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The influence of pH on removal of H_2S and natural organic matter by anion resin

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ABSTRACT

A number of experiments with ''specific''ground water from the Pannonian Plains (the Republic of Serbia) were conducted in order to define a technological process for drinking water treatment. The ''specificity''of this raw water is reflected in increased pH value and increased concentrations of natural organic matter, ammonia, hydrogen-sulphide and some toxic metals. Removal of natural organic matter by the basic macroporous resins in acid medium (pH 6.6–7.2) ranged up to 92% of the input concentration, and of hydrogen-sulphide up to 60%. The remaining hydrogen-sulphide, that was not eliminated on the macroporous resin, was completely removed by adsorption on the Filtersorb FMH. The correlation between the concentration of natural organic matter and the UV extinction in raw and processed water, both in the acid and in the alkaline media, was established. The adsorption of natural organic matter on macroporous resins is more efficient in the alkaline medium than in the acid one.

Keywords: Hydrogen-sulphide; Natural organic matter; Anion resin; UV extinction; Redox potential

1. Introduction

Natural organic matter (humic and fulvic acids, and humics), hereinafter the humic substances, is an undesirable ingredient in drinking water [1,2]. In addition to its influence upon the colour, taste and smell of the water, the humic substances cause biologically quantitative changes in a water supply system. During oxidation and disinfection processes they combine to create compounds harmful to human health and majority of them are classed as carcinogenic or as promoters of carcinogenic compounds [3–6].

The humic substances are made up of amorphous polydisperse colloids [1,2]. Their macromolecular characteristics are the result of aggregates generated by hydrogen bonds, non-polar interactions and polyvalent cation interactions. These forms of natural organic matter are complex mixtures of aromatic and aliphatic hydrocarbon chains to which amide, carboxyl, hydroxyl, ketonic and other functional groups are bonded [7]. Functional groups with aromatic cores and humic substances with free p-electrons can participate in reactions including adsorption-desorption, oxidation-reduction and formation of complexes. Upon dissociation in water, the humic substances have a negative charge, due to the presence of carboxyl and other similar groups. Hydration of charged groups and

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electrostatic attraction-repulsion of their charges results in the conformation of humic acids, which depends on the conditions dominating the medium. Regarding their hydrosolubility, the humic substances are classified into fraction hydrosoluble at any pH values (includes fulvic acids), humic acids fraction hydrosoluble only at pH > 2 and humic fraction insoluble regardless of any pH values [7].

Natural waters contain mostly fulvic substances (responsible for its yellow colour) and smaller quantities of humic acids. Due to their complex structure, the humic acid molecules can make bonds with inorganic and organic agents (ions and dipole molecules). These molecules are especially characterized by affinity towards metal ions and formation of complex organic-metal compounds [8,9]. The properties of humic acids make them difficult to extract from water [10–13]. This prompted workers in the field to focus on optimizing the existing and working on new procedures for drinking water treatment.

Conventional procedures for drinking water treatment include processes such are flocculation [14–16], oxidation [17], adsorption on active carbon [18–20], ionic exchange [21–24] and ultrafiltration [25–27].

Alkaline resins proved to be an efficient adsorbent in the process of the humic substances removal. The humic substances in water act as anions and, due to their net-negative charge, are being adsorbed onto these resins [21–24]. Active groups in the case of anion resins are secondary and tertiary amines, or quaternary ammonia groups, and they provide active patches with net-positive charge on the surface of the resins. The humic substances adsorption kinetics on the alkaline macroporous resins depend upon the extent to which individual humic substances dissociates in water [24,28]. Higher the porosity of the resins, better the results in humic matter removal. Therefore, these resins serve as active cleaners, so-called ''scavengers'', in water purification processes [23].

Adsorption processes of the humic substances onto alkaline macroporous resins are not an unchartered territory [21–24]. However, the literature does not reveal much reference to the specific water domain. The subject of the research described in this paper is the spring water coming from the depths of 160–220 m, within the same geotectonic unit in the Backa area (north-west Serbia), part of the Pannonian Basin [29,30]. The specificity of this water is that in addition to the natural organic matter it contains hydrogen-sulphide as well as toxic metals. Our aim in this work was to determine the optimum conditions for simultaneous removal of the humic substances and hydrogen-sulphide below the concentration values defined by the drinking water quality requirements [34].

The results presented in this paper are obtained on a pilot plant designed to investigate processes in treatment of the specific water leading to drinking water.

2. Materials and methods

The research was performed on a pilot plant of 1 $m^3 h^{-1}$ capacity, in order to define the purification procedure for a ground water of specific chemical composition taken from the wells on the territory of Backa (the Pannonian Plains, Serbia). The characteristics of the raw water used were: pH range of 8.3–8.5; natural organic matter concentration from 18 to 22 mg L^{-1}; hydrogen-sulphide concentration from 0.109 to 0.170 mg L^{-1}; negative redox potential –160 mV vs. N.H.E; electric conductivity 950 μS cm^{-1}. The consequences of the chemical composition were unfavourable sensor properties, unpleasant smell and explicitly yellow colour (Table 1).

Natural organic matter was to be removed in the first column S (volume of 48 L with 37 L of ion exchanger resin Lewatit MP62, Lanxess, Leverkusen, Germany), while the hydrogen-sulphide was to be removed in the next column F (volume 48 L with 30 L Filtersorb FMH, CWG GmbH, Mannheim, Germany) (see Fig. 1). The raw water, (inlet of 1 $m^3 h^{-1}$) whose pH range was adjustable between 6.5 and 8.5 (in point A, by a metering pump FAPVM 10 1.4 EMEC, Italy) with 5% hydrochloric acid, was introduced into the first column S and subsequently into the column F with a 1 $m^3 h^{-1}$ flow (Table 2).

Water samples (1 L) were collected simultaneously from fixed outlets (Teflon valves), at points I, II, III, IV, usually 4 h after the change. The pH value of the samples was *in situ* measured by the pH meter INOLAB pH 730, WTW, Germany, the hydrogen-sulphide concentration by a spectrometer Merck 60, MERCK, Germany [31], the redox potential with an electrode model Sentix ORP at a pH meter INOLAB pH 730, WTW, Germany [31]. The concentration of organic substances was expressed by the consumption of $KMnO_4$ [32], whereas the UV extinction was measured at 254 nm by the spectrometer Lambda 14, Perkin Elmer, USA [31]. The electrical conductivity was measured with the conduct metre WTW 192, WTW, Germany [33], while

Table 1
Initial concentrations in raw water

Parameters	Units	Average	MCL
pH	–	8,4	6.8-8.5
$KMnO_4$	mg/L	20,35	8
H_2S	mg/L	0.132	Without H_2S
Redox potential	mV	−160	–
Conductivity	μS/cm	950	<1,000

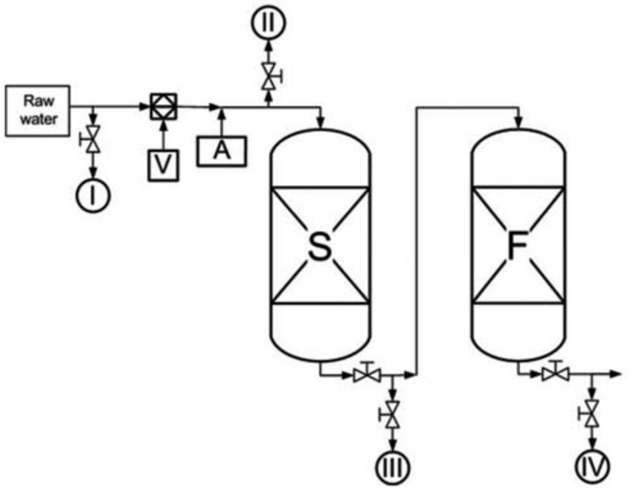

Fig. 1. The chart of the experimental pilot plant.

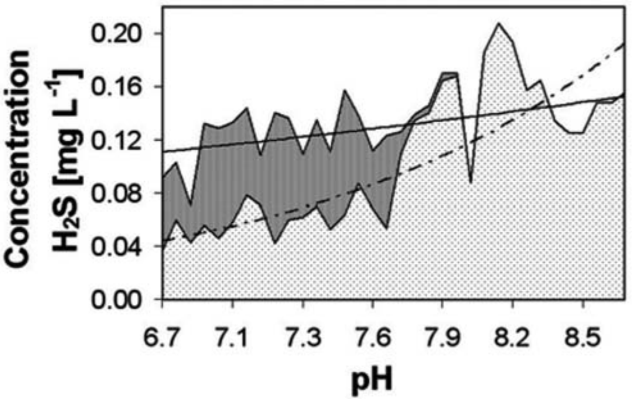

Fig. 2. Average values of the hydrogen-sulphide concentrations at the inlet (II) and the outlet points (III) of the natural organic matter removal column, as a function of the controlled pH value.: C_{inf};: C_{eff};: Expon. (H_2S inlet);: Expon. (H_2S outlet).

the temperature was measured by the pH meter INOLAB pH 730, WTW, Germany [31].

In the statistical processing of data, methods of central tendency (arithmetic mean and standard deviation), regression and correlation analysis were used. The standard stastical package SPSS 8.0 was used.

3. Results

The results are presented as average values of the data obtained in the experiments performed.

Fig. 2 presents the measured values of the hydrogen-sulphide concentrations at the inlet and the outlet points of the column S (Fig. 1) as a function of the pH of the treated water. The percentage of the hydrogen-sulphide removed in column S, expressed as the outlet and inlet concentrations ratio, in relation to the change in the pH at point A (Fig. 1) is shown in the Fig. 3.

The percentage of the natural organic matter removed as a function of the quantity of water treated in the acid (pH range of 6.6–7.0) and alkaline (pH range of 7.0–8.5) media is presented in Fig. 4. The percentage is defined as a ratio between the outlet and inlet concentrations of natural organic matter and the quantity of water treated as a volume of treated water per resin volume unit (V_w/V_r, i.e., BV – bed volume).

Table 2
Characteristics of columns S and F

Column	S	F
Filling material	Lewatit MP62	Filtersorb FMH
Volume charge	37 L	30 L
Volume capacity	48 L	48 L
Manufacturer	Lanxess, Leverkusen, Germany	CWG GmbH, Mannheim, Germany
Density	1.03 g/mL	1.56 g/mL

The relationship between the quantity of natural organic matter adsorbed on the resin and the volume of treated water (V_w/V_r), in fact the cumulative quantity of the adsorbed natural organic matter on the resin, is graphically presented in Fig. 5.

The cumulative quantity of the removed hydrogen-sulphide in an acid medium (pH range of 6.6–7.2) in relation to the treated water volume (V_w/V_r) is presented in Fig. 6.

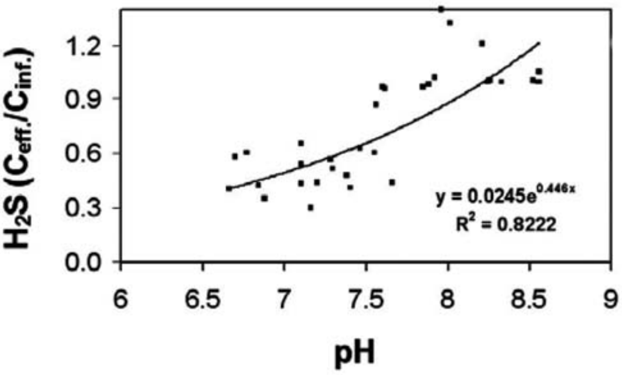

Fig. 3. Average values of the hydrogen-sulphide concentrations ratio at the outlet (III) and the inlet points (II) of the column for natural organic matter removal, as a function of the controlled pH value. (■): $C_{eff.}/C_{inf.}$ H_2S;: Expon. ($C_{eff.}/C_{inf.}$ H_2S).

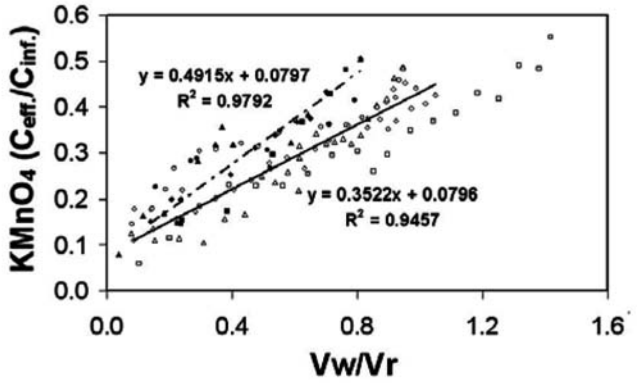

Fig. 4. Average values of the natural organic matter outlet (III) and inlet (II) concentrations ratio as a function of the volume of the treated water per resin volume unit (V_w/V_r) in acid and alkaline media. (◆): acid cycles average; (■): acid cycle 1; (▲): acid cycle 2; (●): acid cycle 3; (◇): alkaline acids average; (□): alkaline cycle 1; (△): alkaline cycle 2; (○): alkaline cycle 3;: linear (alkaline processes average);: linear (acid processes average).

Fig. 7 presents the ratio of the water UV extinction (at 254 nm) measured in the samples obtained from the outlet and the inlet points of the column S, as a function of the ratio of natural organic matter concentrations at the outlet and the inlet points of the column S, both for the acid and for the alkaline media.

4. Discussion

In order to understand the chemistry of hydrogen-sulphide removal, it was necessary to analyse the chemistry of the natural organic matter removal at the anion resin in the column S.

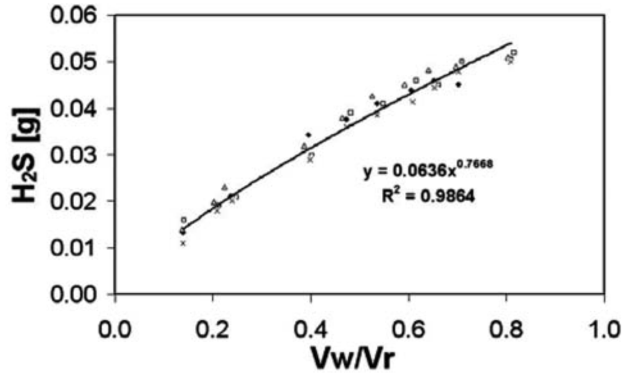

Fig. 6. Average values of cumulative quantity of the removed hydrogen-sulphide as a function of the volume of the treated water (V_w/V_r) in acid medium. (◆): average H_2S; (□): H_2S cycle 1; (△): H_2S cycle 2; (x): H_2S cycle 3;: power (average H_2S).

At equilibrium a relationship exists between the concentration of the species in solution, C, and the ''concentration'' of the same species in the adsorbed state X/M (i.e., the amount of species adsorbed per unit mass of adsorbent) [35–38]. The adsorption equilibrium relates X/M to C. The equilibrium is a function of the temperature. The adsorption equilibrium relationship obtained at a given temperature is typically referred to as *adsorption isotherm*, i.e.:

$$(X/M) = f(C_e), \tag{1}$$

where X is the mass of the adsorbate; M is the mass of the adsorbent (X/M *is* equilibrium concentration of

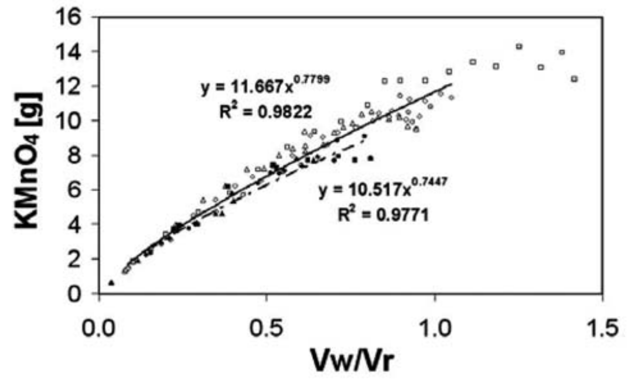

Fig. 5. Average values of cumulative quantities of adsorbed natural organic matter as a function of the volume of water treated (V_w/V_r) in acid and alkaline media. (◆): acid cycles average; (■): acid cycle 1; (▲): acid cycle 2; (●): acid cycle 3; (◇): alkaline acids average; (□): alkaline cycle 1; (△): alkaline cycle 2; (○): alkaline cycle 3;: linear (alkaline processes average);: linear (acid processes average).

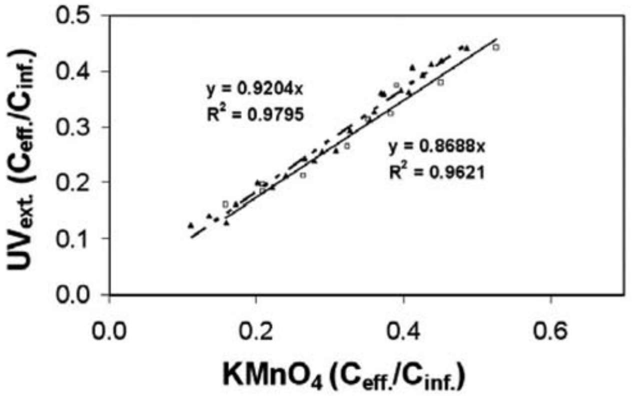

Fig. 7. Dependence of the average values UV water extinction ratio at the outlet (III) and the inlet points (II) of the column S on the natural organic matter concentration ratio for the alkaline process; see same water in the acid and the alkaline media. (■): acid process; (△): linear (acid process);: linear (alkaline process).

adsorbable species in solid adsorbent); C_e is an adsorbate equilibrium concentration in the solution. Since no assumption of reversible adsorption and desorption of the adsorbate molecules can be made and adsorption of mixtures of compounds on the resin is very probable, in our case the removal of the adsorbate from the solution can be described by Freundlich's adsorption isotherm:

$$(X/M) = kC_e{}^{1/n}, \tag{2}$$

where k and n are specific adsorption coefficients (k is related to the capacity of the adsorbent, and $1/n$ is a function of the strength of adsorption).

To determine the relationship between the concentration of an adsorbate in solution (C) and the amount of adsorbate adsorbed per unit mass of adsorbent (X/M) one can proceed with the solution being sampled and analyzed for the adsorbate.

A mass balance for the adsorbate in the system is:

$$V(C_0 - C) = M\left[(X/M) - (X/M)_0\right] \tag{3}$$

from which a relationship between a value of C and the corresponding equilibrium value of X/M can be established. $C_0 = C_{\mathrm{inf}}$ = initial adsorbate concentration in solution (mg/L); $(X/M)_0 = (X/M)_{\mathrm{inf}}$ initial amount of adsorbate per unit mass of adsorbent (mg/g resin); M = mass of resin (g) and V = volume of the water in contact with the adsorbent–the resin (L).

In our case, virgin resin was used to determine equilibrium relationship: $(X/M)_0 = 0$, and at the beginning of the experiment, i.e. for the time $t = 0$:

$$(X/M)_t = V/M(C_{\mathrm{inf}} - C_t). \tag{4}$$

Note that V/M is the ratio between the volume of the water treated in contact with the resin and the mass of the resin, i.e., the value of the bed volume (B) and at any time t:

$$C_t = C_{\mathrm{inf}} - (M/V)\left[(X/M)_t\right]. \tag{5}$$

This equation represents an *operating line* (from a mass balance) for the system. If the time elapsed is long enough for equilibrium to be established then this equation becomes:

$$C_{\mathrm{eq}} = C_{\mathrm{eff}} = C_{\mathrm{inf}} - (M/V)\left[(X/M)_t\right]. \tag{6}$$

In our case the long enough time is the time elapsed from the beginning of the contact of the raw water (starting concentration of the adsorbate C_{int}) with the resin, and the time when the concentration of the adsorbate in the treated water reaches maximum allowed value, C_{eff} [39,40].

Using Eq. (1) and Eq. (6) one can write:

$$(C_{\mathrm{inf}} - C_{\mathrm{eff}})V/M = X/M = kC_{\mathrm{eff}}{}^{1/n}, \tag{7}$$

where V/M is V_w/V_r = bed volume.

The adsorption is affected by the pH of the solution [22], therefore the experiments were conducted in both alkaline and acid media. The values presented in Fig. 4 show that the specific adsorption is approximately equal in both alkaline and acid media (see the intercepts). However, the slopes of the linear approximations differ. The slope is higher in the acid medium. This points to a higher quality adsorption represented in a larger quantity of adsorbed natural organic matter per unit of resin volume. This simultaneously means that the resin will become saturated faster in the acid medium. Therefore, the volume of the processed water will be smaller compared to the alkaline medium, as indicated by a steeper slope of the straight line in Fig. 4. There is also a possibility that alongside the natural organic matter slow adsorption process an ion exchange process is carried out, the latter being a faster one.

The straight line, representing the organic matter adsorption in alkaline medium (Fig. 4), shows a lower slope. This means a smaller quantity of organic matter adsorbed from the same quantity of water in alkaline than in acid medium, and therefore a larger quantity of processed water in this medium.

The saturation level of the resin is defined by the concentration of 8 mg L^{-1} $KMnO_4$ in effluent water. This value is also the maximum allowable concentration (MAC) in drinking water. Using this criterion, it was found that 669 dm^3 of water per resin dm^3 were processed in the acid medium and as much as 934 dm^3 were processed in the alkaline one before the resin saturation level was reached. The average values lines have revealed that at the very beginning of the work cycle of the column S the organic matter concentration reduction was 92%, declining to an average of 60% towards the end of the working period (Fig. 4). The cumulative effect of natural organic matter removal up to the resin saturation level presented by average values in Fig. 5 shows that the adsorption is more intensive in the acid medium. This was reflected in the slope of the average values line. In the acid medium the resin adsorbed 7.64 g L^{-1} natural organic matter, which amounts to 11.4 mg g^{-1} of the resin. In the alkaline medium this mass was 11.24 g L^{-1}, which equals 16.77 mg g^{-1} of the resin. The technical data provided by the manufacturer (Lanxess, Germany) state that the resin can adsorb 12 mg of organic matter (expressed in the consumption of $KMnO_4$), which would be 17.9 mg g^{-1} of the resin.

The obtained average values lines (Fig. 4) show that the total adsorption in the alkaline medium approximates the above stated quantity. In the acid medium, however, a lesser quantity of organic matter is adsorbed up to the resin saturation point. This pointed to the possibility that it is not only the natural organic matter adsorption process that goes on in the acid medium.

The dissociation equation:

$$H_2S \leftrightarrow H^+ + HS^- \tag{8}$$

and the diagram of the hydrogen-sulphide dissociation as a function of pH shows that in the range of $pH < 6.9$ the dissociation reaction tends to move to the left, to the formation of H_2S [41]. With pH value exceeding 6.9, the dissociation tends to move to the right, increasing the HS^- ions concentration.

During aeration process H_2S would leave water, hence the hydrogen-sulphide concentration in the water had do be determined immediately upon sampling. The average values of the hydrogen-sulphide concentration at the inlet port of the column S, and at the outlet point of the column are presented in Fig. 2. This shows that in the pH range 6.6–7.2 as much as 60% of hydrogen-sulphide concentration of the inflow water was removed in the column S. A further increase in pH value to 7.5 caused a decrease in the hydrogen-sulphide removal. At pH >7.5 the removal of hydrogen-sulphide is minimal. At $pH > 7.9$ the HS^- ion concentrations measured were larger in the effluent than in the influent water. This can be explained by the dissociation equation moving even farther to the right due to the additional pH increase in the water passing through the scavenger filter. Increased, or approximately equal, concentration of HS^- at the outlet port compared to the inlet port was observed (see Fig. 3).

Looking at Fig. 6, which shows the average values line for a cumulative removal of hydrogen-sulphide, one can come to a conclusion that this line closely follows that of the natural organic matter adsorption in the acid medium. The analyses have show that there is no hydrogen-sulphide adsorption in the alkaline medium, and the explanation for the processes in the acid medium can be found in the chemistry of the reactions on the active group of resin. In this case, a free electron pair lies on the nitrogen atom in the tertiary amide group. Due to the dispersion of charge density in this group a net positive charge appears which allows for the adsorption and ion exchange processes to proceed. This group is simultaneously a weak alkali that can react with a weak acid, which in our case is hydrogen-sulphide. Products of these ion exchange reactions cover part of the adsorption surface intended for the natural organic matter adsorption. The result was a faster saturation of resin, but also an increased removal of hydrogen-sulphide in the gaseous form.

In the alkaline medium, however, there is a surplus of HS^- ions and OH^- ions. In their competition to pair with the active resin groups the advantage is on the side of the OH^- ion, which forms a bond faster. It is for this reason that hydrogen-sulphide was not removed in the alkaline medium, however, a larger quantity of natural organic matter was. This is further supported by the fact that upon dissociation of humic and fulminic acids in water, the competition for winning the active patches on the resin surface among their anions and the OH^- groups is in favour of the acidic anions.

Starting from these hypotheses, the values of the UV extinction of effluent and influent water ratio and the ratio of concentration of natural organic matter in the effluent and influent water were analysed (see Fig. 7). It shows that in both the acid and the alkaline media the natural organic matter concentrations and the UV extinction in the water are linearly correlated, with negligible deviations. The above stated hypotheses are further supported by Fig. 8 which shows that the ratio of UV extinction of effluent and influent water in the acid medium, in relation to the quantity of water treated, is higher compared to that in the alkaline medium.

Hence, there is something else that is removed on the resin in the acid medium, which does not influence the UV extinction in the way natural organic matter does. The analysis of the cumulative curves also shows

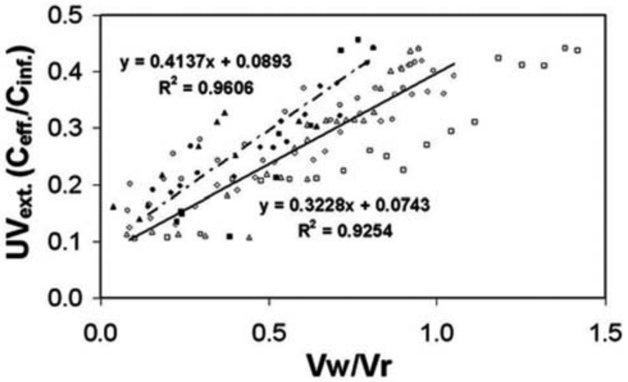

Fig. 8. Average values of the water UV extinction at the outlet (III) and the inlet (II) points of the column S, as a function of the volume of the water treated (V_w/V_r) in the acid and the alkaline media. (◆): acid cycles average; (■): acid cycle 1; (▲): acid cycle 2; (●): acid cycle 3; (◆): alkaline acids average; (□): alkaline cycle 1; (▲): alkaline cycle 2, (○): alkaline cycle 3;: linear (alkaline processes average);: linear (acid processes average).

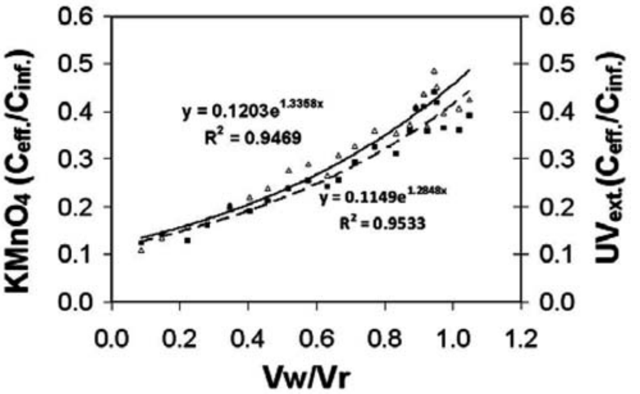

Fig. 9. Average values of the UV extinction ratio and the ratio of the natural organic matter concentrations at the outlet (III) and the inlet points (II) of the column S, as a function of the volume of the water treated ($V_\mathrm{w}/V_\mathrm{r}$) in the alkaline medium. (▲): $C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ $\mathrm{KMnO_4}$; (■): $C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ UV;: Expon. ($C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ $\mathrm{KMnO_4}$);: Expon. ($C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ UV).

that it is hydrogen-sulphide. This is supported by Figs. 9 and 10, which present the comparison of the ratio (percentage) of natural organic matter removal and the ratio of the UV extinction values for the effluent and influent water ratios in the alkaline and the acid media, both as a function of the quantity of water treated (BV).

Fig. 10 shows that the value of the UV extinction ratio in the acid medium is considerably lower compared to the ratio of natural organic matter removed for the same BV. In the alkaline medium (Fig. 9), the difference between the value of the UV extinction ratio and that of the percentage of the natural organic matter removed for the same BV is considerably smaller than that shown in Fig. 10.

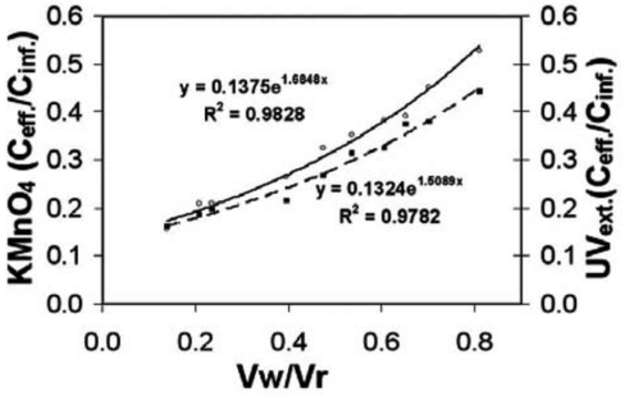

Fig. 10. Average values of the UV extinction ratio and the ratio of the natural organic matter concentrations at the outlet (III) and the inlet points (II) of the column S, as a function of the volume of the water treated ($V_\mathrm{w}/V_\mathrm{r}$) in the acid medium. (○): $C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ $\mathrm{KMnO_4}$; (■): $C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ UV;: Expon. ($C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ $\mathrm{KMnO_4}$);: Expon. ($C_{\mathrm{eff.}}/C_{\mathrm{inf.}}$ UV).

The analysis of the results obtained by measuring the redox potential has shown that the redox potential of raw water ranged from –160 to –31 mV vs. N.H.E., that of the water leaving the column S ranged from –74 to 60 mV vs. N.H.E., whereas after the column with Filtersorb FMH it ranged from 56 to 272 mV vs. N.H.E. In the alkaline medium, the redox potential after the column S ranged from –74 to 19 mV vs. N.H.E., whereas in the acid medium it ranged from 13 to 60 mV vs. N.H.E. The measurements of the redox potential after the column F showed the values from 100 to 272 mV vs. N.H.E. for the acid medium, and from 56 to 166 mV vs. N.H.E. for the alkaline medium. This suggests that hydrogen-sulphide is removed in the acid medium and that the water from the reduction state passes into the oxidation one.

Following the treatment in the column S, the remaining hydrogen-sulphide in the water (40% in the acid medium and about 100% in the alkaline medium) is successfully removed in the column F. Furthermore, it was established that the water redox potential values at the outlet of the column F were positive vs. N.H.E. in the case when the column S functioned in the acid as well as in the alkaline media. This allows for the hypothesis that dissolved hydrogen-sulphide contributes to the negative values of the raw water redox potential. In the acid medium the column has a considerably longer working cycle due to the quantity of the hydrogen-sulphide removed in the previous segment (the column S with macro porous resin).

5. Conclusions

The research into the removal of natural organic matter from specific ground waters on alkaline macroporous resin shows that the quantities of natural organic matter removal differ in relation to the pH of the water, which is reflected in the volume of the purified water. The alkaline medium allows for a larger quantity of water to be purified.

The removal of hydrogen-sulphide was planned to be performed in the column F placed after the scavenger filter S. However, the experimental results have shown that the hydrogen-sulphide can also be removed on the macroporous resin scavenger filter S, and that its removal depends on the conditions under which the natural organic matter is removed. Therefore, the column F was used only for an additional removal of the hydrogen-sulphide.

The experiments conducted have shown that hydrogen-sulphide was efficiently removed in an acid medium (pH range of 6.6–7.2) of the natural organic matter removal column (S).The research has shown that the removal of hydrogen-sulphide on macroporous resin is directly preconditioned by the pH of water. In the acid medium, and up to the pH 7.2, the hydrogen-sulphide is being removed intensively, whereas in the alkaline medium the hydrogen-sulphide is not removed on macroporous resin, which is the information of importance when designing the technology of water purification.

The hydrogen-sulphide that is not removed in the natural organic matter removal column S is successfully removed on the Filtersorb FMH up to the values lower than the detection limit, in both the acid and alkaline media.

The correlation between the UV extinction at 254 nm and the concentration of natural organic matter in the water is a valid indicator for tracking the saturation of the alkaline macroporous resin for natural organic matter removal in the water treatment plants. The determination of the resin saturation level on the basis of the potassium-permanganate consumption in effluent water is a slower and a more demanding analysis, and measuring of UV extinction can be performed on line in the water preparation processes.

Acknowledgements

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