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INVESTIGATION OF THE INFLUENCE OF NICKEL IN PRECIPITATION THROUGH THE SURFACE PROPERTIES OF MOSS *PLEUROZIUM SCHREBERI*

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Abstract: 3D stereophotogrammetric scanner was used to obtain 3D model of canopy structure of *Pleurozium schreberi* moss samples in order to determine changes in the surface roughness index caused by the exposition to the simulated precipitation with known nickel concentrations. In mosses, surface roughness index is known to be a significant indicator of the environmental conditions and is strongly correlated with microclimatic state of the vicinity of the plant. Samples were divided to two groups and either 5 $mg.l^{-1}$ or 50 $mg.l^{-1}$ solutions of pH 5 were applied as a simulated rainfall for the total period of eight weeks, 3D model of the sample surface was obtained every time before and after irrigation. In addition, organic material was analysed for the final nickel content using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Calculated surface roughness indices revealed substantial alteration the pattern of canopy properties changes during irrigation – nickel in the simulated precipitation therefore affects the surface of the moss canopy and thus the ecophysiological properties of the moss used. Total accumulated nickel was found to reflect the concentration of the metal in the precipitation with the nickel content in moss being ten times higher in the case of ten times higher content in the solution used for the irrigation (1922 $mg.kg^{-1}$ compared to 195 $mg.kg^{-1}$ following the application of 50 $mg.l^{-1}$ and 5 $mg.l^{-1}$ nickel solution, respectively).

Key words: Nickel, *Pleurozium schreberi*, photogrammetry, surface roughness index, canopy structure

1. INTRODUCTION

Pollution in precipitation in big cities are produced both by mobile and stationary sources of pollution related with particular type of industry and traffic. Trace elements in biosphere are widespread and, at the same time, their interactions may have toxic effects. Collection of bulk atmospheric deposition is common and practical approach for monitoring of atmospheric deposition of heavy metals and others elements which can be found in environment (Aničić et al., 2009). In these cases alternative methods of monitoring are chosen instead of standard analytical methods. Harmens et al., 2008 proved bryophytes to be suitable monitors of time of accumulation of heavy metals. Even slight changes in atmospheric quality can change life conditions of organisms thus attention to the pollutants which can effect environment should be paid. Air and other associated elements infiltrates the organism so their state is directly affected. Models of heavy metals depositions in Czech Republic are provided by Czech hydro-meteorological institute; measurement of the parameters of environment is carried out by different institutions such as State health institute, Czech hydrometeorological institute etc (Šantrnoch, 1999). Evaluation and air quality management in Czech Republic is determined by the law number 86/2002 which is further specified under government decree number 597/2006. In the European scale, concentrations of 12 trace elements (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sb, V, Zn) are monitored in naturally growing moss (Harmens et al., 2011).

Biological material as an indicator is well known concept for more than one hundred years. Originally, the method of monitoring was focused mainly to such air components as sulphur oxides and hydrofluoric acid. Moreover, tracheophytes and bryophytes serving as bioindicators provide us with additional information to the standard monitoring methods (Falla et al., 2000). Mosses are known for their ability of retention of water in ecosystems. They are also able to rapidly absorb water and keep it in their cells thereby starting their metabolism after a period of dessication which allows them to survive temporarily unfavourable environmental conditions (Rao et al., 1979). Because of such properties of theirs, mosses belong to the category of so called pioneer species capable of thriving in inhospitable conditions (Proctor & Tuba, 2000). There are many advantages of using mosses for the atmospheric pollution bioindication: they occur throughout whole year, are able to live in extremely unfavourable conditions, have slow growing tempo thus accumulate pollutants in long-time term, they are easy to collect, widespread and do have minimal morphological changes during growth (Sarafis, 1971). Biomonitoring of heavy metals in natural environment was used for the first time by Rühling & Tyler, 1968. Zechmeister et al., 2003 states that the application of bryophytes in biomonitoring is advantageous for their high surface: volume ratio leading to the retention of higher amount of particles, also, the lack of cuticle on the bryophyte leaves leads to better accumulation for there is no wax layer hampering it. Detectable physiological changes of the moss structure in reaction to the polluted atmosphere are favourable in biomonitoring too. In bryophytes, exposition to toxic metals is characterized by decrease of growth but, on the other side, exposure to the nitrogen and phosphorus can increase growing ability (Zechmeister & Moser 2001). Capturing of the pollutant from the atmosphere can be realized in three ways: through the water solution from precipitation, in gaseous phase or by sticking on the moss surface (Rao et al., 1979). Lodenius (2013) used mosses as bioindicators of mercury near the sources of contamination and Sert et al., (2011) used bryophytes as an active biomonitor of heavy metals and radionuclides. Author of the latter study also mentioned higher level of accumulation mosses than in vascular plants from the same locality.

2. MATERIAL AND METHODS

Subject under study was the influence of nickel ions in the solution on the surface structure of *Pleurozium schreberi* by determining its surface roughness index. Recently, there were several studies performed with the aim of obtaining three-dimensional model of the bryophyte population in order to calculate an index that would describe morphological characteristics of population with the most promising being the surface roughness index (Sr) as proposed by Rice at al. (2001). Surface roughness index is defined as square root of twice the maximum semivariance derived from the microtopological features of the surface under study.

Moss material was collected in the vicinity of the Zátiší settlement (Ostravian microregion, 303 mamsl) far from the possible local sources of pollution. Research was carried out from September to December of 2001, collection of the material in September and October of the same year. The species chosen for the study was *Pleurozium schreberi* (Brid.) Mitt.; this species is frequently used in biomonitoring surveys, among other things due to its abundance and easy determination.

For the simulation of influence of precipitation on the bryophyte morphology, nickel was chosen. This element was chosen because of its enhanced concentration in Moravian-Silesian region environment due to the anthropogenic causes – mainly steelworks, chemical industry, combustion processes associated with energy production, waste waters from the surface metal coating or from non-ferrous metallurgy and emissions from traffic.

Precipitation was simulated using the solution of nickel ions of pH = 5, such pH is common in the precipitation of the region in question. Mass concentration of the two solution used was 5 and 50 $mg.l^{-1}$, these concentrations were chosen according to the study of Uygur (2010). According to the historical meteorological data (CHMI, 2009), mean precipitation in September is 9 mm per week; this was simulated in the scheme of twice a week/4.5 mm of precipitation/sample.

3. PREPARATION AND TREATMENT OF THE SAMPLES

After each collection, samples obtained were transferred to laboratory for immediate treatment and consequent desiccation. The treatment consisted of 30 s thorough washing up with distilled water to secure removal of adhering matter (mainly dust) from the surface. Such period of time is sufficient to wash away particles adhering to the surface and not disrupting the cellular structure at the same time (Fernández et al., 2007). 1 g of dry weight of the moss per Petri dish was applied for the experiment.

4. SAMPLE ANALYSIS

4.1. Surface roughness index determination

Analysis performed dealt with the influence of the nickel ions on the canopy of the bryophyte *Pleurozium schreberi*, particularly its surface roughness index. Measurements to determine the index were performed using 3D stereo photogrammetry scanner. Scanning of the samples was performed for four weeks twice a week, always before the simulated precipitation with the nickel solution and 5 minutes after. Precipitation was simulated using a pipette. 3D photogrammetry scanner hereby applied uses this passive, non-contact method for obtaining values of the distance of the camera from the surface, then the values are used to calculate variograms and the surface roughness index value is determined. Scanning was performed under the daylight, camera with attached additional light source was used to take photographs of the sample from different angles. Then, using the trigonometrical approach, the distance of the surface in various points was determined, the process itself is comparable to the process of depth perception carried out by the human eye. Figures 5-10 shows the reconstructed surfaces, Y axes shows the distance of reconstructed points from the camera.

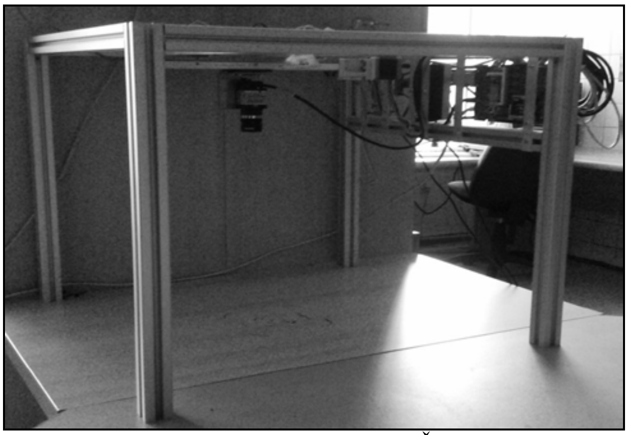

Figure 1. 3D photogrammetry scanner (Čecháková, 2013)

Applied scanner was developed by Krumnikl et al., (2009), it consists of hardware part – optical system of the camera and the rider it is moving on, and analytic software part for assessment of the obtained data. The camera mounted is Imaging Development System (2240-M-GL, monochromatic, 1280x1024 pixels, ½‘‘ CCD with lenses PENTAX, f = 12 mm, F 1.4). Overall view of the scanner is presented in the figure 1.

4.2. Chemical analysis of samples

For the determination of the amount of nickel in the samples of *Pleurozium schreberi* exposed to the simulated precipitation with the known concentration of nickel, inductively coupled plasma atomic emission spectroscopy (ICP-AES) was applied. The analyses were performed in the certified laboratory of the Nanotechnology centre VŠB-TUO.

5. RESULTS AND DISCUSSIONS

Figures 2 a 3 present the progress of observed surface roughness index in the course of one month when saturated with Ni^{2+} ions solution (5 and 50 $mg.l^{-1}$). Full line shows values obtained before the application of the solution, dashed line those after application. Fluctuation around the second week of scanning cannot be explained unequivocally, it may mean the moss canopy reacts to the sudden change in exposition to the element and lower pH. In the consequent weeks, the line is increasing which may imply slow adaptation to stress.

Figure 2. After exposure to solution Ni^{2+} 5 $mg.l^{-1}$

Another remarkable finding is that samples exhibit ability to accumulate the toxic metal – nickel. From the outcomes of ICP-AES, it is evident that the moss accumulated ten times more nickel when its amount in the solution was also ten times higher (5 $mg.l^{-1}$ in the solution lead to 195 $mg.kg^{-1}$ in the moss tissue and with 50 $mg.l^{-1}$ lead to 1822 $mg.kg^{-1}$) – as is shown in the figure 4. Thus, it can be concluded that accumulation rates in such levels of heavy metal pollution mimic the actual content of the pollutant in the environment fittingly.

Figure 3. After exposure to solution Ni^{2+} 50 mg.l^{-1}

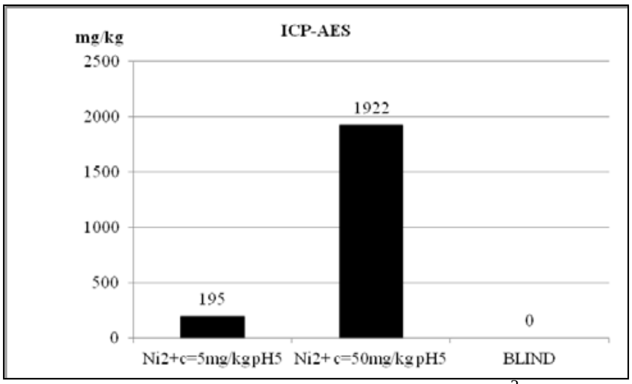

Figure 4. The results ICP-AES for Ni^{2}

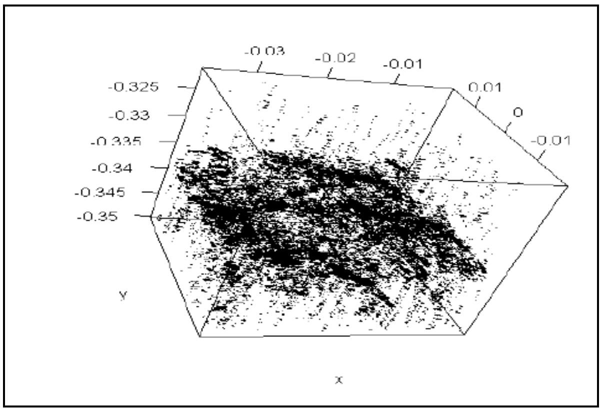

Figure 5. 3D model of moss canopy before exposure Ni^{+2} 5 mg.l^{-1}

Even the visual change was observed in the sample being saturated with the 50 mg.l^{-1} Ni solution. Since the third week of the experiment, it was showing gradual change of the colour from green to yellow or phosphoric yellow.

From the 3D photogrammetry results, 3D models were constructed using the statistical package R. Figures 5-10 shows the result of scanning from the day 28.11. 2011 in the sample exposed to the Ni^{+2} 5 and 50 mg.l^{-1} Ni solution and blind sample before and after exposition with the distance from the camera (in negative numbers) on y axis.

Surface roughness index values derived from the scanning data contradicts the typical habitus of the moss – there was difference observed in all the indices obtained. It appears that intensive change of the surface structure took place due to the application of the solutions. Not only the numeral outcomes (indices) differed – visually there was considerable change of colour, size and connectivity of the canopy observed too.

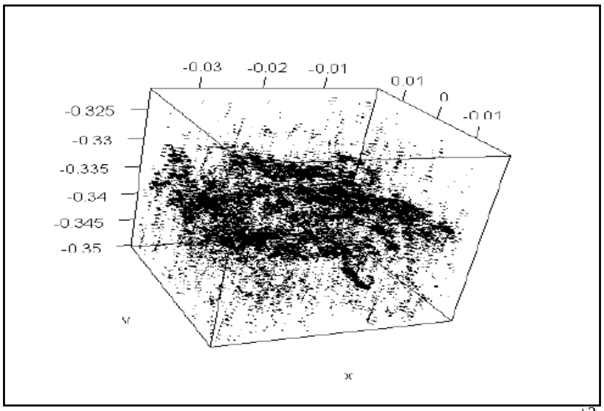

Figure 6. 3D model of moss canopy after exposure Ni^{+2} 5 mg.l^{-1}

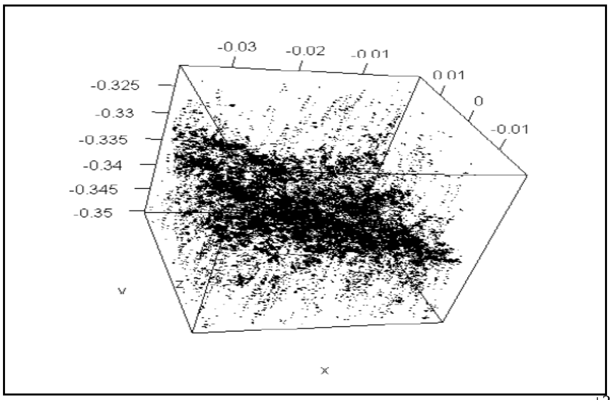

Figure 7. 3D model of moss canopy before exposure Ni^{+2} 50 mg.l^{-1}

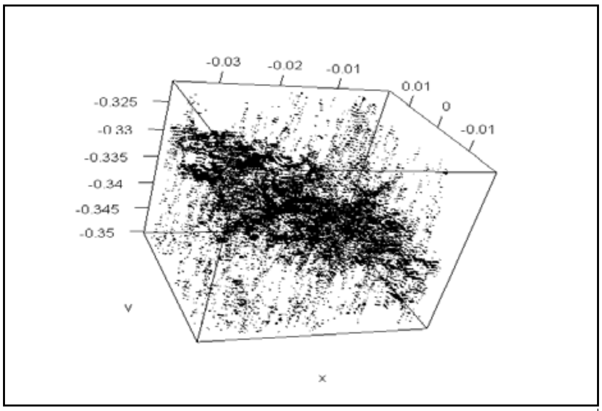

Figure 8: 3D model of moss canopy after exposure Ni^{+2} 50 mg.l^{-1}

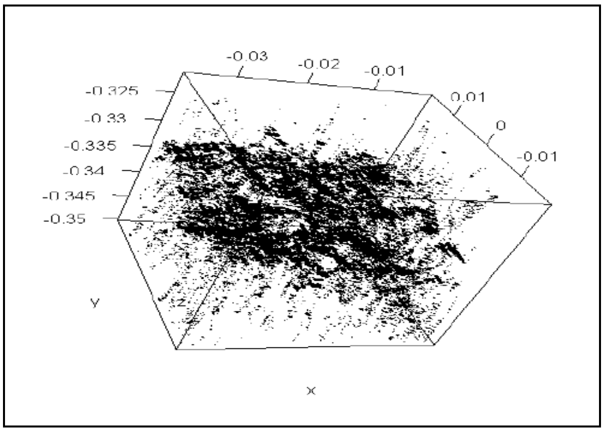

Figure 9: 3D model of moss canopy to the blind before exposure

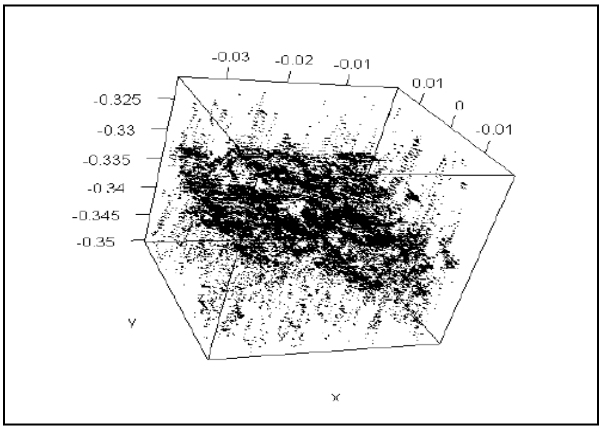

Figure 10: 3D model of moss canopy to the blind after exposure**.**

6. CONCLUSIONS

Using 3D stereo photogrammetry, models of the surface structure of the bryophyte *Pleurozium schreberi* were obtained. Models were then utilized in the statistical analysis of the surface structure which in the end resulted in calculation of the surface roughness index (Sr)

Surface roughness index is a valuable indicator of the eco-physiological state of the bryophyte layer. From its values – obtained both before and after the exposition to the simulated precipitation of lower pH and known concentration of nickel, strong relation between the exposition and the change of the surface structure of the bryophyte can be derived. Nevertheless, possible bias by the environmental variability of the samples collected in the nature, cannot be excluded.

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