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Application of sodium hypochlorite in the technique of soil section preparation

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A b s t r a c t. Image analysis of soil section is often used by soil scientists in order to quantify the soil structure and macro-pore properties. During the computer image analysis the most difficult and error-burdened process is segmentation when pores and solid phase are detected. This paper presents a method of improving the image quality for computer analysis. Sodium hypochlorite was tested with respect to its bleaching effect for solid phase of soil. Different concentrations of NaClO and time of rinsing were tested. The results show that sodium hypochlorite increases the contrast between pores and solid phase and makes the process of image segmentation more precise. The optimum parameters of soil section bleaching are the concentration of 10 g l^{-1} available Cl and duration of 48 h.

K e y w o r d s: sodium hypochlorite, soil structure, soil section

INTRODUCTION

Soil structure is one of the most important properties affecting crop production because it determines the depth that roots can penetrate to, the amount of water that can be stored in the soil, and the movement of air, water and soil fauna (Gliński and Stępniewski, 1985; Pagliai *et al*., 2004). Pore space measurements, particularly its shape and size, are increasingly used to quantify soil structural changes following agricultural activities (Bryk *et al.;* 2000; Pagliai and Vignozzi, 2002; Ringrose-Voase and Bullock, 1984). Image analysis on thin sections prepared from undisturbed soil samples allows to quantify the soil pore system (Czachor and Lipiec, 2004; Pagliai *et al*., 1983).

In image analysis of soil sections an important task is to detect the objects of interest. Image segmentation is the tool usually used for partitioning the image into separate regions. It is usually defined as the division of a digital image into multiple sets of pixels, according to a given criterion. Automatic segmentation techniques were developed in recent years (Sezgin and Sankur, 2004; Sofou *et al*., 2001). However, the manual thresholding method is also used. The accuracy of segmentation depends on the difference between the objects (pores) and their surroundings. To find the edges of solid phase of soil is the most difficult problem in the field of computer image analysis of soil sections because of the very low contrast, complex structure and dim edges which characterize these images (Szala, 2001; Wojnar *et al*., 2002). It is a particularly serious problem in analysis of soil samples taken from upper layers of soil with high organic matter content and with dark colouring.

One of the solutions could be the application of dyes during impregnation of soil samples to increase the contrast of the image. However, white and black dyes do not result in significant changes in histograms. Only fluorescent dyes result in positive changes in the image characteristics, but the application of fluorescent pigments is connected with problems in image acquisition. The images need to be illuminated with UV light, which precludes using high resolution scanners (Głąb, 2005).

The aim of this study was to determine the usefulness of application of sodium hypochlorite in soil section preparation technique in order to bleach the solid phase and increase the image contrast. Different concentrations of sodium hypochlorite solution and time of rinsing were tested to evaluate optimum parameters.

MATERIALS AND METHODS

In 2005 soil samples were taken from experimental field located in Mydlniki near Cracow, on brown deluvial soil developed from silt on light silty loam and covered with perennial grasses (Table 1). The soil sections were prepared from undisturbed soil samples. A total number of 84 samples

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T a b l e 1. Characteristics of soil used in the study

pH (KCl)	(-)	6.5
Total organic C	g kg^{-1}	25.8
Total N	g kg^{-1}	2.10
C/N	(-)	12.3
Bulk density	g cm^{-3}	1.20
Total porosity	cm^3 cm^{-3}	0.526
Sand	g kg^{-1}	290
Silt	g kg^{-1}	670
Clay	g kg^{-1}	40

was used in this experiment. They were taken from the 10-18 cm soil layer in a vertical plane, using metal boxes (80/90/40 mm). Samples were dried at room temperature for 4 weeks. Then they were saturated with polyester resin (POLIMAL 109 32K) at a temperature of 20°C. The samples were placed in a vacuum chamber. The pressure was cyclically (5 times) changed from -85 kPa to atmospheric pressure in order to remove any entrapped air. The hardening of the resin took approximately two months. Then the samples were cut to slices (5 mm thick) using a diamond cutting machine with a water cooling system. After cutting, the surfaces of the slices were grinded to remove any scratches (Jongerius and Heintzberger, 1975; Murphy, 1989; Słowińska-Jurkiewicz and Domżał, 1988).

The samples were put into a water solution of sodium hypochlorite in order to bleach the solid phase. The following concentrations of sodium hypochlorite were tested: 1, 2, 5, 10, 20, 50 and 100 g l^{-1} available Cl content. The samples were rinsed for various periods of time: 1, 2, 6, 12, 24, 48 and 96 h.

After rinsing the surfaces of samples were scanned at a resolution of 600 dpi using Epson Perfection 4870 Photo scanner and the images were saved as .tiff files. The images were analysed using the APHELION software for image analysis (ADCIS SA, AAI Inc.). In order to compare the effect of sodium hypochlorite application, image histograms were prepared and the histogram shape index (HSI) was calculated. This index has been developed by the author and it was found to be useful in research where different pigments were used, due to improved segmentation accuracy (Głąb, 2005):

$$HSI= [(a-c)/a]*[(b-c)/b]*[d/256] \quad (1)$$

where: number of pixels for: a – the first maximum, b – the second maximum, c – the minimum between two maximums, d – grey level distance between two maximums.

This Eq. (1) is suitable for images with two maximums in their histograms (Fig. 1). The HSI index varied from 0 to 1. The lower values indicate that it is very difficult to detect the border between pores and solid phase because the minimum (c), where point of segmentation is located, is not clearly visible. According to Wojnar *et al*. (2005), the segmentation, especially the automatic method, is easy and precise to conduct when two distinct peaks are present (which means higher HSI value).

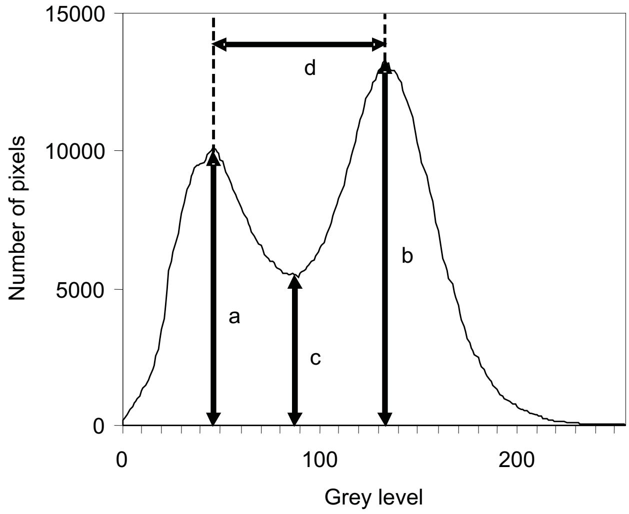

Fig. 1. Example of histogram with two maximums (a, b, c, d - description in the text), characteristic for images of soil section. Figure taken from Głąb (2005).

RESULTS AND DISCUSSION

The histograms of the investigated images were characterized by two maximums: the first (with lower grey level value) for pores and the second for solid phase. This shape of histograms is typical for porous, upper layers of tilled soils (Głąb, 2005). For the control image, not treated, the difference between two maximums was very unclear (Fig. 2). The addition of sodium hypochlorite changed the features of the histogram characteristics. The bleaching affected the second maximum (b). It got higher values in grey level scale due to increase in time of rinsing and concentration of NaClO. The minimum of histogram (c) got lower values at the same time. The first maximum (a), responsible for dark areas, did not change its position. It means the bleaching solution did not affect the optical properties of resin and the pores were the same colour as before rinsing. These changes in features of histogram were reflected in the values of HSI index (Fig. 3). The lowest HSI value (0.07) was noticed for untreated image and it increased when higher concentrations of NaClO were applied and the time of rinsing was longer. The greatest increments were noticed at the beginning of the bleaching. During the process of bleaching this effect was gradually lower. It was found that 10 g l^{-1} available Cl content was the optimum

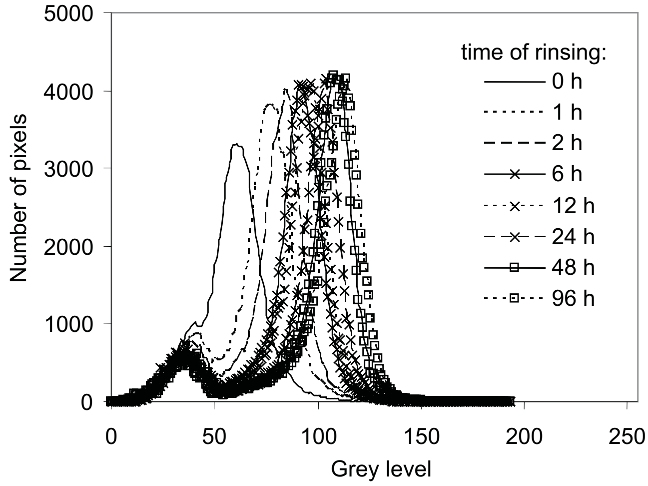

Fig. 2. Influence of time of rinsing on the histograms shape for the solution with 10 g l^{-1} available Cl content.

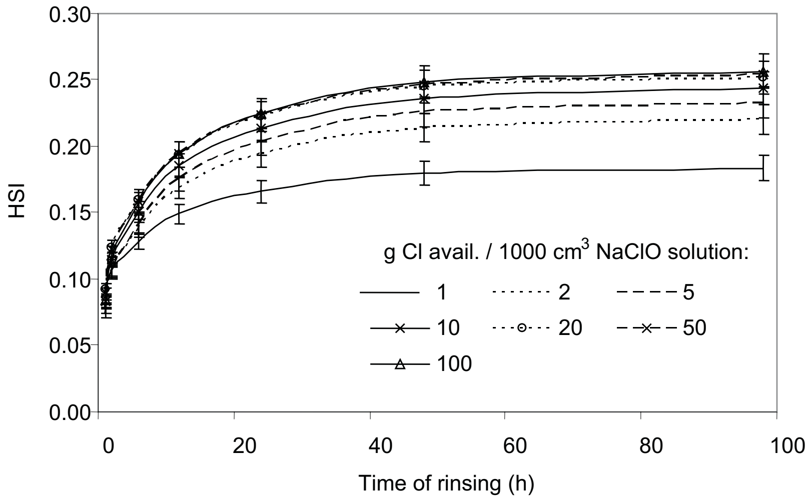

Fig. 3. Influence of solution concentration and time of rinsing on HSI index. Bars represent standard errors.

concentration of NaClO with 48 h of rinsing (Figs 3 and 4). The higher Cl concentration and longer time of bleaching did not play any statistically significant role in features of histograms and value of HSI index. The use of sodium hypochlorite gives better results in changes in histogram shape as compared to white or black dyes used for colouring the polyester resin where HSI index reached maximum value of 0.126 (Głąb, 2005).

Szala (2001) stated that, from the segmentation point of view, the best grey image should have two sets of pixels significantly different in grey level values. This is also confirmed by Wojnar *et al.* (2002) who indicate that in two-maximum histograms, with clearly separated peaks, it is also possible to use some automatic methods of segmentation. However, this ideal shape of histogram is very rarely present in the image of soil section from the upper layers of soil. In these sections it is usually difficult to achieve favourable results in segmentation due to low contrast, complex structure and often overlapping components (Maragos *et al.*, 2004). The problem is more pronounced in upper soil horizons, where solid phase is much darker then in lower layers due to higher organic matter content. The obtained results indicated that the presented method can be applied to improve the soil section preparation technique for the upper layer of silty loam Mollic Fluvisol through some favourable changes in the features of images. Thus, further work is needed to study the usefulness of the bleaching method for other soils.

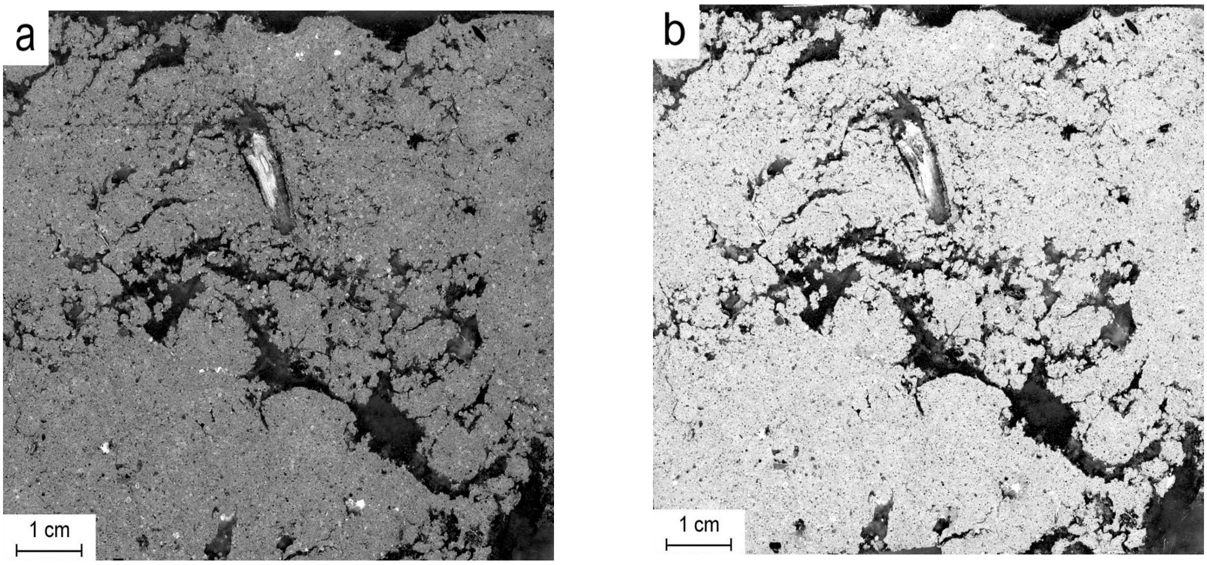

Fig. 4. Bleaching effect of soil section rinsing in NaClO solution: a – before rinsing, b – after 48 h in water solution of 10 g l^{-1} available Cl content.

CONCLUSIONS

1. The use of NaClO for bleaching soil sections significantly changes the features of image histogram. It increases the distance between two maximums of the histogram and decreases the value of the minimum between two maximums where the point of segmentation is localized.

2. The optimum parameter of soil section bleaching is 10 g l^{-1} available Cl content during 48 h of rinsing.

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