



Effect of pH on the ^{60}Co adsorption capacity by micro particles of polystyrene

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1. Introduction

The synthetic polymeric materials known as plastics possess the qualities of being lightweight, durable, and impermeable. They can be customized to exhibit rigidity or flexibility, transparency or color, all at a relatively low cost. As a result of these numerous benefits, plastics have found wide application in various sectors of contemporary society [1].

Plastic has become an indispensable material in human life and is used in almost every sector of society: agriculture, packaging, automotive, construction, medicine, among others [1]. Nanoplastics, with particles ranging from 1 to 1000 nanometers, exhibit colloidal behavior and mainly result from the physical and photochemical degradation of microplastics exposed to environmental conditions [2].

In the domain of aquatic environments, a commonly found type of nanoplastic is polystyrene. PS is widely used for its insulating properties and low weight, being produced from the plastic monomer styrene (vinyl benzene) based on petroleum.

PS residues generate micro and nanoparticles through mechanical friction and the action of UV light [3]. The photodegradation of PS fragments is still capable of functionalizing the particles with carboxylic groups on their surface [4], making them chemically eager for metal ions [5], which could be responsible for the dispersion of metal ions.

The focus of this study was to investigate the adsorption parameters: contact time, pH, and ionic strength, for the Co ion (Cobalt-60) on PS nanoplastics and determine under which conditions metal ions are

preferentially bound to this polymer.

2. Methodology

The tests for determining the adsorption capacity of ^{60}Co were conducted using a standard solution of known activity provided by the Institute of Radioprotection and Dosimetry (IRD). For the preparation of the adsorption tests, 10 ml of ultrapure water type I Milli-Q®, 100 μl of ^{60}Co solution with an activity of 789.75 Bq/g, and 300 mg of powdered polystyrene (PS) were used.

To obtain the adsorbent, a cryogenic mill from the brand Freezer/Mill® – SPEX Sample Prep, Model 6775, was used. Initially, the PS was reduced to small fractions and introduced into a grinding vial with an impactor that moves rapidly between its ends. Then, the grinding vial was immersed in a compartment containing about 3 liters of liquid nitrogen, which froze the material at an approximate temperature of 77 K (-196.15 °C). The equipment operates in stages for freezing: precool, cool, and grinding. Each of the stages lasts 5 minutes, 3 minutes, and 2 minutes, respectively.

The pH of the solutions was adjusted to 3, 4, 5, 6, and 8 with HCl and NH_4OH , left to rest for 30 minutes, filtered through filter paper, and dried in an oven at 40 °C. After drying, the PS was transferred to sealed containers, weighed, and subsequently, the activity was measured on a Ge-Hyperpure EG&G Ortec detector, by gamma spectroscopy.

3. Results and Discussion

Cobalt exists in its metallic form (Co^0) and in the valence states Co(II) and Co(III), with the reduced ionic form being the most stable. Compounds containing oxidation states of -1, +1, +4, and +5 are uncommon [6]. As a cation positively charged surfaces may cause repulsion between the adsorbent surface and the adsorbate, reducing adsorption.

A Figure 1 illustrates the effect of different pH values on cobalt adsorption in Bq g^{-1} and in the percent of the initial ^{60}Co activity in the solution. It can be observed that the adsorption effect tends to be higher in environments close to neutral to alkaline. This adsorption process at the active site is typically controlled by interaction forces arising from affinities between the adsorbent and the adsorbate [7].

To verify the hypothesis of equality between the means the ANOVA and Tukey tests was used and the result is showed in Figure 2. Although the priori power was low (0.07566), the H_0 was rejected, indicating that there is a statistically significant difference between the groups. Tukey test showed that the ^{60}Co adsorption in PS in pH 3 significantly differs from that in pH 5 and pH 8.

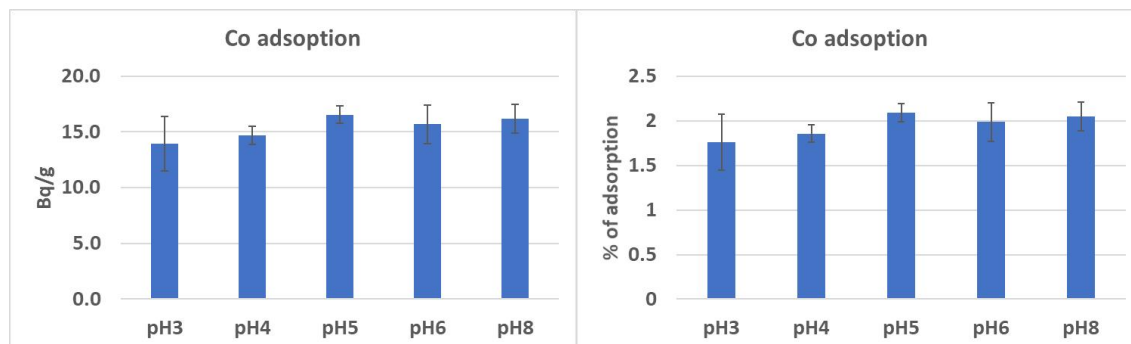


Figure 1: Effect of pH on cobalt adsorption in Bq g⁻¹ and in percent of the ⁶⁰Co activity concentration in the solution.

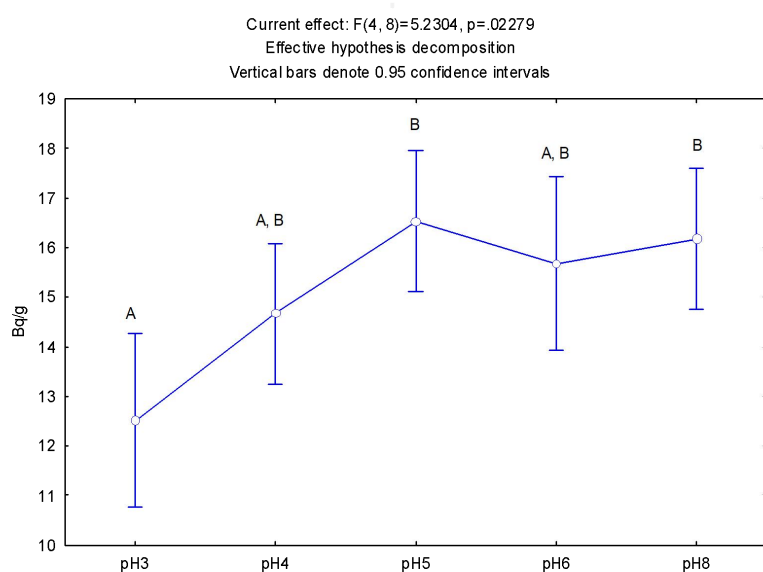


Figure 2: Results of ANOVA and Tukey test for the difference between the means in each pH test.

The efficient adsorption of cobalt can be influenced by different factors: a) Zero Charge Point (ZCP) of polystyrene, which is the pH at which the polymer surface has no net charge. Under conditions close to neutral pH, polystyrene tends to be near its ZCP, providing a more favorable surface for the adsorption of metal ions like cobalt; b) Stability of Coordination Complexes, where functional groups in polystyrene and cobalt ions may be in the most stable form for coordination complex formation at neutral pH. Ionized functional groups in polystyrene (such as carboxylic or phenolic groups) can interact more effectively with cobalt ions, forming stable complexes through coordinated bonds; and c) Competition with Hydrogen and Hydroxyl Ions, as the concentration of H⁺ and OH⁻ ions in the solution is relatively low at neutral pH, reducing the competition of these ions with cobalt ions for adsorption on the surface of polystyrene. This may allow for more efficient cobalt adsorption.

4. Conclusions

This study demonstrated that PS can adsorb cobalt ions from aqueous solutions; therefore, this process can also occur with its nano and microplastic particles in the environment. Polystyrene is a polymer with well-known adsorption properties due to its porous structure and the presence of functional groups that can interact with metal ions and the results showed that the most suitable pH was closer to neutral to slightly alkaline.

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