Eurasia Specialized Veterinary Publication

International Journal of Veterinary Research and Allied Science

2021, Volume 1, Issue 1, Page No: 32-35

Available online at: www.esvpub.com/

Evaluating the Sorptive Potential of Enterosorbents in Cases of Heavy Metal Toxicity Risk

S. F. Andrusenko[1]*, O. I. Anfinogenova[1], E. V. Denisova[1]

[1]Department of Biomedicine and Physiology, North-Caucasus Federal University, Stavropol, Russia.

***E-mail** ✉ sandrusenko@ncfu.ru

ABSTRACT

A comparative evaluation was conducted to evaluate the detoxifying efficiency of different sorbents concerning heavy metals. Metal ion sorption was carried out under static conditions using solutions of $CuCl_2 \cdot 2H_2O$, $ZnSO_4$, $PbCl_2$, and NiCl, all of analytical grade. Lead, nickel, and zinc concentrations were determined through complexometry, while copper concentration was measured by iodometry. To examine the desorption processes, a solution of “artificial” intestinal juice was prepared. The study showed that the half-adsorption time was about 30 minutes and remained constant regardless of the sorbent type. The maximum sorption capacity of the sorbents for heavy metals was determined, and the sorbents were ranked according to their activity. The effect of pH on the specific adsorption values of the sorbents was investigated. In addition, the desorption processes were analyzed under conditions similar to physiological environments, specifically using “artificial” intestinal juice, to investigate the potential for secondary metal intoxication. The findings are useful for selecting the most effective detoxifying agent and optimizing the treatment of heavy metal poisoning.

Keywords: Heavy metals, Enterosorbents, Toxicity risk, Detoxifying efficiency

Received: 02 April 2021
Revised: 12 June 2021
Accepted: 14 June 2021

How to Cite This Article: Andrusenko SF, Anfinogenova OI, Denisova EV. Evaluating the Sorptive Potential of Enterosorbents in Cases of Heavy Metal Toxicity Risk. Int J Vet Res Allied Sci. 2021;1(1):32-5.

Introduction

The issue of heavy metal contamination has become a global concern in contemporary settings, primarily due to the pollution of water and soil with rare and dispersed elements that exhibit biocidal properties. This results in the accumulation of heavy metals through the food chain, contributing to serious health problems in humans [1]. Among various treatment methods, sorption deoxidation plays a crucial role [2], including its application in clinical practice [3]. A variety of sorbents are available, with some of the most well-known being "POLYSORB" [4], "Enterosgel" [5], alginates [6], pectin [7], and peat sorbents [8]. Numerous publications have compared their characteristics [9]. Despite this, the study of sorbents remains highly relevant, particularly regarding the balance between their toxic and toxic effects. The presence of certain chemical structures in sorbents raises questions about the relationship between the chemical composition of a substance and its pharmacological properties. One key quality metric for all enterosorbent drugs is their adsorption activity [10].

The importance of this study stems from the variety of synthetic, semi-synthetic, and natural sorbents available, as well as the prevalence of heavy metal poisoning, which leads to toxicity and accumulation in internal organs. Heavy metals are particularly hazardous due to their capacity for bioaccumulation, meaning they can build up in the tissues of living organisms, becoming toxic when present in excessive amounts [11]. Globally, heavy metal contamination, especially in wastewater, poses a significant environmental challenge, though in certain contexts,

it can also be beneficial [12, 13]. Therefore, investigating the efficacy of different sorbents in combating heavy metal overdose is a crucial medical issue.

This study aims to evaluate and compare the detoxification effectiveness of widely used medical sorbents concerning heavy metals.

Materials and Methods

Metal ion sorption was carried out under static conditions using solutions of $CuCl_2 \cdot 2H_2O$, $ZnSO_4$, $PbCl_2$, and NiCl, all of analytical grade. Lead, nickel, and zinc concentrations were determined through complexometry, while copper concentration was measured by iodometry [14].

To assess the sorption capacity of the sorbent, 1 g samples of the sorbent were weighed on an analytical electronic balance (EVA SKA-220V model). The samples were placed in glass beakers, and 30 ml of the metal salt solution with varying concentrations was added. The mixture was stirred at 150 rpm using a LAB-PU-01 device at 25 °C for 60 minutes. Afterward, the solution was centrifuged using an ELMI SkyLine CENTRIFUGECM-6M (1000 rpm for 3 minutes), and the equilibrium metal concentration was measured in the supernatant. For each metal, five measurements were taken during the experimental adsorption process. The data obtained were subjected to statistical analysis, with a relative uncertainty of less than 5%. The remaining metal concentration in the solution after sorbent treatment was calculated using the following formula:

$$Ssp = \frac{(\mathrm{Ccor} - \mathrm{Ccom}) \times V}{\mathrm{m}} \quad (1)$$

In the calculations, m represents the mass of the enterosorbent suspension, Ssp is the specific adsorption in mg/g of the sorbent, V is the volume of the solution in milliliters, and Ccor and Ccom correspond to the initial and final metal concentrations at equilibrium in mg/ml [15].

To evaluate the effects of different pH levels, "artificial" gastric and intestinal juices were prepared. Initially, 7.0 ml of concentrated hydrochloric acid was carefully added to a 1000 ml flask. Following this, two grams of sodium chloride were dissolved into the acid, and the solution's volume was adjusted to reach a pH of 2.0 ± 0.05 with distilled water. The pH was measured using a pH-150 M meter. Sorbent samples with bound metal were then placed into glass containers, and 3 ml of the "artificial" gastric juice was pipetted into each. The mixtures were stirred at 150 rpm for an hour at 37 °C. Afterward, the solutions were centrifuged at 1000 rpm for three minutes, and the metal concentration in the supernatant was measured [16].

To examine the desorption processes, a solution of "artificial" intestinal juice was prepared. This was done by adding one gram of sodium chloride to a 500 cm^3 flask and then filling it with distilled water to the mark. Sodium bicarbonate was gradually added to adjust the pH to 7.5 ± 0.05. To assess desorption, the sorbent, which had previously adsorbed metals at pH 2, was combined with 3 cm^3 of "artificial" intestinal juice. The mixture was stirred at 150 rpm for an hour at 37 °C. Afterward, the solution was centrifuged at 1000 rpm for three minutes, and the metal concentration in the supernatant was measured [16]. The percentage of desorbed metal relative to the amount initially adsorbed was calculated using the formula:

$$\%\ desorption = \frac{\mathrm{C\ substance} \times 100}{\mathrm{C\ initial} - \mathrm{C\ equilibrium}} \quad (2)$$

In the calculations, Ccon represents the concentration of the substance after desorption in mol/l, while Ccor and Ccom refer to the initial and equilibrium concentrations in mol/l.

Results and Discussion

The study focused on two key characteristics of sorbents: their sorption capacity and the time required to reach sorption equilibrium. To investigate the effect of time on the specific adsorption of sorbents towards heavy metals, the binding rate of metals was measured using sorbents like Enterosgel and white coal. Samples were analyzed at intervals of fifteen, thirty, sixty, and ninety minutes. Results showed that equilibrium was reached relatively

quickly, approximately within 60 minutes. Notably, nearly fifty percent of the metals were bound within the first thirty minutes, indicating that the half-sorption period is around 30 minutes and is independent of the sorbent type. The effect of mixing on the specific adsorption of heavy metals by medical sorbents was examined. The results indicated that mixing had little to no impact on the specific adsorption levels, suggesting that the sorption process is mainly governed by the internal diffusion of metals into the sorbent.

The sorption capacities of various medical sorbents for heavy metals were measured. For lead cations, POLYSORB exhibited a sorption capacity of 102.11 mg/g, activated carbon had a capacity of 49.18 mg/g, and white coal showed a capacity of 150.28 mg/g. These results demonstrate that sorption efficiency is influenced by the sorbent's properties, including its ability to form complexes, polarity (hydrophobicity and hydrophilicity), and porosity. Activated carbon primarily undergoes physical adsorption, while POLYSORB and white coal primarily engage in chemisorption.

The maximum sorption capacities for heavy metal ions were assessed, with white coal demonstrating the highest capacity and activated carbon showing the lowest. The activity levels of sorbents towards heavy metals were ranked as follows: "White coal" ≥ "POLYSORB" ≥ "Enterosgel" ≥ "Smekta" ≥ "Filtrum" ≥ "Activated carbon." Sorption efficiency varied across metal ions in the order of $Cu^{2+} < Ni^{2+} < Zn^{2+} < Pb^{2+}$, which can be attributed to the increasing ionic radii of the metals in this sequence.

Subsequently, the effect of pH on specific adsorption was investigated. Sorbent activity was measured under conditions simulating the acidic environment of the stomach. In this acidic environment, the sorption values for all metals were found to be slightly lower compared to those observed at neutral pH. This pH-dependent variation in sorption can be explained by changes in the pore volume or surface structure of the sorbents, which affects their availability for sorption.

Desorption processes were analyzed under conditions simulating physiological environments using "artificial" intestinal juice to assess the potential for secondary heavy metal intoxication. The results showed minimal desorption of metals in most cases, except activated carbon, which could be attributed to the physical adsorption mechanism. In other instances, a strong sorbent-metal bond was observed, likely due to chemisorption. Based on these findings, it can be concluded that the risk of secondary intoxication from the desorption of heavy metals from the tested medical sorbents in the human body is unlikely.

Conclusion

A comparative analysis was conducted on the sorption capacities of common medical sorbents, including Filtrum, Smecta, Enterosgel, Polyphepane, White coal, and activated carbon, concerning heavy metal ions Cu^{2+}, Ni^{2+}, Pb^{2+}, and Zn^{2+} through in vitro experiments. This allowed for the identification of the most efficient sorbents for heavy metal removal. The study also examined the effects of agitation and sorption time on the establishment of equilibrium in the enterosorbent-metal system. The half-sorption period was found to be around half an hour, regardless of the sorbent type. The influence of heavy metal concentration on particular adsorption was investigated, revealing that white coal, with its primary component being silicon dioxide, exhibited a higher adsorption capacity for heavy metals. Specifically, its adsorption capacity for lead was ten times greater than that of activated carbon and 1.5 times higher than POLYSORB. The maximum sorption capacity of each sorbent was determined concerning the heavy metal ions studied. The sorbent activity rankings for the metals were as follows: "White coal" ≥ "POLYSORB" ≥ "Enterosgel" ≥ "Smekta" ≥ "Filtrum" ≥ "Activated carbon", with the sorption efficiency increasing in the sequence: $Cu^{2+} < Ni^{2+} < Zn^{2+} < Pb^{2+}$. The effect of pH on particular adsorption was also studied, with sorption values at pH 2.0 (simulating stomach conditions) being lower for all metals compared to those observed at neutral pH (pH = 7). Desorption processes were analyzed, and in the majority of instances, desorption was minimal due to the formation of stable sorbent-metal complexes. The results of this study can be useful in selecting the optimal detoxifying agent and improving treatment.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Teplaya GA. Tyazhelye metally kak faktor zagryazneniya okruzhayushchej sredy. Astrahanskij vestnik ekologicheskogo obrazovaniya. 2013;1(23):182-92.
2. Zaharenko SM. Enterosorbtsiya v praktike infektsionista. RMZh. 2010;18(30):1829-33.
3. Panfilova VN, Taranushenko TE. Primenenie enterosorbentov v klinicheskoi praktike. Pediatricheskaia farmakologiia. 2012;9(6):34-9.
4. Vershinin AS, Bychkovskikh VA, Smirnov DM. Primenenie enterosorbenta Polisorb MP (kremniia dioksida kolloidnogo) v kompleksnoi terapii razlichnykh patologicheskikh sostoianii, soprovozhdaiushchikhsia endotoksikozom (obzor literatury). Vestn. IuUrGU. 2013;13(3):125-9.
5. Kudin MV, Tsaregorodtsev AD, Fedorov YN, Dlin VV, Skripkin AV. Effektivnost' enterosgelyavkom- pleksnomlecheniiekologicheskidetermini- rovannykhzabolevaniipochekudetei. Rossiiskii vestnik perinatologii I pediatrii. 2013;(4):72-7.
6. Peretz S, Anghel D, Elena V, Florea-Spiroiu M, Stoian C, Zgherea G. Synthesis, characterization and adsorption properties of alginate porous beads. Polym Bull. 2015;72(12):3169-82. doi:10.1007/s00289-015-1459-4
7. Ustinova YV, Latkova EV, Poznyakovskii VM. Razrabotka, tovarovednayakharakter- istika i otsenkaeffektivnostienterosorben- tanovogopokoleniya // Tekhnika i tekhnologiyapishchevykhproizvodstv. 2015;(2):93-7.
8. Ivanov AA, Savel'eva AV, Yudina NV, Burkova VN. Otsenkaadsorbtsionnoisposobnosti modifitsirovannykhtorfyanykhenter- osorbentov. Khimiya rastitel'nogo syr'ya. 2013;(1):215-20.
9. Filippova VA, Lysenkova AV, Ignatenko VA, Dovnar AK. Sravnitel'nayakharakteristikaadsorbts ionnykhsvoistventerosorbentov. Problemy zdorov'ya i ekologii. 2016;47(1):41-6.
10. Gernikova EP, Luttseva AI, Bokovikova TN, Mamashina EA, Biglova- Yu.R. Opredelenieadsorbtsionnoiaktivnosti enterosorbentov // VedomostiNTsESMP. Ezhekvartal'nyiretsenziruemyinauchno- prakticheskiizhurnal. 2013;(4):47-50.
11. Hamitowa SM, Glinushkin AP, Avdeev YM, Nalyuhin AN, Beliy AV, Zavarin DA, et al. Assessment of microorganisms and heavy metals' content in the soils of arboretum named after nikolai klyuev. Int J Pharm Res Allied Sci. 2017;6(3):47-55.
12. Nafees S, Nafees H, Rehman S, Rahman SZ, Amin KM. Microbial load, Pesticides residue, Aflatoxin estimation and heavy metals analysis of a single Unani drug Badranjboya (Mellissa officials). Pharmacophore. 2018;9(4):8-13.
13. Habib SA, Elbakry MA, Sakran MA, Toson EA, El-Baz RA, Elafify ME. The impact of heavy metals in impairment of spermatogenesis and sperm density in the human. J Biochem Technol. 2018;9(4):1-8.
14. Ryabinina EI, Zotova EE, Ponomareva NI. Izuchenie adsorbci onnojaktivnostienter- osorbentovrazlichnojprirodypootnosheni- yu k kationamsvinca. Vestnik VGU, Seri- ya: Himiya. Biologiya. Farmaciya. 2016;(1):21-4.
15. Nikolaev VG, Gerashchenko II, Kartel' NT, Gurina NM, Bakalinskaya ON, Sarnatskaya VV, et al. Doklinicheskoeizuchenieenter- osorbentov: khimiko- farmatsevticheskiiaspekt. Poverkhnost'. 2011;3(18):310-9.
16. Markelov DA, Nitsak OV, Gerashchenko II. Sravnitel'noe izuchenie adsorbtsionnoi aktivnosti meditsinskikhsorbentov. Khim Farm Zh. 2008;42(7):303.