# Bio-material based adsorbent for radioactive copper separation

JungHo Chae [a], JunYoung Lee [a], MinGoo Hur [b], JeongHoon Park [a*]
[a]*Accelerator Radioisotope Development Team, Korea Atomic Energy Research Institute, Jeongeup-si, Jeollabuk-do 56212, South Korea*
[b]*Radiation Utilization and Facilities Management Division, Jeongeup-si, Jeollabuk-do 56212, South Korea*
[*]*Corresponding author: parkjh@kaeri.re.kr*

## 1. Introduction

Radioisotopes have been studied a lot because they have physical properties suitable for the diagnosis and treatment of diseases in nuclear medicine. Among the many radioactive isotopes, $^{64}$Cu is utilized in positron emission tomography (PET) imaging and radiotherapy as beta and positron emitters with a half-life of 12.7 hours, while $^{67}$Cu has a half-life of 61.8 hours, enabling targeted radiotherapy and single-photon emission computed tomography (SPECT) imaging with beta particle emission. Radioactive copper is a promising candidate for radiopharmaceutical applications because of these unique decay properties and chemical properties. [1, 2, 3]

In order to obtain high-purity radioactive copper, it is very important to effectively separate it from the irradiated Ni or Zn target. When separating to obtain radioactive copper from the target, it can be used as a radiopharmaceutical only if the content of metallic impurities is low, and the cost is reduced by recovering the irradiated Ni or Zn target. [4, 5]

Up to now, ion-exchange chromatography and solvent extraction have been mainly used as radioisotope separation methods. Among them, the most effective method is ion exchange chromatography, which has fast kinetics, high selectivity, and is easily applicable for high-purity separations. [6, 7]

In this study, an absorbent for radioisotope separation was synthesized using Pectin and Chitosan, which are inexpensive, biodegradable, biocompatible, environmentally friendly, and available in large quantities. Also, since it is a natural product, it has the advantage that it is harmless even if it is introduced into the body in a small amount. Therefore, through the development of an inexpensive and abundant natural product-based radioisotope adsorbent, there is no need to worry about technology dependence and it is possible to produce and separate radioisotopes on their own. [8, 9]

## 2. Methods and Results

### *2.1 Synthesis of PC(Pectin and Chitosan) beads*

Dissolve Pectin and Chitosan in different ratios (2:8, 4:6, 6:4, 8:2) and stir at room temperature until a homogeneous hydrogel is formed. [10]

The homogeneously formed hydrogel was added dropwise to 1M NaOH using a syringe pump to form beads.

Thereafter, the hydrogel beads were left at a low temperature for about 12 hours to cure through sufficient crosslinking. After filtration, the resulting PC beads were washed with deionized water until the pH became neutral. After washing, the filtrate was removed as much as possible with a pipette and lyophilized.

### *2.2 Characterization*

The size and shape of the synthesized adsorbent were investigated by Scanning Electron Microscope (SEM), and the functional groups of the adsorbent were characterized using FT-IR. The specific surface area for each ratio was confirmed through Brunauer-Emmett-Teller (BET) measurement.

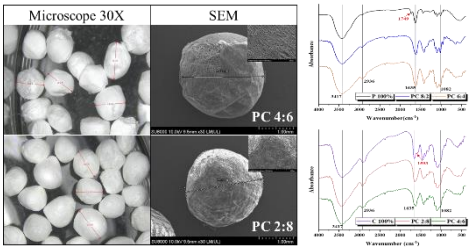


Fig. 1. PC 2:8, 4:6 size and shape analysis result through SEM measurement (a), functional group analysis of PC beads using FT-IR (b)

Table 1 Measurement of specific surface area using BET

| | BET ($m^2$/g) | Pore Volume (cc/g) | Pore Diameter (nm) |
|---|---|---|---|
| **PC 8:2** | 7.148 | 0.014 | 3.824 |
| **PC 6:4** | 9.652 | 0.011 | 3.825 |
| **PC 4:6** | 8.193 | 0.017 | 3.413 |
| **PC 2:8** | 15.915 | 0.037 | 3.054 |

### *2.3 Batch adsorption experiments*

A stock solution was prepared by dissolving $CoCl_2$, $CuCl_2$, $NiCl_2$, $ZnCl_2$, and $GaCl_2$ in deionized water so that the concentration of Co(II), Cu(II), Ni(II), Zn(II), and Ga(II) metal ions was 1000 ppm. (Co(II) and Ga(II) were added as impurities because $^{55}$Co, $^{57}$Co, $^{66}$Ga and $^{67}$Ga were generated together after irradiation from the Ni or Zn target) The effect of initial pH on the adsorption of metal ion was studied in pH range of 2~6. The pH of metal ion solutions was adjusted to the required pH value using HCl and NaOH aqueous solutions. 20.0 mg of the adsorbent was placed in 2 mL of a metal ion solution and shaken at room temperature at 300 rpm for 60 minutes. After adsorption, the supernatant was filtered through a syringe filter, and the solution was analyzed by ICP-MS.

The expression for $K_d$ is

$$K_d = \frac{(C_0 - C_m) * 2}{(C_m * A)}$$

Where
$C_0$ : metal ion solvent concentration before adsorption
$C_m$ : metal ion solvent concentration after adsorption
$A$ : amount of adsorbent

### *2.4 Adsorption results according to pH*

The adsorption capacity of PC 2:8 and 4:6 was compared up to pH 2~6. As a result of comparison, in the case of PC 2:8, as shown in Fig. 2(a), it can be seen that the adsorption capacity for Zn(II) is high, but the adsorption capacity does not change constantly as the pH increases. However, in the case of PC 4:6, as shown in Fig. 2(b), at pH 2, it exhibits selective adsorption capacity for Cu(II), and at pH 3~6, it shows a similar pattern.

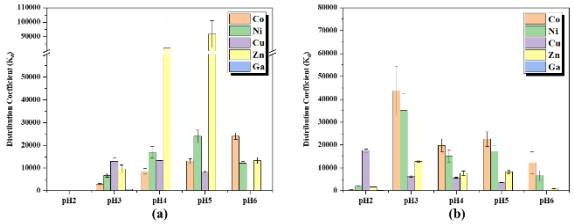


Fig. 2. Adsorption comparison with pH change: (a) PC 2:8 beads (b) PC 4:6 beads

### *2.5 Maximum adsorption for Cu(II)*

In order to confirm the maximum $K_d$ value for Cu(II), the concentration of Cu(II) was gradually increased. As can be seen in Table 2, as the concentration of Cu(II) increased, the $K_d$ value increased and it was confirmed that the equilibrium was gradually approached. The Cu(II) adsorption was compared by fixing the Cu(II) concentration and increasing the Ni(II) content. As shown in Table 3, it was confirmed that the $K_d$ of Cu(II) decreased as the Ni(II) concentration increased, but the $K_d$ value remained above 5000.

Table 2 Maximum adsorption according to Cu(II) concentration

| Concentration of Cu (μg) | 0.3 μg | 1.8μg | 4 μg | 12 μg | 20 μg |
|---|---|---|---|---|---|
| $K_d$ | 1670±132.6 | 5534±220.8 | 9766±243.7 | 20614±487.5 | 25203±1597.2 |

Table 3 Comparison of Cu(II) adsorption according to Ni(II) concentration

| Concentration of Cu (μg) | 20 μg | | | |
|---|---|---|---|---|
| Concentration of Ni (mg) | 0.2 mg | 0.5 mg | 1 mg | 1.3 mg |
| $K_d$ | 26017±450.4 | 18839±603.6 | 9976±176.2 | 7580±72.5 |

## 3. Conclusions

Resins commonly used for radioisotope purification generate many adjuncts and secondary wastes during the pretreatment process. Therefore, it is possible to solve the environmental pollution problem and to expect economic effects through the development of an adsorbent that can purify radioisotopes based on natural products that are easily available in nature. In this study, an adsorbent was synthesized using natural products Pectin and Chitosan, and it was confirmed that Cu(II) selectively adsorbed at a specific condition. Through this, we confirmed the possibility of application as an eco-friendly adsorbent that can be used for radioactive copper purification, which can be used as radiopharmaceuticals.

## REFERENCES

[1] Qaim, S. M. (2019). Theranostic radionuclides: recent advances in production methodologies. Journal of radioanalytical and nuclear chemistry, 322(3), 1257-1266
[2] Ohya, T., Minegishi, K., Suzuki, H., Nagatsu, K., Fukada, M., Hanyu, M., & Zhang, M. R. (2019). Development of a remote purification apparatus with disposable evaporator for the routine production of high-quality $^{64}$Cu for clinical use. Applied Radiation and Isotopes, 146, 127-132.
[3] Souliotis, G. A., Rodrigues, M. R. D., Wang, K., Iacob, V. E., Nica, N., Roeder, B., ... & Bonasera, A. (2019). A novel approach to medical radioisotope production using inverse kinematics: a successful production test of the theranostic radionuclide $^{67}$Cu. Applied Radiation and Isotopes, 149, 89-95.
[4] Katabuchi, T., Watanabe, S., Ishioka, N. S., Iida, Y., Hanaoka, H., Endo, K., & Matsuhashi, S. (2008). Production of $^{67}$Cu via the $^{68}$Zn (p, 2p) $^{67}$Cu reaction and recovery of 68Zn target. Journal of Radioanalytical and Nuclear Chemistry, 277(2), 467-470.
[5] Schwarzbach, R., Zimmermann, K., Bläuenstein, P., Smith, A., & Schubiger, P. A. (1995). Development of a simple and selective separation of $^{67}$Cu from irradiated zinc for use in antibody labelling: a comparison of methods. Applied radiation and isotopes, 46(5), 329-336.
[6] Kawabata, M., Hashimoto, K., Saeki, H., Sato, N., Motoishi, S., Takakura, K., ... & Nagai, Y. (2015). Production and separation of $^{64}$Cu and $^{67}$Cu using 14 MeV neutrons. Journal of Radioanalytical and Nuclear Chemistry, 303(2), 1205-1209.
[7] Kim, J. Y., Park, H., Lee, J. C., Kim, K. M., Lee, K. C., Ha, H. J., ... & Cheon, G. J. (2009). A simple Cu-64 production and its application of Cu-64 ATSM. Applied Radiation and Isotopes, 67(7-8), 1190-1194.
[8] Schwarzbach R, Zimmermann K, Blauenstein P, Smith A, Schubiger PA (1995) Development of a simple and selective separation of Cu-67 from irradiated zinc for use in antibody labeling—a comparison of methods. Appl Radiat Isot 46(5):329–336
[9] Rebeles RA, Van den Winkel P, Hermanne A, De VL, Waegeneer R (2010) PC-controlled radiochemistry system for preparation of no-carrier-added $^{64}$Cu. J Radioanal Nucl Chem 286:655–659.
[10] Shao, Z., Lu, J., Ding, J., Fan, F., Sun, X., Li, P., ... & Hu, Q. (2021). Novel green chitosan-pectin gel beads for the removal of Cu (II), Cd (II), Hg (II) and Pb (II) from aqueous solution. International Journal of Biological Macromolecules, 176, 217-225