vegetation, rapperswil-Jona, HSR Hochschule Rapperswil, 2011, abstract, p.30.

[54] Youssef N, Markert B, Gurbanov E, Sevnic H, Wuenschmann S. Tree leaves as bioindicators of trace metal pollution in the atmosphere of three urban sites in Baku City, Azerbaijan; Environmental Engineering and Landscape Management, 2013, accepted.

[55] Tabors G, Brumelis G, Lapina L, Pospelova G, Nikodemus O. Changes in element concentrations in moss segments after cross-transplanting between a polluted and non polluted site, Journal of Atmospheric Chemistry, 2004, 49, 191-197.

[56] Tabors G, Lapina L. Growth dynamics of the Hylocomium splendens moss. In: Nriagu J, Pacyna J, Szefer P, Markert B, Wuenschmann S, Namiensnik J, (eds.) Heavy metals in the Environment. Maralte Publisher, Leiden, 2012, 311-321.

[57] Fraenzle O. Bioindicators and environmental stress assessment, in: Markert, B., Breure, T., and Zechmeister, H., Elsevier, 2003, 41-84.

[58] Wuenschmann S, Oehlmann J, Delakowitz B, Markert Untersuchungen zur Eignung wildlebender Wanderratten (Rattus norvegicus) als Indikatoren der Schwermetallbelastung, Teil 1. UWSF-Z Umweltchem Ökotox, 2001, 13 (5), 259-265.

[59] Wuenschmann S, Oehlmann J, Delakowitz B, Markert B. Untersuchungen zur Eignung wildlebender Wanderratten (Rattus norvegicus) als Indikatoren der Schwermetallbelastung, Teil 2. UWSF-Z Umweltchem Ökotox, 2002, 14 (2), 96-103.

[60] Wuenschmann S, Fraenzle S, Markert B, Zechmeister H. Input and transfer of trace metals from food via mothermilk to the child – bioindicative aspects to human health, in: Prasad M.N.V. Trace Elements: Nutritional Benefits, Environmental Contamination, and Health Implications, John Wiley & Sons, 2008, 555-92.

[61] Schwarz OJ, Jonas WL. Bioaccumulation of xenobiotic organic chemicals by terrestrial plants, Chapter 14, in: Wang, W., Gorsuch, J.W. and Hughes, J., eds., Plants for environmental studies, CRC Press, Boca Raton, 1997, pp 417-449.

[62] Simeonow V, Simeonova P. Receptor modelling in air quality assessment, Lecture given at the 5th International Workshop on Biomonitoring and Atmospheric Pollution BIOMAP), 20-24 September 2009, Buenos Aires, Argentina.

[63] Markert B, Wuenschmann S, Fraenzle S, Wappelhorst O, Weckert V, Breulmann G, Djingova R, Herpin U, Lieth H, Schroeder W, Siewers U, Steinnes E,

Wolterbeek B, Zechmeister H. On the road from environmental biomonitoring to human health aspects: monitoring atmospheric heavy metal deposition by epiphytic/epigeic plants: present status and future needs. Int. J. Environment and Pollution, 2008, Vol. 32, No. 4, 486-498.

[64] Trapp S, Rein A. Modelling of plant uptake and application in environmental science and engineering, RECETO PhD-course, 22-26 June, Technical University of Denmark, Kgs. Lungby, DK, 2009.

[65] Davis L, Stephens G. A community-driven environmental research program. Invited talk at the UEP conference, June 20-23, 2010, Boston.

[66] **Markert** B, Wünschmann S, Herzig R, Quevauviller P. Bioindicateurs et biomoniteurs : Définitions, stratégies et applications. TechIng Paris, 2010, P4 170:1-16.

[67] Markert B, Wünschmann S, Baltrėnaitė E. APLINKOS STEBĖJIMO NAUJOVĖS. BIOINDIKATORIAI IR BIOMONITORIAI: APIBRĖŽTYS, STRATEGIJOS IR TAIKYMAS. Journal of Environmental Engineering and Landscape Management, 2010, 20:3, 221-239.

[68] Markert B**,** Wünschmann S, Diatta JB, Chudzińska E. Innowacyjna Obserwacja Środowiska: Bioindykatory i Biomonitory: Definicje, Strategie i Zastosowania. Environmental Protection and Natural Resources, 2012, No. 53, 115-152.

[69] **Markert B**, Wang, M, Wünschmann S, Chen W 生态环境生物指示与生物监测技术研究进展 (Bioindicators and Biomonitors in Environmental Quality Assessment). Acta Ecologica Sinica, Elsevier, 2013, Vol. 33, No 1, 33-44.

[70] **Markert B**, Wünschmann S, Marcovecchio J, De Marco S. **Bioindicadores y Biomonitores: Definiciones, Estrategias y Aplicaciones.** In: Procesos Químicos en Estuarios J.Marcovecchio & R.H. Freije (eds); 2013, in press

[71] **Markert B**, Fränzle S. Information und Informations-verarbeitung. Die Stufen der Erkenntnis und das Verhältnis von Objektivität und Subjektivität. UWSF-Z. Umweltchem Ökotox, 2007, 19 (2) 86-90.