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Highlighting inconsistencies regarding metal biosorption

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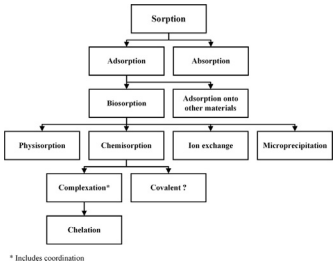
HIGHLIGHTS

- Different classification systems of metal biosorption mechanisms have been compared.
- Mistakes made in previously published articles have been discussed.
- A platform for future discussions among researchers investigating biosorbents.

GRAPHICAL ABSTRACT



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ABSTRACT

Thousands of articles have been devoted to examine different types of biosorbents and their use in cleaning polluted waters. An important objective of some studies has been the identification of the biosorption mechanisms. This type of investigation is not always performed, as it can only be done if scientists are aware of all mechanisms that, at least theoretically, control the removal of the target substances. Mistakes are often made, even in highly cited review articles, where biosorption mechanisms are named and/or grouped. The aim of this article is to highlight errors and inaccuracies as well as to discuss different classification systems of the biosorption mechanisms. This article serves as a guide, as well as a platform for discussion among researchers involved in the investigation of biosorbents, in an effort to avoid reproducing errors in subsequent articles.

1. Introduction

While there is no doubt that biosorption is a widely studied topic, attention has been drawn to insufficient qualification of the researchers involved, the use of loose terminology, and the publication of low quality papers [1,2]. Deficiencies appear in some articles, where mechanisms of biosorption have been indicated and listed, as these lists are incomplete or even incorrect. Errors have appeared in recent studies as well as in highly cited review articles, thus it is necessary to inform the scientific community about those errors in order to avoid pitfalls. Some examples of mistakes are discussed in this article without referring to the paper(s) where these mistakes have appeared. The aim of this article is to highlight the errors and to show different approaches for grouping biosorption mechanisms. A better understanding of the biosorption mechanisms responsible for heavy metal binding could assist in the optimization of performance of new biosorbents [3].

2. Mechanisms of metal biosorption and their classification systems

Mechanisms of metal biosorption can be classified into various groups as presented in Figs. 1–3 . Those classification systems were identified after a careful investigation of the literature and to the best of our knowledge, they have never been shown grouped in one single source.

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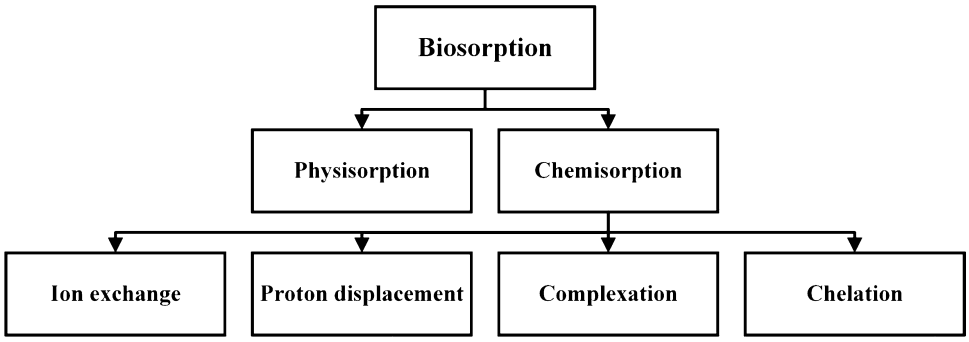

Fig. 1. Classification of metal biosorption mechanisms according to Michalak et al. [4].

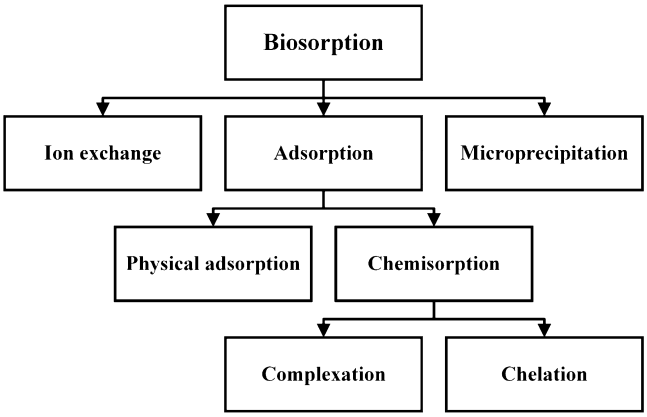

Fig. 2. Classification of metal biosorption mechanisms according to Naja and Volesky [5].

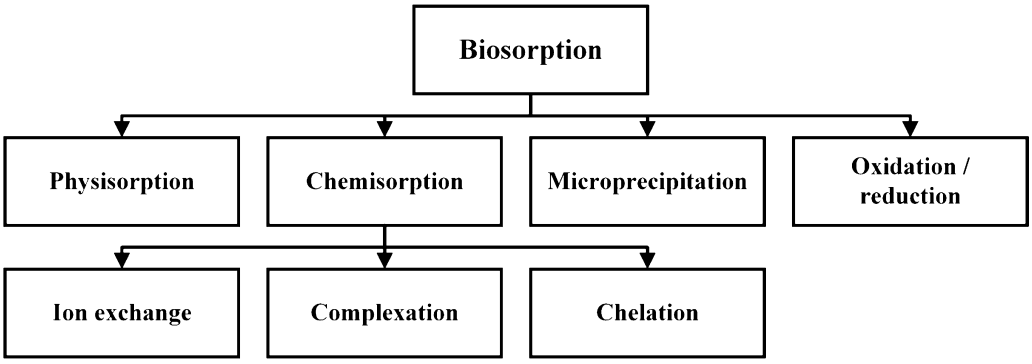

Fig. 3. Classification of metal biosorption mechanisms according to Srivastava and Goyal [6].

"*Biosorption*" is often used as an umbrella term to describe the experimental observations when the amount of sorbate in the solution decreases after a certain period of time due to the attractive forces between the sorbate and biosorbent (i.e., a material of biological origin that is used as an adsorbent) [7]. Using this general description, it is clear why microprecipitation as well as reduction and oxidation reactions leading to uptake on the sorbent material have been considered as part of the biosorption mechanisms (Fig. 3). If a researcher decides not to use the term "*biosorption*", other terms (such as "*removal*", "*binding*" or "*uptake*") can be used, illustrating the biosorbent ability to reduce the concentration of pollutants in water or other environments.

The term "*adsorption*" has been used as a synonym for "*physical adsorption*" by several authors [8–10]. To avoid any confusion, the term "*physical adsorption*" is proposed here to be used instead of "*adsorption*", at least in the biosorption studies, since both chemical adsorption and physical adsorption can play a significant role in the biosorption process. It also seems that some authors consider ion exchange mechanism as a chemisorption process (Figs. 1 and 3), however, other researchers hold a different view (Fig. 2).

The use of the "*microprecipitation*" term (also written as "*micro-precipitation*") has brought a lot of confusion to readers, as the definition of this term has never been given. However, it seems that this term has been used to indicate precipitation taking place locally at the surface of the biosorbent (or within the pores of the biosorbent) due to local conditions [5], therefore a distinction between the terms "*precipitation*" and "*microprecipitation*" has been made. In addition, an alternate term "*surface precipitation*" has been used by other researchers to describe the same phenomenon [8,11]. Farooq et al. [12] stated the following: "*Biosorption mechanism comprises a number of phenomena including adsorption, surface precipitation, ion-exchange and complexation*", showing that the terms "*micropre-cipitation*" and "*surface precipitation*" can be used as synonyms. Du et al. [13] reported that the removal of Pb, Cd and Zn ions from