Metal recovery subsequent to e-waste bioprocessing using biological matrices

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Project Background

- CSIR E-waste Roadmap Project.
- Development of an integrated process flowsheet.
- Extraction and Recovery of Valuable metals.

Project Background

Research team

Research name	Role
Prof. Sue Harrison	**Principal Investigator**
Dr. Elaine Govender-Opitz	Researcher
Dr. Thanos Kotsiopoulos	Researcher/Project coordinator
Mr. Emmanuel Ngoma	Technical/Laboratory support
Ms. Nangamso Cawe	Technical/Laboratory support
Musa Maluleke	PhD
Thabo Mubaka	MSc
Ruane Govender	MSc
Athena Strauss	MSc

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Research method

Results

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Background & Literature review

Waste Electrical and Electronic Equipment (E-waste) in Africa

- Over 1.9 million tons of EEE imported every year.
- 10 % to 20 % of imported EEE is Waste Electrical and Electronic Equipment (E-waste).
- Global production of e-waste was 44.7 million tons in 2017 expected to reach 52.2 million tons in 2021.
- Africa produced about 3.3 million tons of e-waste in 2017 (Baldé et al., 2017).

E-waste environmental impact

- E-waste represents less than 2% of the land fill mass but contributes 70 % of it's hazardous material (Namias, 2013).
- The hazardous material in e-waste includes heavy metals and other compounds such as halogenated flame retardants (Kavitha, 2014)
- Contaminated leachates that pollute water sources and soil.
- Toxic fumes and occupational hazards.

Metal mining in South Africa

- Gold and platinum reserves depleting (Lehohla, 2015).
- Production in mining declining (Baxter, 2016).
- E-waste contains base and precious metals.
- Pyrometallurgy is the current tech for processing e-waste.
- E-waste metal recovery not profitable (Lydall et al., 2017).
- Bio-metallurgy (Bioleaching) potential for process e-waste metal fractions (Kavitha, 2014).

Project Objective

The overall objective of this project is to develop an integrated process flowsheet for the extraction and recovery of value from electronic waste.

Printed circuit boards

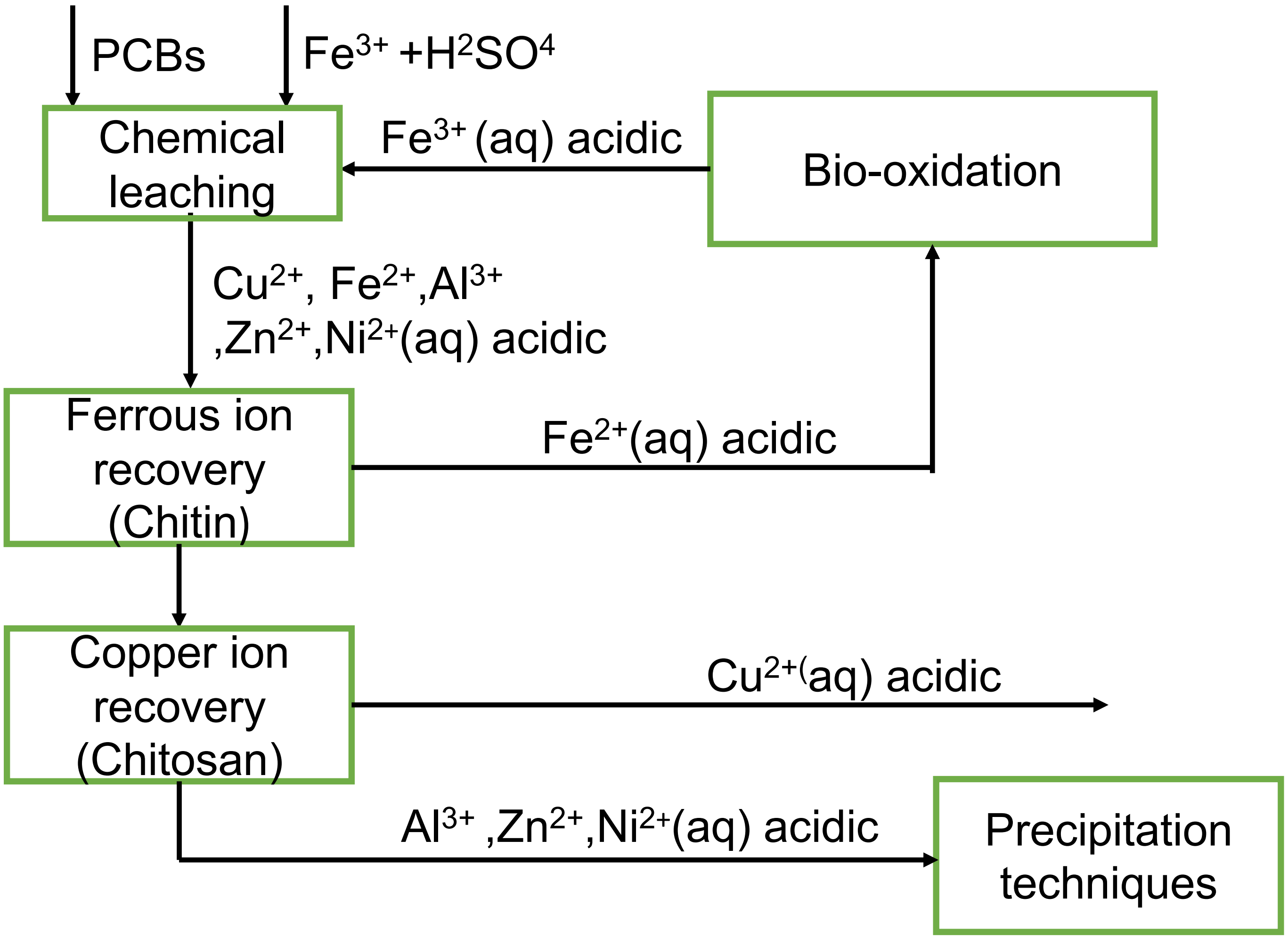
•PCBs make up 8 % of the WEEE collected from small appliances and 3 % of the global mass of WEEE (Luda, 2011).

•Gold and copper hold the highest metal value in PCBs at 74 % and 13 % respectively.

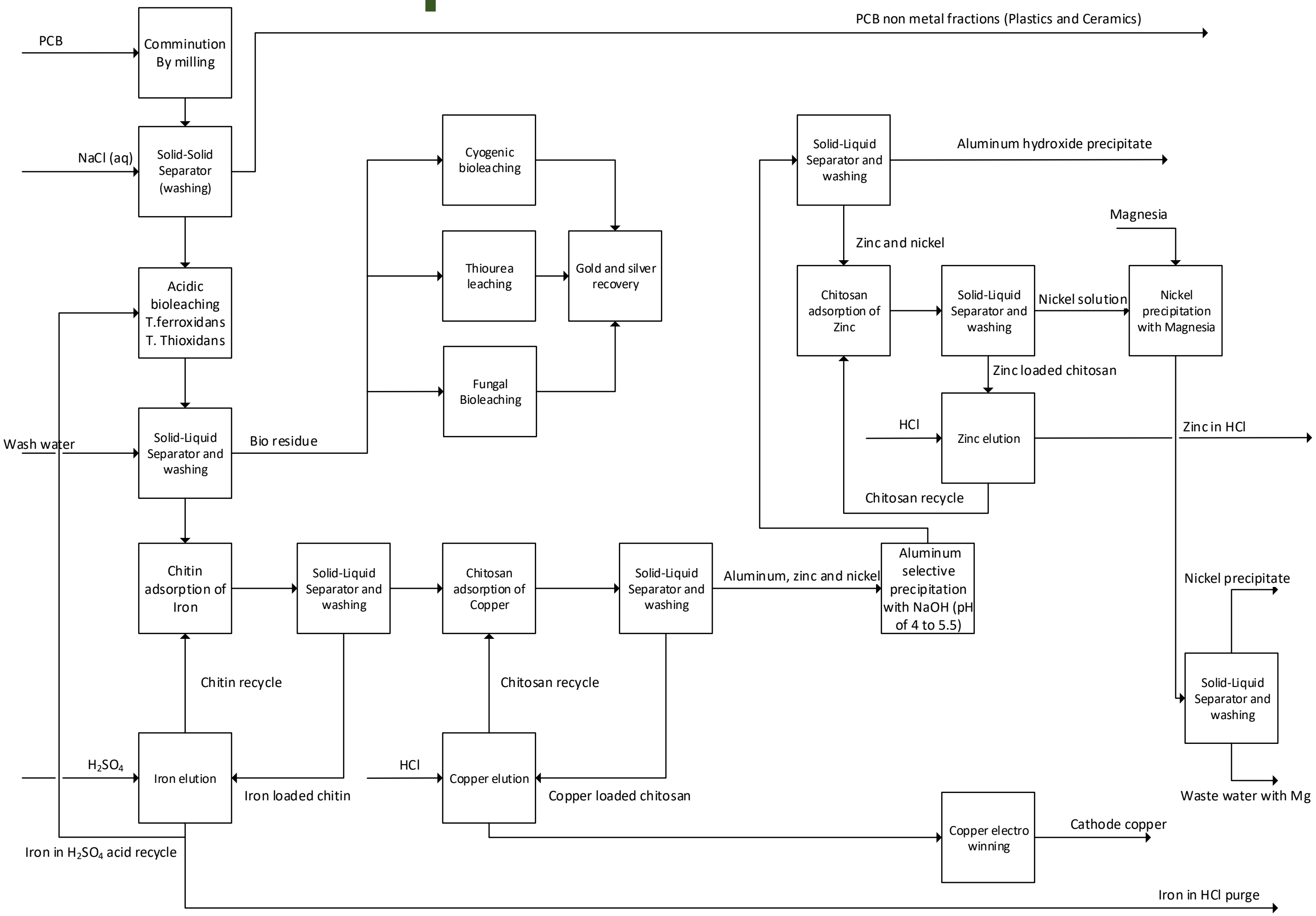
•34 % of the PCB is metal content and valued at $ 7.60 per kg.

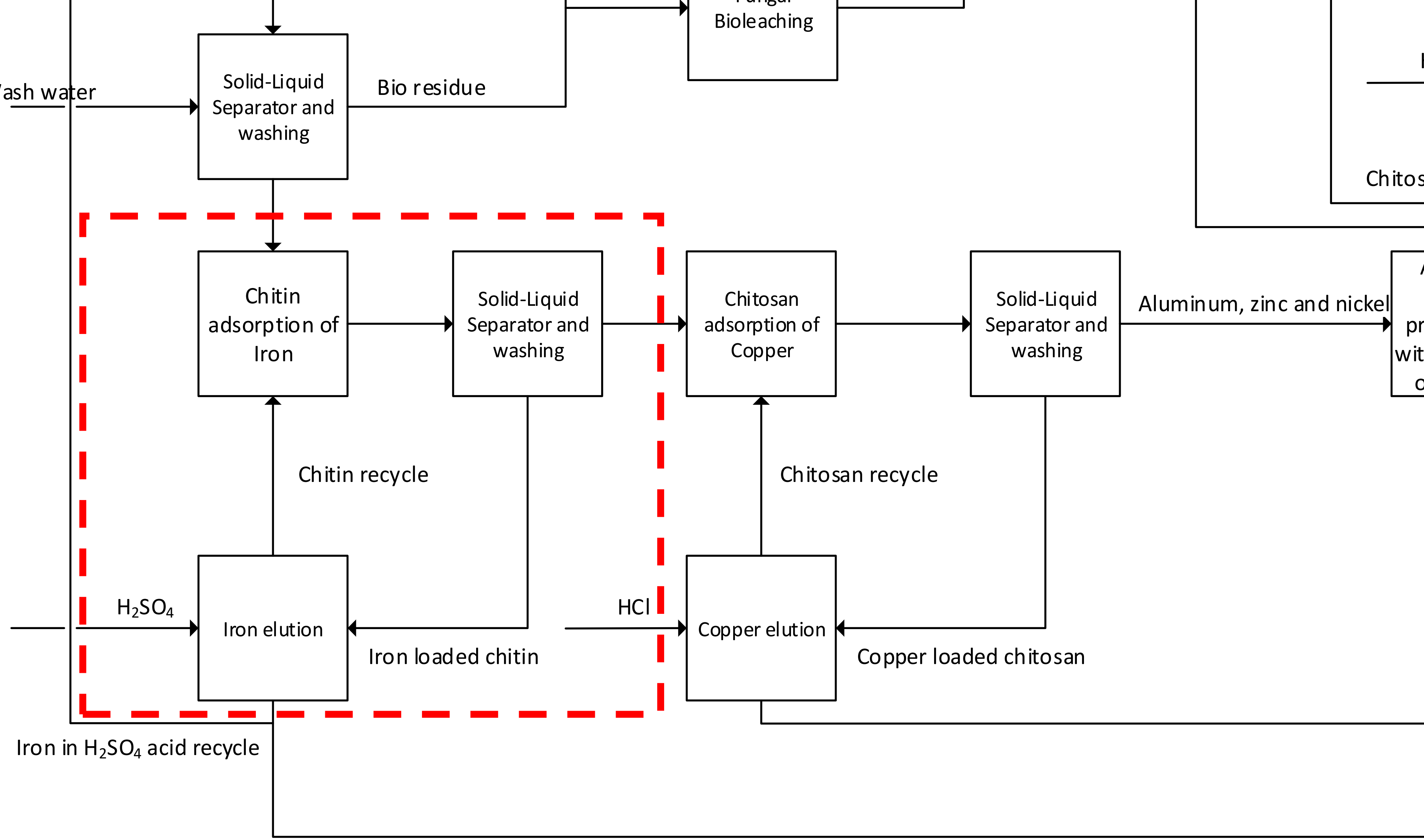
•Base metals: Cu, Fe, Al, Ni, Zn, Pb and Sn.

Proposed route



Proposed route




Bioleaching
Solid-Liquid Separator and washing
Bio residue
Chitin adsorption of Iron
Solid-Liquid Separator and washing
Chitosan adsorption of Copper
Solid-Liquid Separator and washing
Aluminum, zinc and nickel
Chitin recycle
Chitosan recycle
H_2SO_4
Iron elution
HCl
Copper elution
Iron loaded chitin
Copper loaded chitosan
Iron in H_2SO_4 acid recycle

Chitin & Chitosan

- Chitosan has higher maximum metal adsorption capacities than bacteria, fungi, algae, protein and tannin derivatives. (Cui & Zhang, 2008).
- Chitin from Fly larvae (Hermetia illucens) has competitive recovery costs to ion exchange resins (Mabuka et al, 2018).
- Chitin selectivity: $Fe^{3+}>Cu^{2+}>Pb^{2+}>Zn^{2+}>Ni^{2+}>Mn^{2+}$
- Chitosan selectivity: $Cu^{2+}>Mn^{2+}>Ni^{2+}>Zn^{2+}>Pb^{2+}>Fe^{3+}$

(Gyliene et al., 2002; Rhazi et al., 2002; Zhou et al., 2004).

Chitin & Chitosan

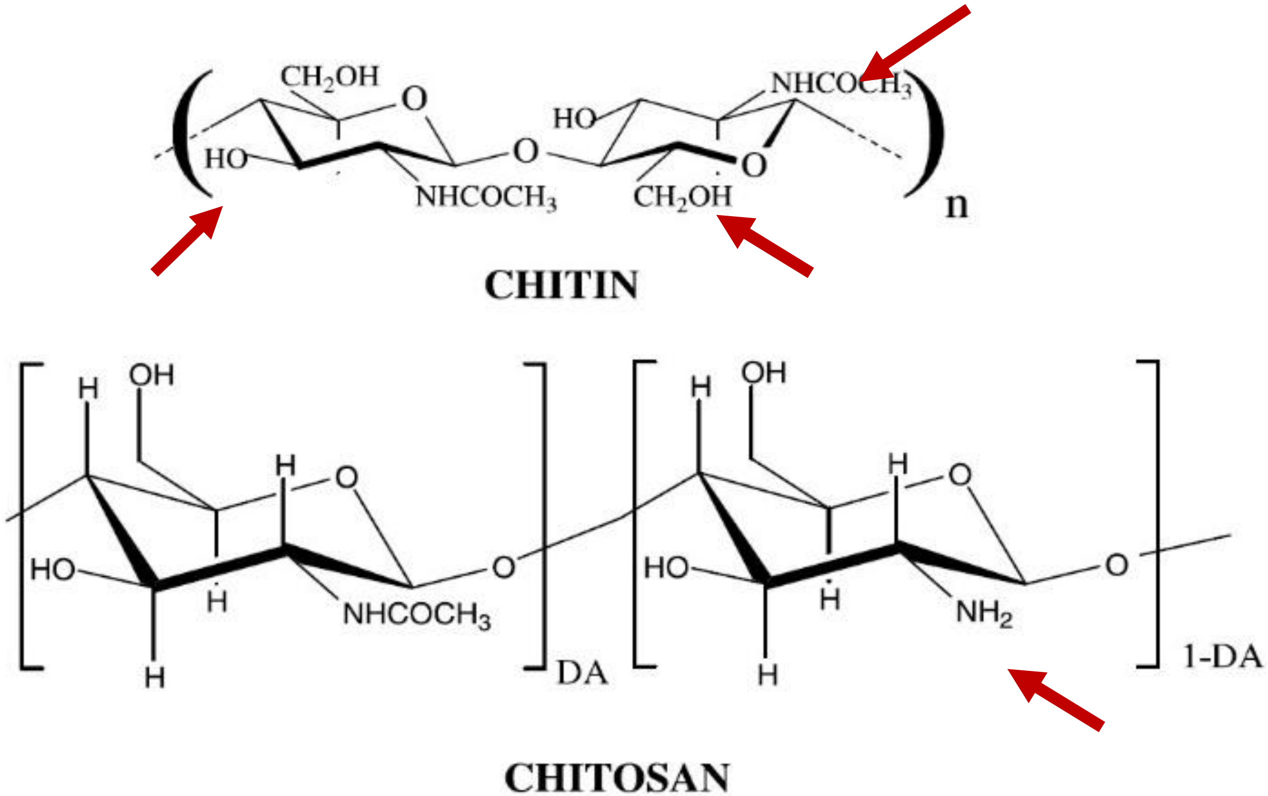


Figure 1: Chemical structure of chitin and chitosan (Rhazi et al., 2002)

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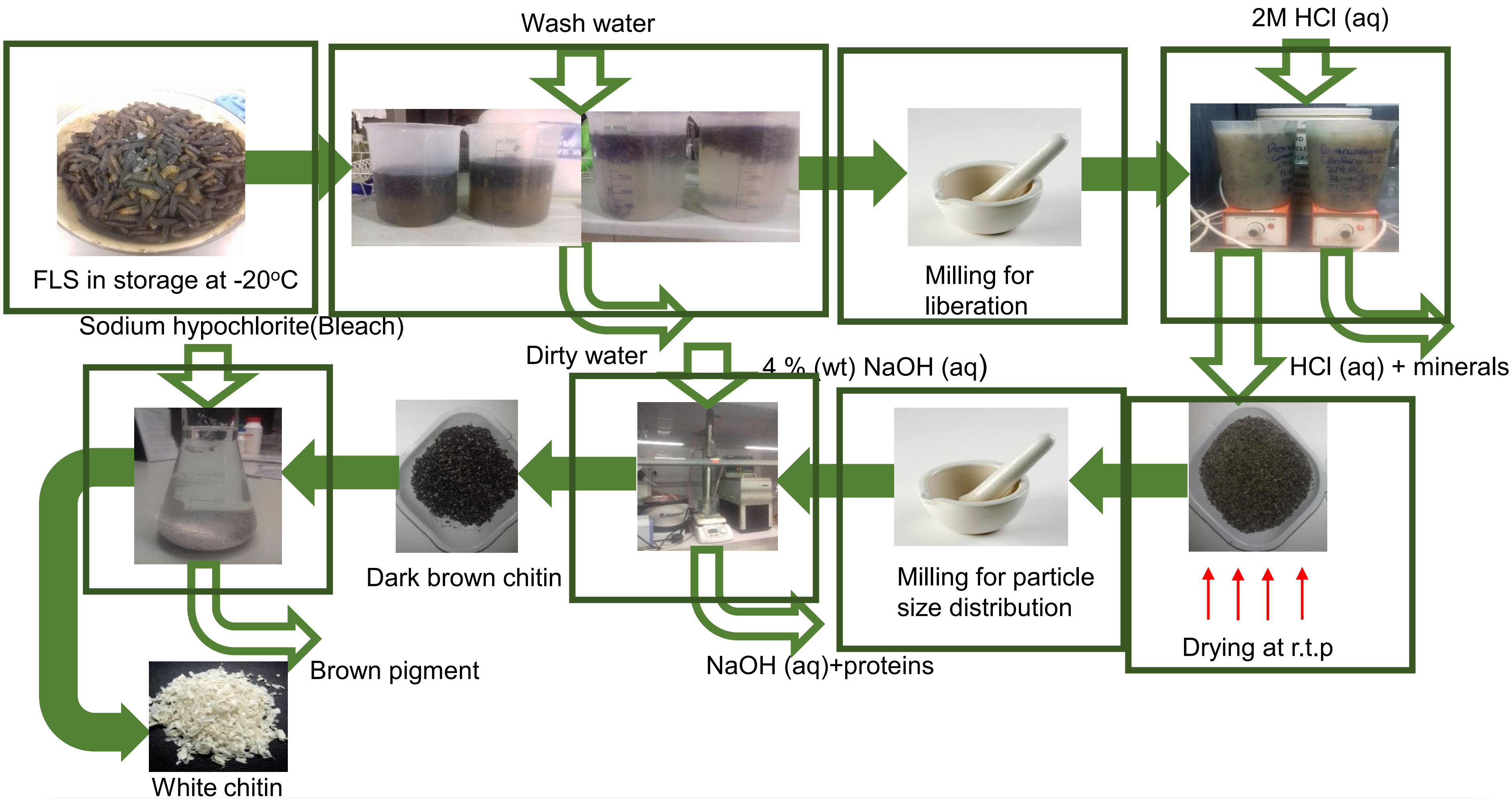
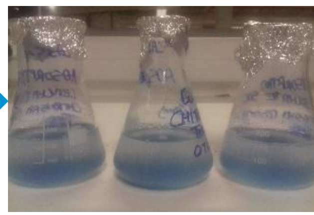
Chitin extraction



Adsorption and desorption

Elution with 0.1M H_2SO_4 (aq)

White or brown chitin/chitosan



200ml of model solution

Filtration

Leachate solution

Chitin/ Chitosan with adsorbed metal

Eluted metal in H_2SO_4 (aq)

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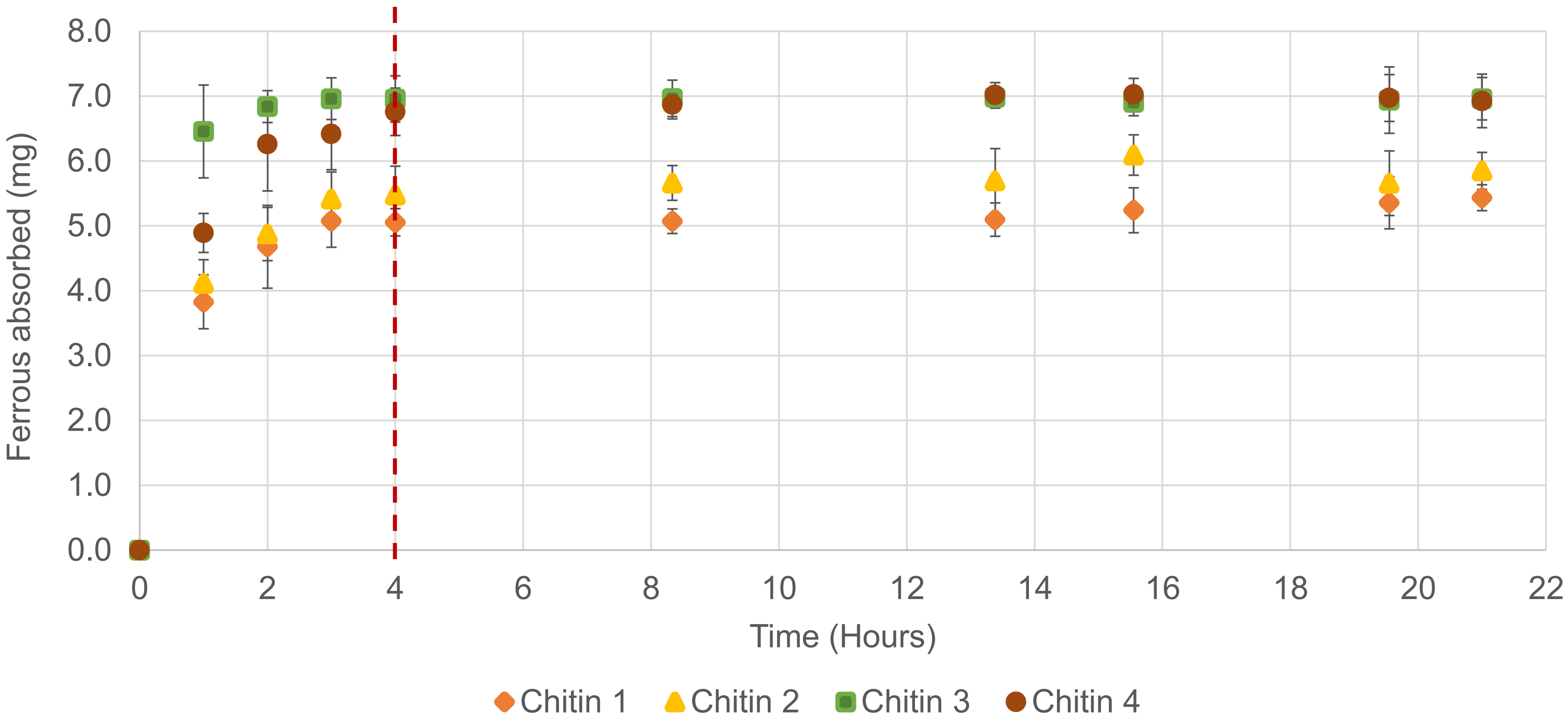
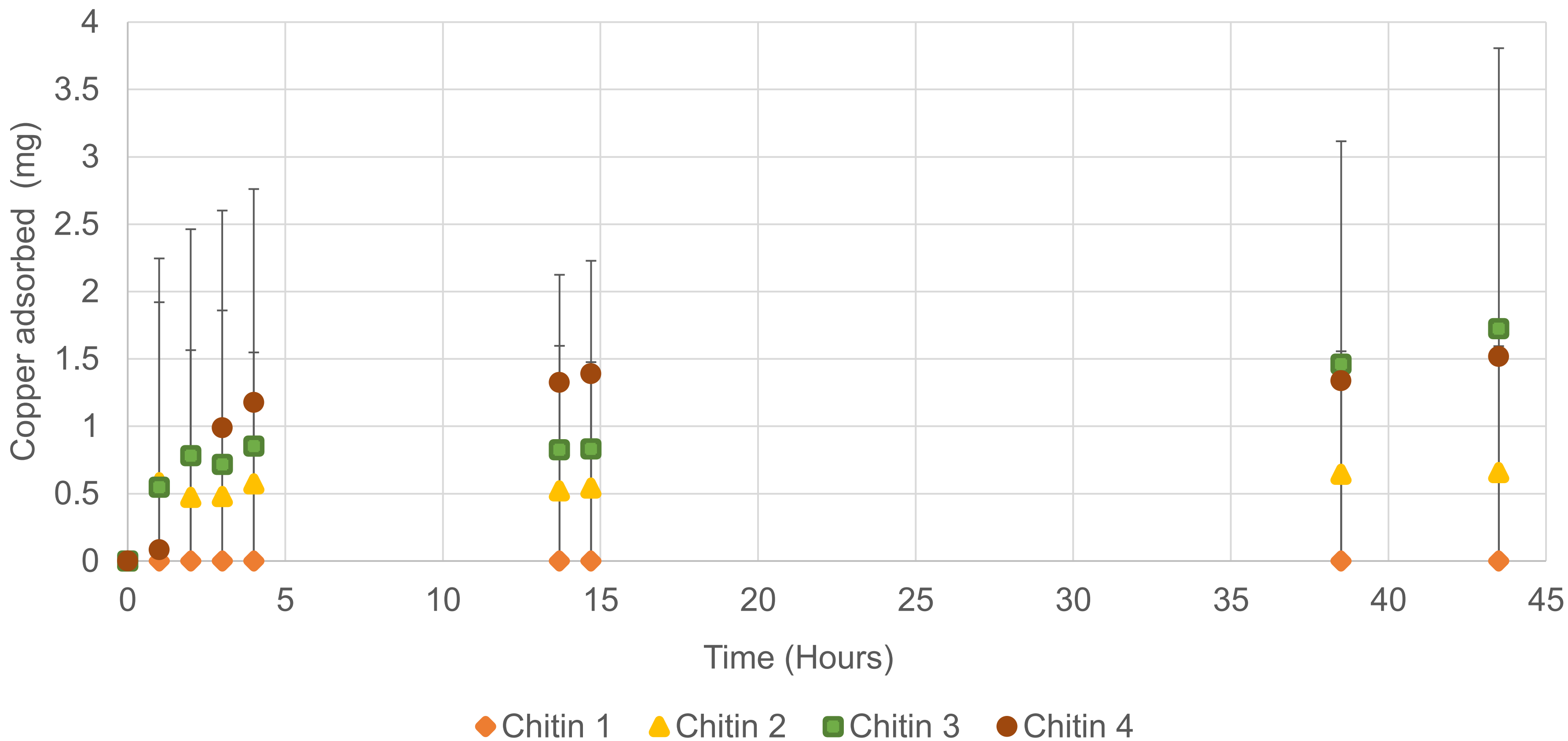
Results

Chitin: Effect of Extraction steps on Ferrous ion adsorption



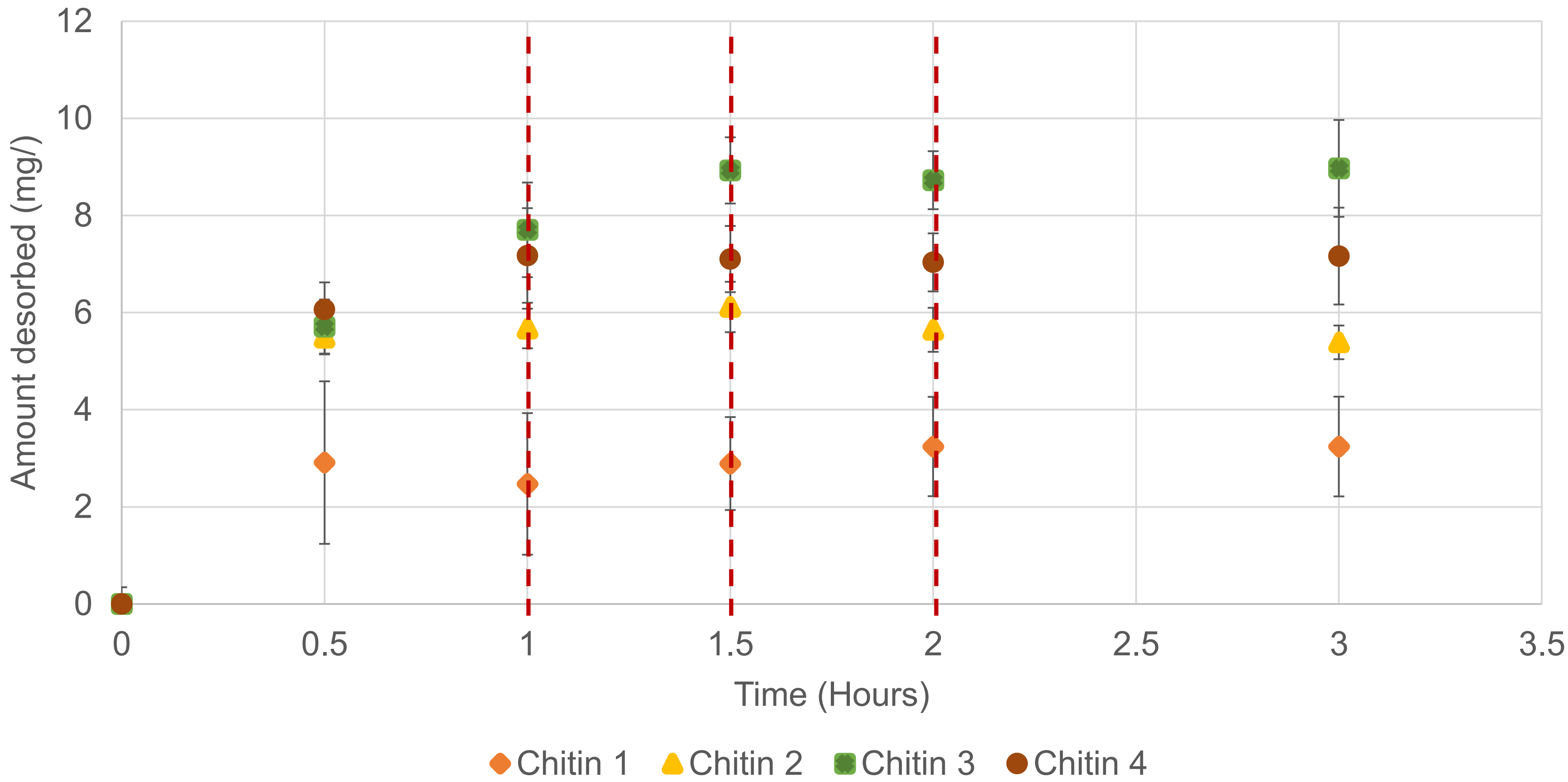
Ferrous ion adsorption on 0.5 g Chitin in 200 mL of 175 mg/L Ferrous ions

Chitin: Effect of Extraction steps on Copper ion adsorption



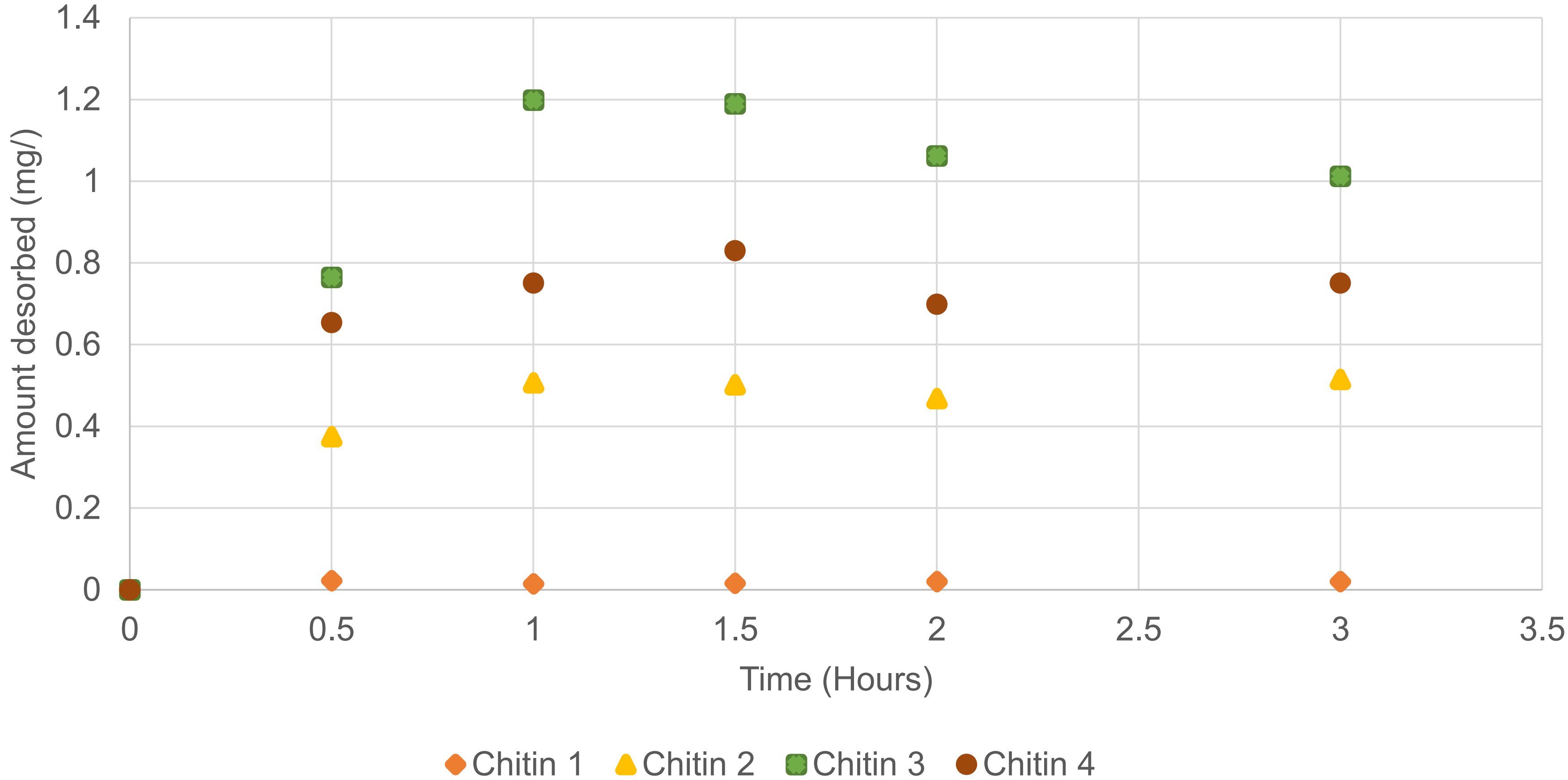
Copper ion adsorption on 0.5 g Chitin in 200 mL of 145 mg/L Copper ions

Chitin: Effect of Extraction steps on Ferrous ion desorption



Ferrous ion desorption of 0.5 g Chitin-Ferrous in 100 mL of 0.1M H_2S0_4

Chitin: Effect of Extraction steps on Copper ion desorption



Copper ion desorption of 0.5 g Chitin-Copper in 100 mL of 0.1M H_2SO_4

Chitin: Effect of Extraction steps on Ferrous and Copper Absorption Capacities

Ferrous and copper ion adsorption capacity for Chitin from Fly larvae (*Hermetia Illucens*)

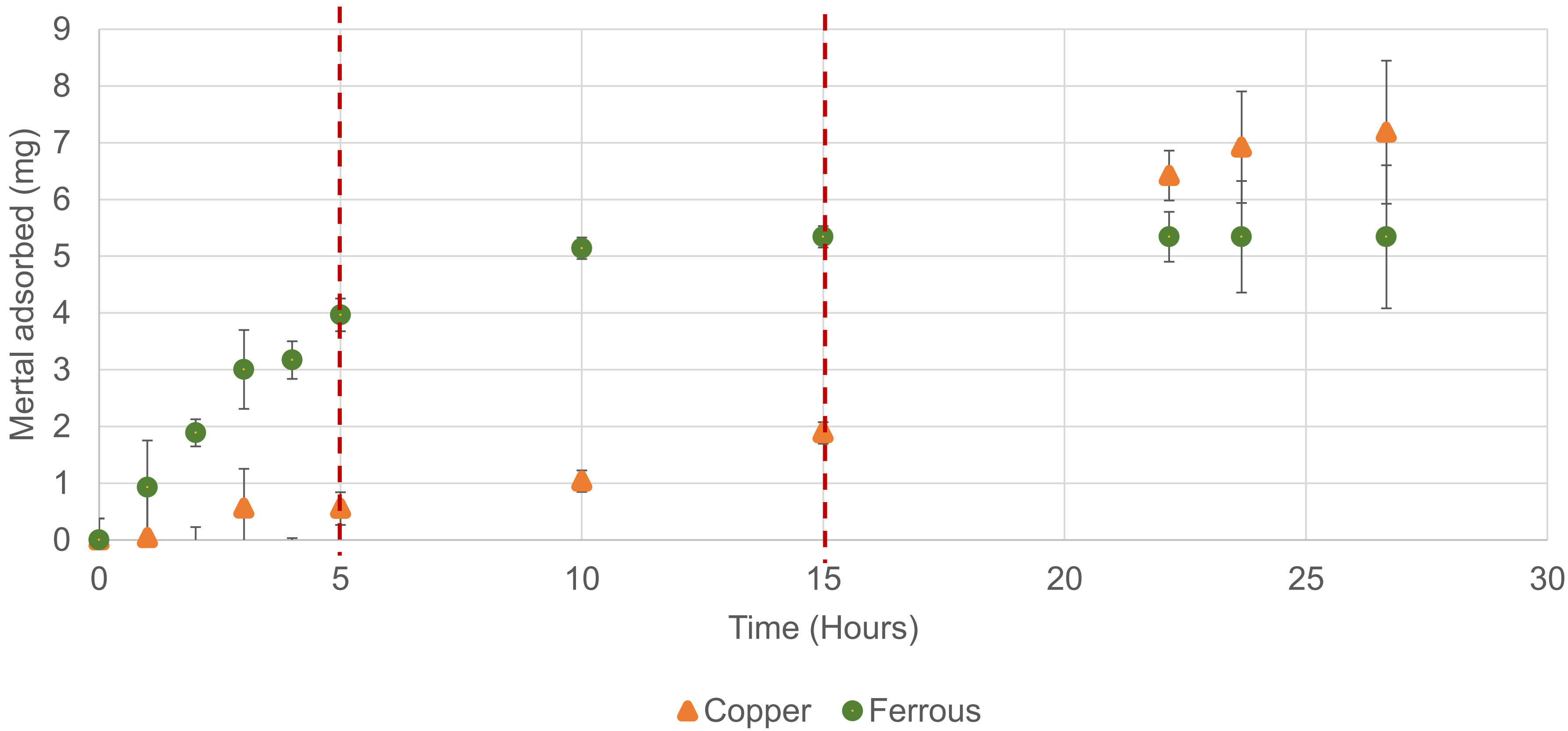
Product	Extraction sequence	Ferrous, Copper adsorption Start pH	Ferrous, Copper Adsorption Final pH	Ferrous adsorption capacity (Fe^{2+} mg/g chitin)	Copper adsorption capacity (Cu^{2+} mg/g chitin)
Chitin 1	Demineralization, Deproteination, Decolourization	3.45	3.56	10.8±0.20	0±1.02
Chitin 2	Demineralization, Deproteination	3.47	3.61	11.7±0.286	1.40±0.937
Chitin 3	Deproteination	3.46	4.05	13.9±0.327	1.33±2.08
Chitin 4	Raw fly larvae	3.45	6.71	13.9±0.413	2.81±1.01

Chitin: Effect of Extraction steps on Ferrous and Copper ion desorption

Table: Yield, production cost and recovery cost for Chitin from Fly larvae (*Hermetia Illucens*)

Product	Extraction sequence	Relative Yield (%)	Reagent Production cost (R/kg)	Recovery costs (R/g Fe)
Chitin 1	Demineralization, Deproteination, Decolourization	4.00	12100	1120
Chitin 2	Demineralization, Deproteination	4.75	385	32.9
Chitin 3	Deproteination	25.3	29.2	2.10
Chitin 4	Raw fly larvae	100	0	0

Chitin 3: Selective Adsorption of Ferrous ions in Copper-Ferrous leachate solution



Adsorption on 0.5 g Chitin 3 in 200 mL of 215 mg/L Copper and 130 mg/L Ferrous

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Circular economy in Waste Industry

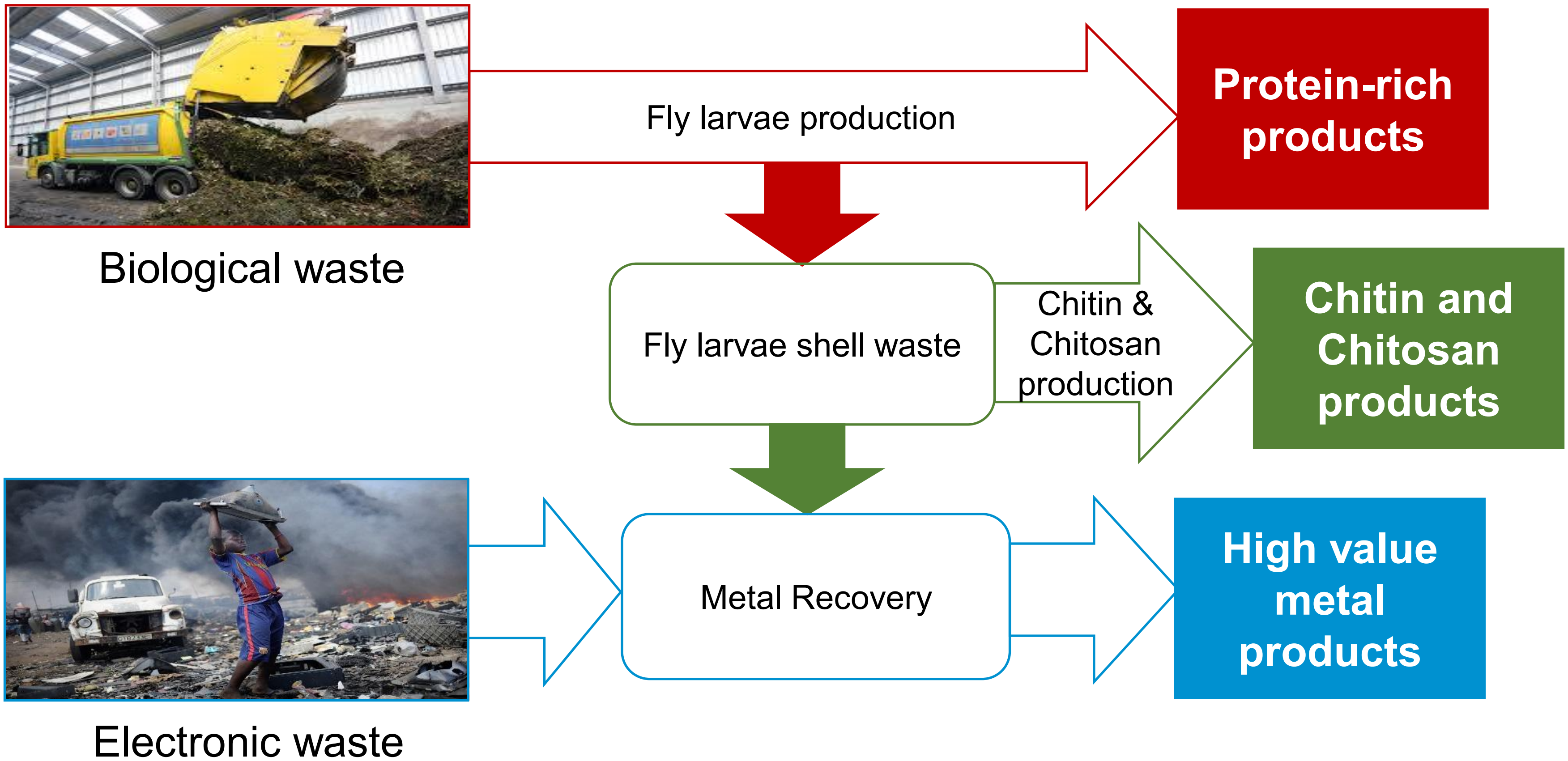

Figure: Potential circular economy in the use of bio-waste to remediate electronic waste

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Thank you for your attention

Any questions

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