The Potential of Near Infrared Spectroscopy (NIRS) for the Environmental Biomonitoring of Plants

Katharina Hoffmann, Monika Nieren, Martina Gäb, Anna Kasper, Gereon Elbers
Faculty of Chemistry and Biotechnology, FH Aachen University of Applied Sciences, Campus Jülich, Germany

*Corresponding author: elbers@fh-aachen.de

Abstract. In the current environmental condition, the increase in pollution of the air, water, and soil indirectly will induce plants stress and decrease vegetation growth rate. These issues pay more attention to be solved by scientists worldwide. The higher level of chemical pollutants also induced the gradual changes in plants metabolism and decreased enzymatic activity. Importantly, environmental biomonitoring may play a pivotal contribution to prevent biodiversity degradation and plants stress due to pollutant exposure. Several previous studies have been done to monitor the effect of environmental changes on plants growth. Among that, Near Infrared spectroscopy (NIRS) offers an alternative way to observe the significant alteration of plant physiology caused by environmental damage related to pollution. Impairment of photosynthesis, nutrient and oxidative imbalances, and mutagenesis.

Keywords: Near Infrared Spectroscopy, environment, biomonitoring, plants, hazard stress

1. Introduction
Protection of environment quality is a global task to give guaranty for good living conditions in the future [1]. This case includes establishing more sustainable processes, saving resources, and minimizing hazards pollution [2]. To assess and predict the status quo and development of the environmental conditions physical, chemical and biological parameters have to be measured to describe the complex biosphere system [3]. The conventional ecological analysis mainly deals with the detection of hazardous substances in water, soil, and atmosphere [4]. Biological methods mostly are used to investigate environmental effects on biological systems [4]. The observation of such effects is the basis for risk assessment of hazards and biomonitoring. Observable parameters of bioindicators can be, e.g., behavior, morphology, health status or metabolism. To measure chemical compounds of metabolism, well-established methods like liquid or gas chromatography most commonly are used. It is remarkable that Near Infrared Spectroscopy (NIRS) in the field of environmental analysis is very rare [5–9]. NIRS is a powerful technique since about two decades and very successfully used for analysis of, e.g., food, raw material, pharmaceutical products, and polymer. Here in our study, we tested NIRS to investigate plants which were treated before by environmental hazards to find out if the NIR spectra can be used for detection of stress effects in bioindicator plants.
2. Methods
In unique designed fumigation chambers, herbs/grass were treated with defined concentrations of NH₃ and trees were fumigated with O₃ [10]. In another experiment test, the plants were exposed to Pd in nutrition water. NIR spectra were recorded from the dried plant leaves/needles, and reference analyses were performed by GC/MS, HPLC, IC, and further routine methods. By applying multivariate calibration methods, NIRS models were developed for numerous chemical compounds of plant metabolism. The NIR spectra of the plants were also directly correlated to the affecting hazard concentrations.

Figure 1. Fumigation chambers for treatment of trees with Ozone (LANUV, Essen, Germany)

3. Results and Discussion
The multivariate calibration statistic parameters showed that it was possible to detect a lot of chemical compounds (e.g., soluble carbohydrates, α-Tocopherol) of indicator plant metabolism by NIRS very rapidly with a minimum of sample preparation. Thus, NIRS can be used to analyze the concentrations of specific compounds in the plants which are influenced by environmental pollution [11].

Beyond that, the NIR spectra of the treated plants highly correlated with the concentrations of O₃ or NH₃ in the fumigation chambers or Pd in growth substrate. The NIR spectrum images the complex influence on plant metabolism by environmental induced stress. We could derive quantitative relationships between the change of NIR spectra and affecting concentrations. NIRS is a powerful tool to detect plant stress and to determine detection limits for pollution effects on plants which can be used for environmental biomonitoring.

4. Conclusion
The future detecting method for monitoring plants stress could be addressed by using a simple and robust method, including NIR spectra. The quantification of pollutant accumulation and certain chemical concentration within the plants can be used as the essential marker for environmental biomonitoring. Hence, NIR spectra provide an alternative solution for the prevention of plant stress and environmental damage caused by pollutant exposure.
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