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## The pH measurement with glass electrode in an electromagnetic field

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**Abstract:** Measurements of pH values of buffer solutions (pH 4.0, 7.0 and 10.0) and distilled water were performed with a glass electrode in an electromagnetic field in the frequency interval of 10–200 MHz and an output power of dispersed and reflected electromagnetic radiation of 0.01–3 W. In all the cases, a reduction of pH values occurred, *i.e.*, a “recorded pH value” was obtained. The reduction appeared within the applied frequency interval, reaching extreme values at specific frequencies. The reduction of the pH values increased with the radiation power and depended of the solution buffer capacity. The effect of electromagnetic field on pH value change was exerted dominantly through the influence on glass electrodes.

**Keywords:** recorded pH value; frequency; power.

### INTRODUCTION

There are data in the literature on the influence of high frequency electromagnetic fields on various systems, causing changes of certain parameters of the systems. In stripping voltammetry, the anode peak currents of Cd(II), Zn(II), Pb(II) and Mn(II) are changed in the frequency range of 0–200 MHz.<sup>1</sup> In solutions for reverse voltammetry that contain *n*-butanol, the peak currents of Cd(II), Pb(II) and Zn(II) were increased due to *n*-butanol desorption from the electrode<sup>2</sup> as well as to the influence of the electromagnetic field. A radiofrequency electromagnetic field caused the disassembly of water molecules in water vapor bubbles.<sup>3</sup> A high frequency electromagnetic field (2450 MHz) is phytotoxic<sup>4</sup> and enabled the suppression of weeds.<sup>5</sup> Electromagnetic fields changed the critical micelle content and the values of thermodynamic functions in a solution of sodium dodecyl sulfate<sup>6</sup> at frequencies of 60–100 MHz. Investigations of the

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influence of strong electromagnetic fields formed around long-distance power lines with voltage interval 66,000–220,000 V on plants, significantly changed the fertility and production of pollen grain,<sup>7</sup> along with other changes. It was found that high frequency magnetic fields of 30–200 MHz affected the adsorption characteristics of inorganic surface-active substances.<sup>8</sup> Water dissociation was also investigated in a radiofrequency electromagnetic field (13.56 MHz).<sup>9</sup>

Previous investigations indicated that variations of both the frequency<sup>10</sup> and the field power<sup>11</sup> led to changes in the recorded pH values when a glass electrode was used. Since pH measurement with this electrode currently prevails, better knowledge of the influence a high frequency electromagnetic field on these measurements is necessary.

#### EXPERIMENTAL

The solution pH was measured with an Iskra MA 5730 pH-meter with electronics without radio lamps. Three combined glass electrodes (consisting of both glass and reference electrodes) as well as two glass and two reference electrodes used separately were applied in these measurements. The glass electrodes (five) were produced by five different manufacturers and differed in previous usage duration.

Three standard buffer solutions (Entech Instruments), with pH 4.0, 7.0 and 10.0 (at 25 °C) were used. For diluting the buffer solutions, when necessary, distilled water was used, always from the same batch. The pH of the water was also measured.

For the measurements of solution pH values, with the both electrode types, a glass cell (Fig. 1) was used. The part of the cell (1) is in an electromagnetic field, spreading between two copper plaques (2a and 2b), dimension 38 mm×20 mm, connected to an electromagnetic field source. The second part of the cell (1a) was not in the electromagnetic field. The diameters of the cylindrical cell parts (1 and 1a) were 20 mm and the heights were 80 mm.

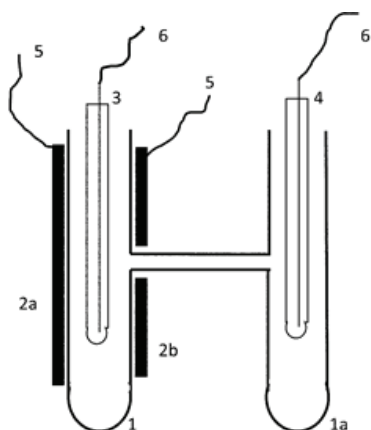


Fig. 1. The cell for the measurement of the solution pH in an electromagnetic field; 1) the cell part in the electromagnetic field; 1a) the cell part out of the electromagnetic field; 2a) and 2b) copper plaques; 3) the electrode in the electromagnetic field; 4) the electrode out of the electromagnetic field; 5) connecting cables to the electromagnetic field source; 6) cables for the connection of the electrodes to the pH-meter.

### *The electromagnetic field production*

To obtain electromagnetic field in the radiofrequency (RF) region, with variable frequency and variable output power, an appropriate device was designed. It consisted of a signal generator and an amplifier.

The signal generator Instek GEG450B yields a sinusoidal voltage. The output power is up to 300  $\mu$ W. The frequency and amplitude of the output voltage may be adjusted within the range of 0.1–150 MHz.

To amplify the signal power from the signal generator, a signal amplifier was constructed. Its basic purpose was to amplify by a constant factor (10,000 times) the signal coming from signal generator to the amplifier input and to conduct it to the amplifier output where from it is transferred to the cell metal plaques producing thus an electromagnetic field between them.

Details related to measuring system and procedure are described in Supplementary material to this paper.

## RESULTS AND DISCUSSION

The “recorded pH values” of the buffer solution of pH 7.0 in dependence on the frequency of the electromagnetic field from three subsequent measurements with separate electrodes (the glass and the reference one) are presented in Fig. 2. A change of the “recorded pH values” with the change of frequency only occurred when the glass electrode was in the electromagnetic field, with the largest shift, which is the curve minimum, at 117 MHz (curve 2) and when both electrodes were in the electromagnetic field with the largest shift at 122 MHz (curve 1). The shift was more significant when only the glass electrode was in the electromagnetic field. The “recorded pH values” of the solution did not change when only the reference electrode was in the field (curve 3). Using the combined electrode in the same solution, the characteristic difference between the “recorded pH values” occurred (Fig. 2, curve 4), with the largest shift at a field frequency of 95 MHz.

In all cases when a glass electrode was in the electromagnetic field, some of the observed “recorded pH values” of the solution were less than the actual pH value. The results undoubtedly indicate that an electromagnetic field exerts an influence on a glass electrode.

The characteristics of the curves showing the dependence of the “recorded pH values” of the solution on the frequency of the electromagnetic field include a decrease in the “recorded pH values” within a certain frequency range, which leads to the formation of a decrease band with a minimum at certain frequency, *i.e.*, a spectrum of the “recorded pH values” is formed.

Analogous measurements using pH 7.0 buffer solutions were performed with four electrodes with different duration of prior usage, produced by different manufacturers, three of which were combined and two were only glass electrodes. In all these cases, the same curves types as in the Fig. 2 were obtained, with minimums at frequencies 95, 117, 122 and 135 MHz. The “recorded pH

values” of the solution within the range of variation were always lower than 7.0 with the extreme decrease to pH 4.0.

The same measurements were performed with the pH 4.0 buffer solution as well as and distilled water using the combined electrode. The obtained curves were of the same type as with the pH 7.0 buffer, *i.e.*, in all cases, spectra of the “recorded pH values” were formed.

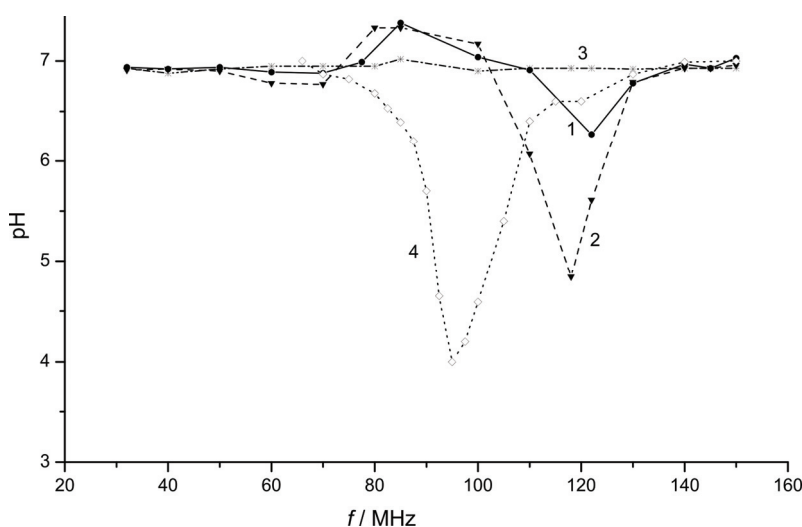


Fig. 2. Changes of the “recorded pH values” of the buffer solution with electromagnetic field frequency, when 1) both electrodes, 2) glass electrode, 3) reference electrode and 4) combined electrode were in the solution (buffer solution, pH 7.0).

Using the same combined glass electrode, “recorded pH values” spectra of the three buffer solutions with pH value 4.0, 7.0 and 10.0 were measured. In all cases, the same type of spectra was obtained (Fig. S-3 of the Supplementary material). These results indicate that the electromagnetic field has a basic influence on the “recorded pH values”, *i.e.*, the influence of this field on the glass electrode surface causes an electrode potential change and the formation of a “recorded pH values”.

Considering that electromagnetic fields may have different intensities, the curves are presented in Fig. 3 showing the changes of the “recorded pH values” of the solution in dependence of the output power (W) of the dispersed (curve 1) and reflected (curve 2) radiation, at a constant electromagnetic field frequency of 135 MHz, for the pH 7.0 buffer solution with a glass electrode in the electromagnetic field. The obtained results show that the intensity of the radiation had a significant influence on the changes of the recorded solution pH values. Similar results were obtained with the other glass electrodes, showing, however that the extent of the changes of the “recorded pH values” of solution depended also on

the type and the duration of previous usage of the glass electrode, which has already been mentioned. The same types of curves were obtained when distilled water was used at a constant frequency of 120 MHz.

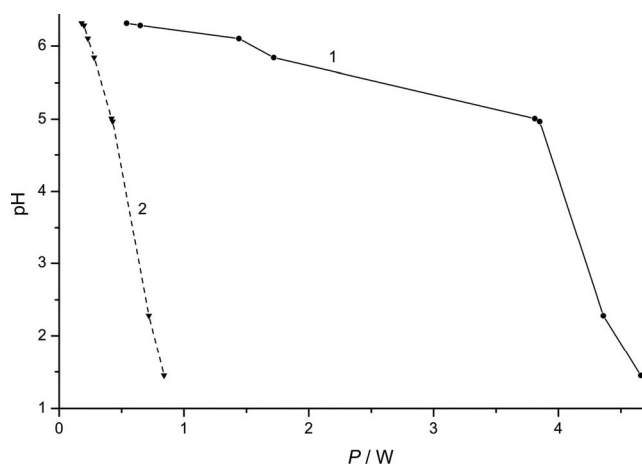


Fig. 3. Changes of the “recorded pH values” of a buffer solution (pH 7.0) with signal output power, 1) dispersed ray and 2) reflected ray, the field frequency was constant at 135 MHz.

An electromagnetic field may affect the “recorded pH values” of the solution, through the cables that connect the electrodes with the pH-meter, if they are not protected against this influence. An investigation was performed by fixing 1, 2 or 3 ferrite rings on the connecting cables of the combined, glass and a reference electrode, positioned at the middle and the ends of the cable. The curves of the changes of the “recorded pH values” in buffer pH 7.0 solution with variation of the electromagnetic field frequency both with and without ferrite rings on the cables are presented in Fig. 4. These curves are the confirmation that the achievement of the “recorded pH values” could be partly the consequence electromagnetic field activity on the connecting cable. The shape of the spectrum of the “recorded pH values” was not changed, which means that this type of electromagnetic field influence does not act on the electrodes. Moreover, this shows that the connecting cables should be protected against electromagnetic fields before the measurement of the pH of a solution. Similar curves were obtained with the pH 4.0 buffer solution.

The determination of “recorded pH values” of bi-distilled water was performed at varying the electromagnetic field frequency, using the combined glass electrode. The curves obtained in two independent measurements of two water samples are presented in Fig. 5. The obtained shape of the spectra of the water “recorded pH values” was the same as with the buffer solutions, with a minimum at 130 MHz. These results confirm that the occurrence of such “recorded pH

values” is the consequence of the influence of an electromagnetic field on the glass electrode.

In this case, the lowest recorded pH value of bi-distilled water was lower than with buffer solutions, which shows that the solution components also affect the achievement of the solution recorded pH value and its final value.

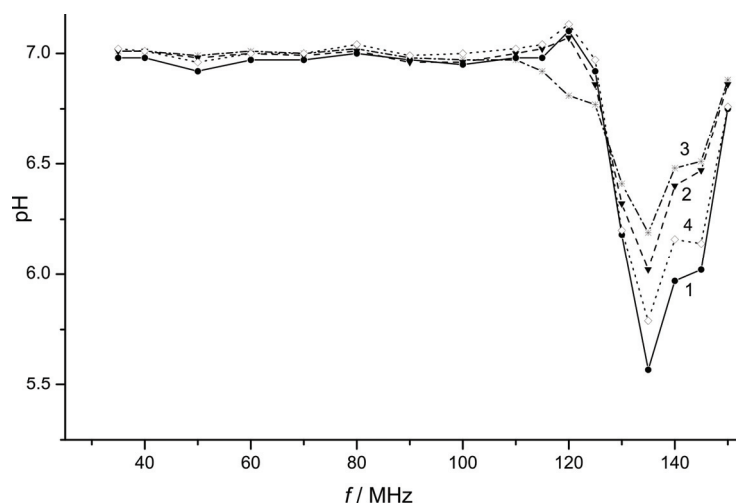


Fig. 4. Change of the “recorded pH values” of a pH 7.0 buffer solution with electromagnetic field frequency; 1) without a ferrite ring on the connecting cables and with 3 ferrite rings on the connecting cable of: 2) a glass electrode, 3) both electrodes, 4) the reference electrode.

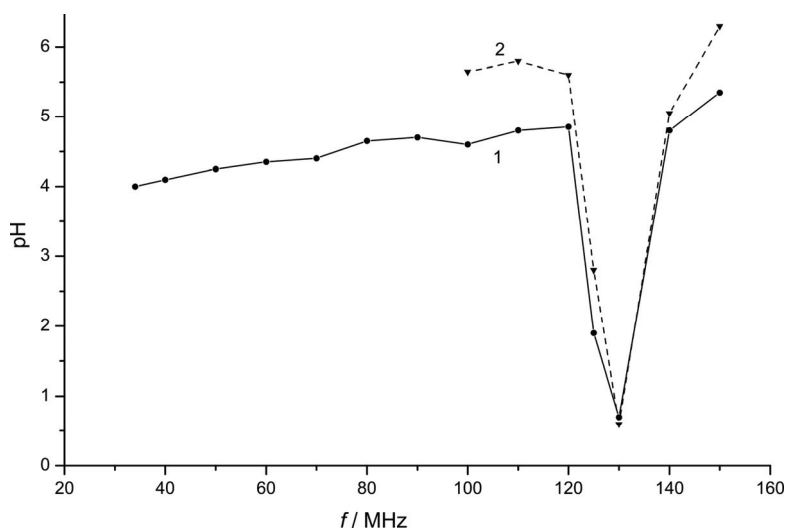


Fig. 5. Change of the “recorded pH values” of distilled water (pH 6.0) with electromagnetic field frequency. 1) First water sample and 2) second water sample.

## CONCLUSIONS

Based on the obtained results, it may be concluded that an electromagnetic field did influence the system glass electrode–buffer solution, inducing a “recorded pH values”. This pH value change did not arise if only the reference electrode was in the electromagnetic field, *i.e.*, the electromagnetic field either did not influence the reference electrode or that the influence was very weak and lower than the measurement error. This conclusion applies to the frequency interval and the output power interval of the direct and reflected field used in this study. The presented results enabled the conclusion that when a combined glass electrode was used, the electromagnetic field induced a “recorded pH value” exclusively by its effect on the glass electrode. This conclusion is supported by the fact that the spectrum of the “recorded pH value” was variable, *i.e.*, it was dependent on the age and previous use of the glass electrode.

The formation of the “recorded pH value” of a solution during measurement in an electromagnetic field may be not only the consequence of the influence of the electromagnetic field on the glass electrode but also of the pH value of the solution being measured. However, when the same buffer solution was used for a series of measurements with different glass electrodes, the obtained “recorded pH values” were different, as well as the corresponding spectra, which indicates that it is the effect of electromagnetic field on the glass electrode that is dominant, and not the effect on the solution.

Furthermore, when using the same glass electrode was used in three different buffer solutions with pH values 4.0, 7.0 and 10.0, the same shape and position of maximal “recorded pH values” of the spectra were obtained. This leads to the conclusion that the appearance of “recorded pH values” is a consequence of a change of the adsorption characteristics of  $H^+$  ions on the surface of the glass electrode, which is in accordance with the finding<sup>9</sup> that an electromagnetic field changes the adsorption characteristics of surface-active substances.

If the influence of the electromagnetic field on the solution, *i.e.*, on the equilibrium processes in the solution, were the dominant one, the same “recorded pH value” would be obtained when using different glass electrodes, which was not found in the present study.

The influence of the electromagnetic field on the solution and the solvent cannot be excluded. This was confirmed by the appearance of “recorded pH values” for distilled water, which was within the range obtained for the buffer solutions. This is because the buffer capacity of water is negligible in comparison with the capacity of buffer solutions, *i.e.*, buffer solution capacity also affects the height of the “recorded pH value” peak.

The obtained results, *i.e.*, the influence of electromagnetic field on glass electrode and appearance of a “recorded pH value” indicate that during pH

measurements, an electromagnetic field should be excluded, *i.e.*, electromagnetic sources should be removed from the vicinity of the measuring space.

#### SUPPLEMENTARY MATERIAL

Details related to measuring system and procedure, as well as the data at different pH values, are available electronically at the pages of journal website: <http://www.shd.org.rs/JSCS/>, or from the corresponding author on request.

#### ИЗВОД

#### УТИЦАЈ ЕЛЕКТРОМАГНЕТНОГ ПОЉА НА МЕРЕЊЕ рН СТАКЛЕНОМ ЕЛЕКТРОДОМ

ДРАГАН С. ВЕСЕЛИНОВИЋ<sup>1</sup> и ЗОРАН ВЕЛИКИЋ<sup>2</sup>

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Мерена је рН вредност пуферских раствора (4,0; 7,0 и 10,0) и дестиловане воде са стакленом електродом у електромагнетном пољу у опсегу фреквенција од 10 до 200 MHz и излазној снази диспергованог и рефлектованог електромагнетног зрачења од 0,01 до 3 W, коришћењем конструисаног уређаја. У свим случајевима долази до снижења вредности рН, пуферских раствора и дестиловане воде, т.ј. до настајања "очитане вредности рН" зависно од фреквенције и снаге електромагнетног поља. До снижења вредности рН долази у одређеном опсегу фреквенција, са највећим снижењем при одређеној фреквенцији, тј. настаје спектар „очитаних вредности рН“. Снижење „очитане вредности рН“ повећава се са излазном снагом зрачења и зависи од пуферског капацитета раствора. Деловање електромагнетног поља на измену вредности рН је последица деловања овог поља преваасходно на стаклену электроду.

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