A Systematic Review on Biosorption of Copper (II) ions in using Water Hyacinth as a Biomass

INTEGRATED SCHOOL

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Abstract

Due to the recent increase in concentration of heavy metals in urban bodies of waters in the Philippines due to industrialization, the study sought to determine ideal methods of adsorbing these substances and prevent them from posing negative health effects to surrounding communities. The proposed method in the study reviewed literature on using water hyacinth biomass as an adsorbent of heavy metals, specifically copper (II) or Cu(II), in contaminated areas susceptible to contaminated wastewater runoff. With this, the ideal adsorbent was determined through factors of particle size, initial ion concentration, adsorption time, ideal conditions, and the adsorbent structure. From the reviewed studies, water hyacinth is an effective biosorbent for copper ions and can be used to reduce copper concentrations in wastewater bodies. Ideal factors for maximum adsorption in terms of wastewater characteristics were conclusive amongst the chosen literature. Other parameters, however, require further investigation to determine if there are trends in how they affect adsorption capacity and removal percentage of the biomass.

Keywords: adsorption; batch process; biosorption; copper; water hyacinth

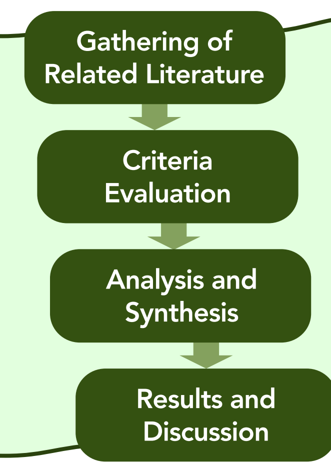
Introduction

The study was conducted to explore the capabilities of water hyacinth as a biomass in the adsorption of heavy metals, specifically Cu(II). As a result, the researchers utilized quantitative studies that tested the capabilities of water hyacinth as an adsorbent of Cu(II) to determine the ideal conditions for metal adsorption. The conditions include initial metal ion concentration, ideal water conditions, adsorbent structure, adsorbent particle size, and adsorption time.

Methodology

The study followed the given flow to reach its conclusion: Gathering of Related Literature, Criteria Evaluation, Analysis and Synthesis, and the Results and Findings.

With access via the De La Salle University Libraries, the researchers used the following electronic databases: EBSCO Research Databases, ScienceDirect, Scopus, and Google Scholar.



Results

Water Hyacinth as an adsorbent for Cu(II) ions

- Water hyacinth has been noted to be an effective due to its high ionic radius giving it a higher affinity for adsorption binding sites
- Its biosorbent forms vary depending on the parts used and whether or not acid treatment was applied
- Has higher overall removal percentage compared to other organic biosorbents
- Roots have better adsorption capacity than aerial parts
- Biomass concentrations that increase from 0.2 g/L until 1.6 g/L significantly affect adsorption percentage, increasing to 74.12% for whole biomass and 92.01% for acid-treated biomass as seen in Figure 1 (Gandhimathi et al., 2013).
- Concentrations greater than 1.6 g/L have negligible increases due to the number of available bonding sites as seem in Table 3 (Gandhimathi et al., 2013; Oktaviyana Lussa et al.,2020).

Ideal Wastewater Conditions

- Factors that affect maximum adsorption capacity affect adsorption through how it attracts and binds the ions (Saraswat & Rai, 2010).
- Studies used indicate an optimal pH range of 4.5-5.5, with lower pH levels hindering adsorption, and only minor outliers of pH 6 and 7 as seen in Table 4
- Initial metal ion concentration as an important adsorption parameter because it is dependent on the adsorptive surface area of the biomass and affects the saturation of the binding sites (Saraswat & Rai, 2010).

Metal Ion Adsorption Process

- Maximum adsorption was reached with 30 minutes of contact time between the solution and the biomass as seen in Table 5 (Li et al., 2013; Zheng et al., 2009).
- Mahamadi and Zambara (2013) made use of a filtration column for manual filtration without agitation, recommending a setup of loosely packed

Table 1. *Batch Process Adsorption using Water Hyacinth Biomass*

Biosorbent Form	Optimal Parameters	Adsorption Capacity	Removal Rate	Reference
Acid-treated	pH 7 10mg/L Cu(II) solution (100 mL) 0.1g/100 mL biomass concentration 300µm - 600µm particle size 75 minute contact time	6.56 mg g^{-1}	89.04%	Gandhimathi et al. (2013)
Leaves, Shoots	250 mL Cu-wastewater 10 g biomass Sieved with 100 meshes 1 hour contact time	22.19 mg g^{-1}	98.19%	Oktaviyana Lussa et al. (2020)
Roots	pH 5 100 mg/L Cu(II) concentration 1 g/100 mL biomass concentration 300µm - 600µm particle size 30°C 20 minute contact time	32.51 mg g^{-1}	80%	Li et al. (2013)
Roots	pH 5.5±0.5 20 mg biomass 50 mL Cu(II) solution, varying concentrations Biomass cut into segments	22.7 mg g^{-1}	>75%	Zheng et al. (2009)
Roots	25 mg/L Cu(II) concentration adsorbent 10 g/L biomass concentration 250–350 µm particle size 5 hour contact time	21.80 mg g^{-1}	>95%	Singha & Das (2013)
Whole Biomass	pH 7 10mg/L metal ion solution, 100 mL 0.1g/100 mL biomass 300µm - 600µm particle size 60 minute contact time	0.49 mg g^{-1}	65.93%	Gandhimathi et al. (2013)
Whole Biomass	pH 7 0.5-1mm particle size 25°C 4 hour contact time	181.8 mg g^{-1}	95.1%	Sadeek et al. (2015)
Whole Biomass	pH 9 0.5-1mm particle size 25°C 3 hour contact time	181.8 mg g^{-1}	98.8%	Sadeek et al. (2015)

Table 2. *Accumulation of Cu(II) in Water Hyacinth parts*

	Concentration in Water Hyacinth (µg g^{-1} dry matter)						
Heavy Metal Concentration	1 mg l^{-1}	3 mg l^{-1}	5 mg l^{-1}	7 mg l^{-1}	10 mg l^{-1}	50 mg l^{-1}	100 mg l^{-1}
Root	57	68	252	1105	700	1525	1900
Aerial Part	1750	2110	2710	2750	2900	2950	2800

Note. Data retrieved from Soltan and Rashed (2013).

Figure 1. *Effect on Biosorbent concentration on %Removal*
Note. Data retrieved from Gandhimathi et al. (2013).

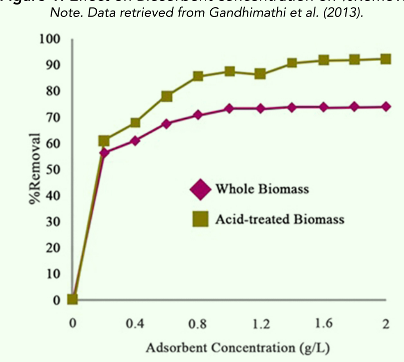


Table 3. *Effect of Mass adsorbent on Cu(II) Adsorption*

			Adsorption Percentage		
Adsorbent Mass	Wastewater Volume	Adsorbent Concentration	30 min contact time	60 min contact time	90 min contact time
10 g	250 mL	40 g/L	97.9626 %	98.1918 %	97.9741 %
15 g	250 mL	60 g/L	96.7479 %	98.1345 %	97.9282 %
20 g	250 mL	80 g/L	97.6990 %	98.0886 %	97.9168 %

Note. Data retrieved from Oktaviyana Lussa et al. (2020).

Table 4. *Optimization of pH Level*

Biosorbent Form	Optimal pH Used	Reference
Live Plants	6	Lu et al. (2014)
Plant Fibers	4.63	Pisitsak et al. (2019)
Roots	5.7	Zheng et al. (2009)
Roots	5.5 ± 0.05	Zheng et al. (2016)
Root Powder	5	Li et al. (2013)

Table 5. *Effect of Agitation and Contact Time*

Rotation Speed	Temperature	Time	Q.	Reference
175 rpm	303K	20 min	13.15 ± 0.26	Li et al., (2013)
150 rpm	308K	20 min	24.3	Zheng et al., (2009)
150 rpm	-	5 hr	5.74 (RWH) 9.06 (TWH)	Gandhimathi et al., (2013)

Conclusion

- Water hyacinth is an effective biosorbent for reduction of copper concentrations in wastewater bodies.
- Roots are often preferred over aerial parts for better adsorption results; however, limited studies exist comparing adsorption capacities of parts under the same conditions.
- The amount of biomass must be optimized for efficiency to avoid excessive biomass and waste of material.
- Optimal adsorption results are often produced within pH 4-7, with pH 5 commonly cited as the point of significant increase.
- Metal ion concentration in the water can affect removal percentage.
- Longer contact time during agitation does not garner better adsorption results, thus requiring more studies under the same testing conditions.
- Results while using a filtration column heavily depend on its bed depth. It recommends loosely packing the biosorbent at a higher bed depth, without much emphasis being placed on the height of the setup itself or how much time was spent in contact with it.