EFFECT OF SALINITY ON PARAMETERS AND EFFICIENCY OF NOBLE METALS ADSORPTION PROCESS SUPPORTED BY MICROWAVES

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Abstarct - Many industrial companies generate waste solutions containing a trace of noble metals. The recovery of these metals is essential not only for economic but also for ecological reasons. Activated carbon adsorption is a low-cost process, making it possible to recover metals from dilute aqueous solutions. Modification of the process by microwaves will increase the efficiency of the process. In this paper, the recovery of noble metal ions by adsorption on the surface of active carbon was proposed. In addition, the process was modified by microwave heating, which made it possible to effectively increase the temperature and pressure inside the reactor. As a result, a high degree of adsorption of noble metal ions was achieved, and the ions were reduced to a metallic form.

Keywords - Activated Carbon, Adsorption, Microwave Heating, Noble Metals Recovery

I. INTRODUCTION

Many industrial companies generate waste containing noble metals, for example, metal production and recycling plants [1], companies dealing with the recovery of metals from waste electrical and electronic equipment [2], [3], and plants processing spent catalysts [4], [5]. The recovery of precious metals, i.e., gold, platinum, and palladium, is important not only for economic but also for ecological reasons [6]. It is known that the compounds of these metals exhibit toxic and, in some cases also, mutagenic properties. Therefore, the recovery of these metals must be carried out with particular care for the natural environment. From the point of view of the profitability of the conducted process, the recovery should be carried out in the cheapest possible way, allowing high efficiency with low expenditure, both energy, and material. Moreover, the waste obtained as a result of the process should be recyclable in an equally simple and safe way.

The recycling of precious metals is most often carried out by hydrometallurgical recovery of these metal ions from aqueous and organic solutions by methods like, for example, liquid-liquid extraction [7] or adsorption, including biosorption [8]–[10] or adsorption on nanomaterials [11]. One of the most preferred methods is to adsorb these ions. In practice, adsorbents such as ion resins [12]–[18] are used, these materials work well in the selective recovery of individual metals, but they are often expensive and unfavorable to the environment. As a cheap, easily available, and environmentally friendly material, activated carbon is used as an adsorbent [19]–[23]. The microwaves are used in hydrometallurgical processes, for example, in the case of microwave-assisted leaching [24], for preparation of adsorbent [25], or during adsorption of organic ions [26] on activated carbon. In this work, an innovative approach is to carry out the process of adsorption of metal ions on the surface of activated carbon in microwaves.

II. EXPERIMENTAL

For the experimental work, reagents of analytical purity from ChemLand, Poland, were used. Chlorides of noble metals and deionized water (>18 MΩ, Polwater, Poland) were used to prepare the solutions. Tests for the adsorption of Au, Pt, Pd, and Rh metal ions were performed at higher pressure (42-45 bar) and higher temperature (240-250 °C). Adsorption was carried out in the ERTEC Magnum II microwave mineralizer with a reactor made of PTFE. The mineralizer is equipped with temperature and pressure sensors inside the reactor. Granular activated carbon (AC) (CAS: 7440-44-0) was used as the adsorbent. Each time, a new portion of the solution in the amount of 25 ml was used in the experiments.

The efficiency of the adsorption process was determined by changing the concentration in the solution before and after the process. The concentration of Rh, Pt, Pd, and Au ions was measured using an Agilent MP-AES 4200 emission spectrometer with microwave-induced plasma. Phase analysis of the adsorbent was performed using the XRD method (Rigaku MiniFlex II). The activated carbon was analyzed by scanning electron microscope (JEOL JCM 6000 PLUS), and elemental analysis was performed using the EDS technique.

III. RESULTS

As mentioned, the change in concentration was analyzed using the MP-AES spectrometer. The following concentrations of noble metals in the solution before the adsorption process were determined: 5.556 ppm Pt, 7.775 ppm Au, 5.395 Pt, 3.425 ppm Rh. The change in the concentration of noble metals in solutions after the adsorption process is shown in Fig. 1.

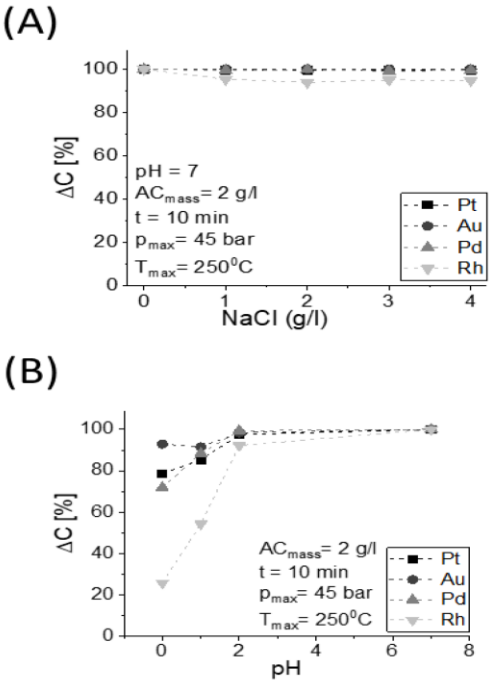


Fig. 1 Noble metals concentration change depending on salinity (A) and pH (B).

The influence of the salinity of the solution on the adsorption of noble metals was analyzed (Fig. 1A). This series of measurements was made due to the desire to recreate conditions similar to industrial ones. Namely, most often, waste solutions containing precious metals are contaminated with other salts from previous technological processes. Even a low salinity of 1 g/l of NaCl reduces the adsorption efficiency, but there is no bigger difference depending on the amount of this salinity. Only in the case of gold ions does salinity has no effect - this metal is 100 % removed from the solution, regardless of the concentration of NaCl in the solution.

The effect of pH on the final concentrations of noble metal ions after 10 minutes of adsorption process is presented in Fig.1B, in a solution with a salinity of 4 g/l of NaCl. In this case, the influence of pH on the process is visible. In acidic pH solutions, the efficiency of the adsorption process is lower, which is especially noticeable in the case of rhodium ions. In this case, it is recommended to neutralize the solutions before the adsorption process.

For microwave heated systems, salinity is an important parameter. The presence of salt increases the ability to absorb microwave radiation. As a result, a faster temperature increase in the reactor is visible. The used reactor was equipped with a temperature sensor. Hence it was possible to monitor the temperature during the experiments. Fig. 2 shows the temperature change in time in two solutions with different salinity.

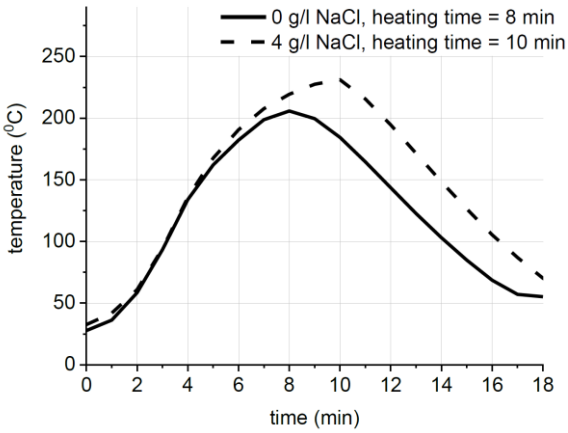
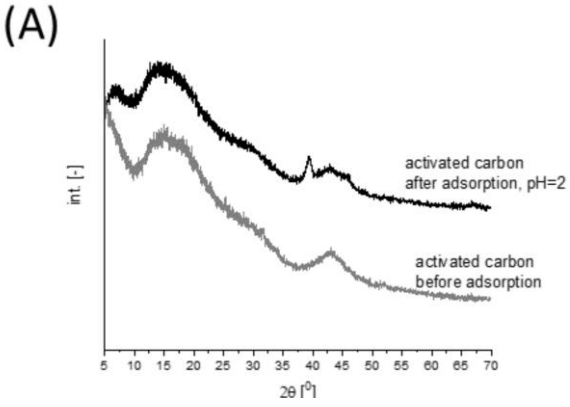


Fig. 2 Reactor temperature changes depending on the process duration and salinity

As can be seen in Fig. 2, after 8 minutes, the temperature inside the system is 205 °C. The temperature inside the reactor, where there was the same amount of solution, was recorded in a similar way. In this case, the solution was salted with NaCl, and the concentration of this salt was 4 g/l. The temperature recorded after 8 minutes of heating was equal to 218 °C. Taking into account the fact that the same initial parameters concerning the reactor power were given, it can be concluded that in this case, the salinity influences the increase of the final temperature of the reactants.

After the conducted experiments, carbon was analyzed by XRD, SEM and EDS methods. The results obtained in the analyzes are shown in Fig. 3.



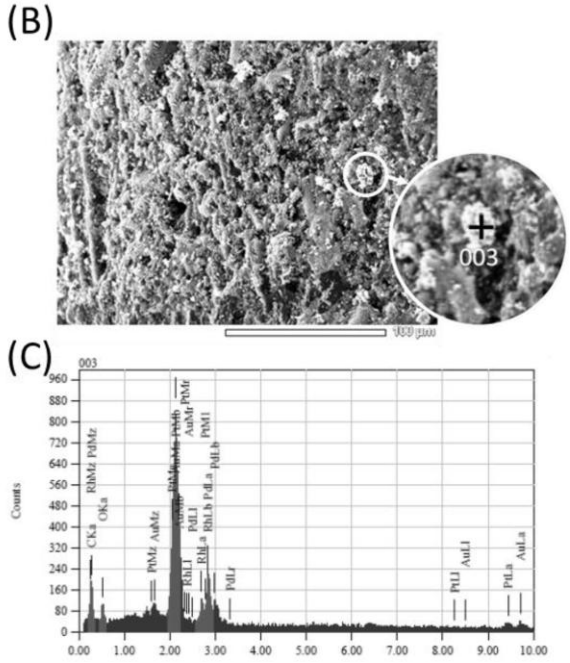


Fig. 3 A) Carbon XRD curves before and after the adsorption process; B) SEM picture; C) EDS analysis of the point marked in SEM picture; Adsorption parameters: 2 g/l AC, pH = 2, t = 10 min

IV. CONCLUSION

The aim of the research was to determine the dependence of parameters such as salinity and pH of the initial solution on the adsorption rate of noble metals. Modification of the process of adsorption of noble metal ions through the use of microwaves allows for achieving 100% efficiency in most of the analyzed cases. Thanks to microwave heating in the system, it was possible to achieve increased pressure and temperature. In the case of acidic solutions, the adsorption efficiency for some metals decreases, therefore, it is recommended to neutralize the solution before the process.

The analysis of the adsorbent after the adsorption process showed that metal ions are adsorbed on the surface of the AC granules and are reduced to metallic and alloy forms. After burning the coal, it is possible to obtain a metallic powder that can be a commercial product.

The experiments conducted in the microwave reactor are preliminary studies for the implementation of the adsorption of noble metal ions in a continuous flow. Measurements in a static state are the basis for the approximate determination of parameters of processes carried out in a dynamic state.

V. ACKNOWLEDGMENT

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