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Intensification of purification of solutions from ions of heavy metals in a magnetic field

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Abstract

Possibility to replace mechanical stirring by the magnetic field induced one was shown for considerable intensification of Cu (II) and Cr (VI) ion biosorption by the yeast *Saccharomyces cerevisiae 1968*. Combined method of metal ion recover, including Cu ion sorption by yeast Saccharomyces cerevisiae and Cu cementation on a surface of a steel matrix, is tested in case of magnetic field induced stirring. In case of purification from Cr (VI) ions, the combined method included Cr ion sorption by yeast Saccharomyces cerevisiae 1968 and Cr (VI) reduction in the presence of a steel matrix.

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At present wastewater purification from ions of heavy metals is one of the important problems. There are many methods of the wastewater treatment (including chemical, mechanical, physicochemical, biological etc.). Physicochemical methods attract more and more attention of researchers from many countries because they allow to intensify considerably the abrading process, to shorten the process time. Contamination of the purifying water by the accompanying chemicals is absent in the majority of such engineering procedures [1], i.e. the purified water is suitable for the repetitive utilization in manufacture. However, the methods require great consumption of expensive reagents and electricity charges [2]. As the practice shows, utilization of one of the methods (for example, chemical) is ineffective. In connection with multicomponent composition of wastewater of different manufactures, the necessity of creation of fundamentally new purification technologies appeared, i.e. combined purification methods.

Biosorption is one of the perspective methods of the wastewater purification from ions of heavy metals. Utilization of biosorbents of the heavy metals is an alternative to the existing methods of extraction of heavy metal ions from the effluents. However, biosorption should

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be technologically and economically competitive with the existing abrading processes. The yeast is potential biosorbents of metals. Wide range of heavy metal ions can be extracted from a solution combining with the cell membrane of the yeast. It is well known that different types of the yeast biomass can sorb ions of different heavy metals with different selectivity. It depends on structure of the cell membrane of yeast, composition of the purifying solution and preparatory biomass treatment [3]. Yeast can be uses as biosorbents to extract Cu (II) and Cr (VI) ions from the wastewater. The Cu (II) and Cr (VI) ions are among the most dangerous contaminants. Mechanical stirring is traditionally used to intensify biosorption of heavy metal ions. But in a number of cases, the magnetohydrodynamic stirring (MHDS) is more effective then the mechanical one for the chemical and biological applications [4]. For example, it is possible to create the Lagrange chaos (analogue of turbulence) at the very low Reynolds numbers [4].

In this work effectiveness of application of MHDS was studied in order to purify solutions from heavy metal ions such as Cu (II) and Cr (VI) by means of the combined methods including the biosorption by yeast *Saccharomyces cerevisiae 1968* as a treatment stage. In a combined method, the MHDS is realized in a constant magnetic field in the vicinity of a steel matrix, immersed into a solution with the biosorbents. The matrix consisted of 40 identical steel cylinders with diameters of 525 micrometers, with a length of 3000 micrometers. The cylinders were distributed uniformly in the container volume with the help of a nonmagnetic holder nonreacting with the solution. Cementation of copper and simultaneous biosorption takes place in case of extraction of Cu (II) in the presence of a steel matrix in a magnetic field. In case of Cr ion extraction, reduction of highly toxic Cr (VI) to the less dangerous Cr (III) is realized together with Cr (VI) extraction by means of biosorption in a magnetic field.

The yeast *Saccharomyces cerevisiae 1968* was cultivated on a mineral Rider medium of the following composition (g/l): $(NH_4)_2SO_4$ – 3,0; $MgSO_4$ – 0,7; NaCl – 0,5; K_2HPO – 0,1; KH_2PO_4 – 1,0; glucose – 10,0 and yeast autolysate – 1,0 in aerobic conditions at the temperature of 28°C. Yeast were cultivated in 250-ml Erlenmeyer's flasks on rocking-bars at 220 rotations per minute. Daily culture (the beginning of a stationary growth phase) was centrifugalized and washed twice by a sterile physiologic solution. Beforehand a magnetic field influence on yeast *Saccharomyces cerevisiae 1968* survival was investigated in the presence of a syeel matrix. An aqueous suspension of cells was used for this purpose. The cells were washed off 2 day's culture that was cultivated on an agar wort medium at 28°C. Glass container with a matrix was filled by the cell suspension with concentration 10^6 cells/ml. The container with a matrix and yeast suspension was exposed to the 240 kA/m constant magnetic field influence during 30 minutes. The sampling was made within the certain periods of time (5, 10, 15, 20, 30 minutes). After certain dilution, the samples were seeded on the wort medium. Survival of the yeast *Saccharomyces cerevisiae 1968* was calculated 3 days later.

The survival curve has a sigmoid form (fig. 1). At 5^{th} minute of a magnetic field influence, negligible inactivation of the yeast cells was observed. Then the curve turns into exponential part of inactivation where the survival amounts to 30% in 20 minutes. After that, the slope of the curve decreases abruptly. It can point to the presence of residuary cells resistant to a magnetic field.

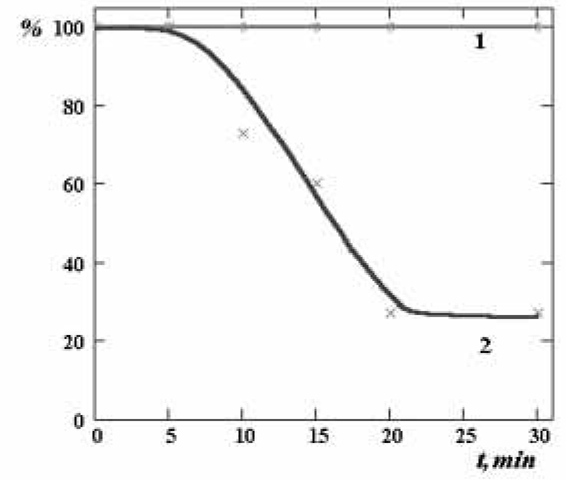

Fig. 1 Survival of the yeast cells *S. Cerevisiae 1968:* 1 – control (survival without a magnetic field); 2 – survival of the yeast, exposed to the 240 kA/m constant magnetic field influence in the presence of a steel matrix.

Solutions of $CuSO_4$ (with a concentration of 50 mg/l) and K_2CrO_4 (with a concentration of 100 mg/l and pH 2) containing the yeast *Saccharomyces cerevisiae 1968* in a quantity of 0.1 g of bone-dry substance in 100 ml were prepared in order to investigate effectiveness of MHD mixing during purification of a solution from Cu (II) and Cr (VI) ions by means of the combined method. The glass containers were filled with the solutions. The container with the matrix was exposed to the influence of the 240 kA/m constant magnetic field within 1 – 60 minutes. The value of pH was chosen to be equal to 2 with the help of nitric acid. Control experiments were made with the same solutions and matrix without yeast in a magnetic field and without a magnetic field. After the experiments the solution was separated from the yeast cells by means of filtration. The residual quantity of Cu (II) ions in the solution of $CuSO_4$ was determined with the help of the atomic absorptive spectrophotometer C-115-M1. The residual quantity of Cr (VI) ions in the solution of K_2CrO_4 was determined with the help of the diphenylcarbazide method.

The results of the investigation have shown that it is possible to extract 70% and 92% of Cu (II) ions by means of the combined method in a magnetic field for 5 minutes and 1 hour correspondingly. 45.7% and 99% of Cu (II) ions can be extracted without yeast in a magnetic field during 5 minutes and 1 hour correspondingly. The similar data amounts to 36.7% and 93% without a magnetic field and without yeast (fig. 2).

The combined method as well as the Cr (VI) reduction process only facilitated extraction of 100% of Cr (VI) ions in a solution of K_2CrO_4 in a magnetic field during 1 minute. Control experiments have shown that about 89% and 100% of Cr (VI) ions could be extracted by means of the combined method but without a magnetic field during 1 minute and during 5 minutes correspondingly. It was possible to extract 100% of Cr (VI) ions without a magnetic field and without yeast for 10 minutes due to the reduction process only.

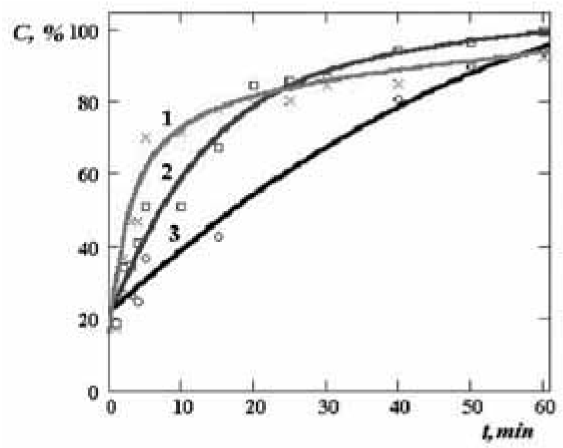

Fig. 2 Extraction of Cu (II) ions from a solution by means of the combined method (1) in a magnetic field, with the help of the cementation process in a magnetic field (2) and with the help of the cementation process without a magnetic field (3).

Our previous investigation has shown that the effectiveness of MHDS depends on an area of metallic matrix surface. As well as the steel matrix, described above, represented a model matrix we carried out investigation of Cr (VI) reduction where a steel chip with the diameter of 0.2 mm was taken as a matrix (weight percentage in the range from 2 up to 18% relative to the quantity of the purifying solution). Steel chip is widely used as a cheap matrix in a high gradient magnetic filtration (separation) [6]. The container with the chip was placed in the 240 kA/m constant magnetic field for 1 minute. The results have shown that the solution was purified from 100% of Cr (VI) ions if the weight percentage of chip amounted to 10% in a magnetic field and 18% without a magnetic field (fig. 3).

The experiments utilizing traditional mechanical stirring under the same conditions were carried out at the Institute for Microbiology and Virology NAS of Ukraine. As a result of the control experiments it was shown that the yeast *Saccharomyces cerevisiae 1968* sorbed 37% of Cu (II) and 15% of Cr (VI) during 3 hours.

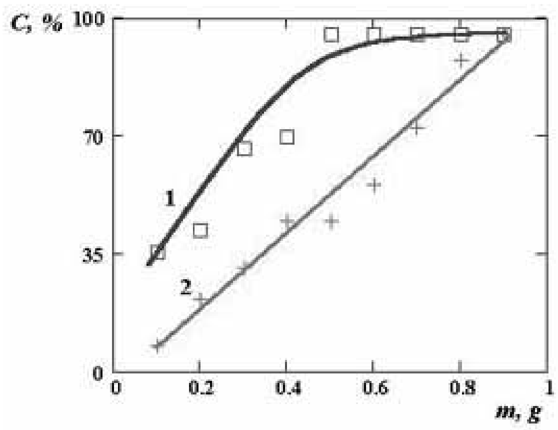

Fig. 3 Dependence of Cr (VI) ion reduction on weight percentage of the chip matrix in a solution (1) in a magnetic field, (2) without a magnetic field.

It was shown in the paper that a magnetic field application intensifies considerably biosorption of Cu (II) and Cr (VI) ions by the yeast *Saccharomyces cerevisiae 1968* in the presence of a steel matrix. It is especially urgent for the galvanic manufacture where the multi-stage purification, including different methods, is used. In the paper, considerable intensification of the abrading process is proposed with the help of a magnetic field application for such processes as biosorption, cementation and reduction due to MHDS effect in the vicinity of a steel matrix.

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