



WASTE FISH SCALE AS COST EFFECTIVE ADSORBENT IN REMOVING ZINC AND FERUM ION IN WASTEWATER

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ABSTRACT

Biosorption of heavy metals by *Mozambique tilapia* (*M. tilapia*) fish scales is one of the treatment that has emerged as an environmental friendly method for the removal of metal from synthetic and domestic wastewater. The objectives of this study are to characterize the fish scale, determine the adsorption isotherm and biosorption kinetics in synthetic wastewater, and efficiency of fish scale in removing zinc (Zn) ion and ferum (Fe) ions in domestic wastewater. After biosorption process, scanning electron microscopy (SEM-EDX) analysis shows the presence of shiny bulky particles that indicate the appearance of Zn and Fe ion. Fourier-transform infrared (FTIR) spectrum confirmed the involvement of nitro compound, carbonyl and amine group in biosorption process. The results also show that optimum condition of Zn ion was best selected in removing heavy metal in domestic wastewater. In addition, Langmuir and pseudo-second-order models exhibited the best fit data for isotherm and kinetic study, respectively. This study highlighted that *M. tilapia* fish scale is a promising adsorbent in removing Zn and Fe ion from synthetic and domestic wastewater solution.

Keywords: biosorption, fish scale, Fe, *tilapia*, Zn.

INTRODUCTION

Some metals, such as Zn and Fe ions are considered bioessential. However, even bioessential metals may cause physiological and ecological problems if present at significant concentrations (Lu *et al.*, 2007). Small amount of heavy metal can result in physiological damage and easily absorbed into the human body (Wong *et al.*, 2003; Othman *et al.*, 2011). Due to its toxicity towards aquatic, human and other forms of life, its removal from polluted water has become one of the most imperative environmental issues (Villaescusa *et al.*, 2004; Akar and Tunali, 2006; Witek-Krowiak *et al.*, 2011).

Currently, the uses of conventional method namely physical, chemical, and physicochemical have been applied to remove heavy metal from wastewater. However, the application of these methods such as chemical precipitation, electrochemical treatment, membrane technologies, adsorption on activated carbon often limited due to their high operating costs, low selectivity, incomplete removal, and production of large quantities of wastes (Das *et al.*, 2008; Witek-Krowiak *et al.*, 2011).

A new approach to remove heavy metals in wastewater has lead to exploration of the biosorption method as an alternative for conventional methods. It can be defined as a technique using physico-chemical binding for the removal of a metal or metalloid species or radionuclides or particulates from solution using biological material (Gok *et al.*, 2011). Seashell, mandarin peels, rice bran, crab carapace, pecan nutshell, algae-yeast, peanut shell, palm shell, and others have been discovered as a natural biosorbent to remove heavy metal (Tudor *et al.*, 2006; Pavan *et al.*, 2006; Kadir *et al.*, 2013; Lu *et al.*,

2007; Vaggetti *et al.*, 2009; Gok *et al.*, 2011; Witek-Krowiak *et al.*, 2011; Kadir and Puade, 2013). Febrianto *et al.*, (2009) reported that biosorption process is non-polluting, easy to operate, offers high efficiency of treatment of wastewaters containing low metal concentrations and possibility of metal recovery.

Recently, studies had reported the used of fish scale in biosorption (Nadeem *et al.*, 2008; Rahaman *et al.*, 2008; Srividya and Mohanty, 2009; Othman and Irwan, 2011). The cell wall surface of fish scale contained several of functional group such as carbonyl, nitro, and amine groups for metal ions attached onto fish scale and the porous layer may provide a good possibility of metal ions to be adsorbed on its surface (Kumar *et al.*, 2008; Nadeem *et al.*, 2008; Vieira *et al.*, 2011). However, limited research has been reported on the use of fish scales from Asian countries such as Malaysia. Therefore, this research will explore the unexploited property of local fish scales, *M. tilapia* available in abundance as waste material from the wet market, as a new biosorptive approach to remove target heavy metals such as Zn and Fe ions from wastewater (Nadeem *et al.*, 2008).

MATERIALS AND METHODS

Preparation of biosorbent

Waste *tilapia* fish scales were obtained from the fish market at Parit Raja, Batu Pahat. The fish scales were soaked in 15% nitric acid for 24 h and stored in a thick plastic container to remove any adhering dust and soluble impurity. The scales were further soaked in distilled water for 24 h and then dried in an oven at 60°C until they became constant weight. The dried scales were ground



with a mortar grinder, and the pulverized scales were sieved through 100 mesh to achieve 150 µm particle size (Srividya *et al.*, 2009; Sheikh and Sweileh, 2008).

Preparation of stock solutions

Zn and Fe ion solutions were prepared by dissolving 0.440 g of zinc sulfate and 0.484 g of ferric chloride in 100 ml of ultrapure water to produce a 1000 mg/L solution each. The synthetic solutions were then diluted from 1000 mg/L to desired concentration. All reagents used in this study were analytical grade.

Experimental design

Domestic wastewater samples were taken directly from the wastewater treatment plant in University Tun

Hussein Onn Malaysia, Batu Pahat. Domestic wastewater were collected once a week for a period of two months. The concentration of heavy metals in wastewater need to be identified before experimental works begin and optimum condition were applied based on the results from optimization study (Zayadi and Othman, 2013b). The working condition of Zn and Fe ion in domestic wastewater is shown in Table-1. The biosorbents were filtered through a 0.45 µm filter paper and stored in an airtight container for further analysis using SEM-EDX, XRF, and FTIR analyses. Finally, the supernatants were stored in airtight plastic bottles and analyzed by inductively coupled plasma–mass spectrometry (ICP-MS). All experiment analysis was conducted in triplicate.

Table-1. Working range of Zn and Fe ions in domestic wastewater.

Heavy metals	pH	Biosorbent dosage (g)	Contact time (hr)	Initial metal ion concentration (µg/L)
Zn	6.0	0.020	3	9.771-11.117
Fe	5.5	0.001	2	0.281-0.348

Tables 2 and 3 show working ranges of Zn and Fe ions for kinetic and isotherm modeling, respectively. These working ranges were optimized from a batch study. The correlation coefficient R^2 for both models was obtained using Microsoft Office Excel 2010 for statistical analysis.

Table-2. Kinetic modeling.

Heavy metals	Zn	Fe
pH	6.0	4.5
Biosorbent dosage (g)	0.020	0.800
Concentration of heavy metal (µg/L)	10.000	300.000
Contact time- kinetic study (min)	5-300	5-300

Table-3. Isotherm modeling.

Heavy metals	Zn	Fe
pH	6.0	4.5
Biosorbent dosage (g)	0.020	0.800
Contact time(hr)	3	3
Concentration of heavy metal – isotherm study (µg/L)	10.000-17.000	300.000-1000.000

Data analysis of biosorption efficiency

Zn and Fe ion uptake were calculated through the concentration difference method (Zayadi and Othman, 2013a; Zayadi and Othman, 2013b). The sorption percentage and uptake capacity of Zn and Fe ions were determined using Eqs. (1) and (2):

$$\text{Sorption (\%)} = [(C_0 - C_f) / C_0] \times 100 \quad (1)$$

where C_0 is the initial metal concentration (µg/L) and C_f is the final metal concentration (µg/L).

$$q = (C_0 - C_f) (V / M) \quad (2)$$

where q is the metal uptake (µg/g), C_0 is the initial metal concentrations in solution (µg/l), C_f is the final metal concentrations in solution (µg/l), V is the volume of solution (l), and m is the mass of biosorbent (g).

RESULT AND DISCUSSIONS

XRF analysis

XRF analysis was used to analyze the chemical composition in *M. tilapia* fish scales before and after chemical pretreatment (washing) with nitric acid. Table-4 shows chemical composition and concentration of untreated and treated fish scales use in this study. Untreated fish scales show the presence of chemical compounds such as iron oxide (FeO) and plumbum oxide (PbO). Previous studies reported that most part of fish has natural ability to concentrate metals or pollutants in water.



Fish is one of the most vulnerable to toxic substances present in water compare to other water dwellers (Aktar *et al.*, 2011). In this study, the presence of FeO and PbO in fish scales need to be removed to increase the biosorption capacity of fish scales.

The results of XRF analysis clearly show the absence of FeO and PbO in preparation of biosorbent after chemical pretreatment with nitric acid. A clean biosorbent is important to enhance the efficiency of biosorption process. Among various chemical modification methods, chemical pretreatment (washing) has been selected due to its simplicity and efficiency. Acid-washing can removes the mineral elements and improves the hydrophilic nature of surface (Bhatnagar *et al.*, 2013).

The results from Table-4 also demonstrates calcium oxide, (CaO) as the highest chemical compound in biosorbent at 63.8%. The presence of CaO is important as it confirms the high potential and efficiency of *M. tilapia* fish scales in adsorbing heavy metals. Analysis of XRF after biosorption of heavy metals can be used to correlate the presence of CaO which is responsible in adsorption of Zn and Fe ions through redox reaction and precipitation. However, XRF analysis after biosorption of Zn and Fe ions were not conducted in this study.

Table-4. Chemical Composition and Concentration of Treated Fish Scales.

Formula	Concentration (Untreated)	Concentration (Treated)
Original (g)	7	7
Added (g)	3	3
CO ₂	0.10%	0.10%
CaO	52.40%	63.80%
P ₂ O ₅	28.60%	32.40%
FeO	9.75%	-
MgO	3.25%	0.24%
Al ₂ O ₃	2.04%	-
PbO	1.76%	-
SO ₃	1.51%	2.64%
SrO	0.20%	0.17%
SiO ₂	0.16%	0.24%
Na ₂ O	0.15%	-

SEM analysis

Figure-1 shows Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX) micrographs of native *M. tilapia* fish scales (treated). The fish scale (Figure-1) appears to have a rough surface and are characterized by white and dark regions. The white region refers to inorganic material containing a high proportion of

calcium and phosphorus whereas the dark region is rich in protein as it has a high proportion of carbon and oxygen (Srividya and Mohanty, 2009). Figures 2 and 3 represent the SEM-EDX of Zn and Fe ions loaded biosorbent, respectively. These micrograph clearly shows the presence of new shiny bulky particles over the surface of metal ions loaded biosorbent which are absent in the native biosorbent. Physical adsorption might be responsible mechanism in this study. The shiny bulky particles indicate presence of heavy metal namely, Zn and Fe ions after biosorption.

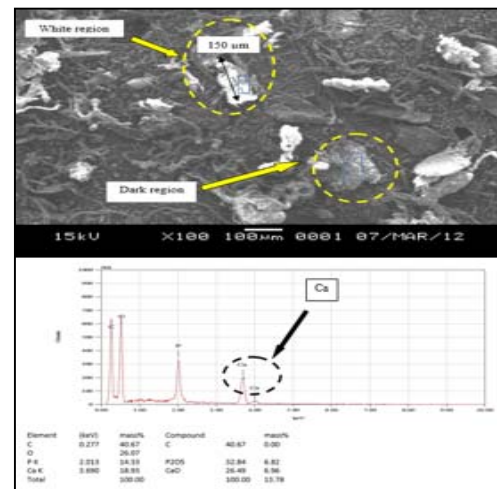


Figure-1. SEM-EDX of *tilapia* scale native biosorbent.

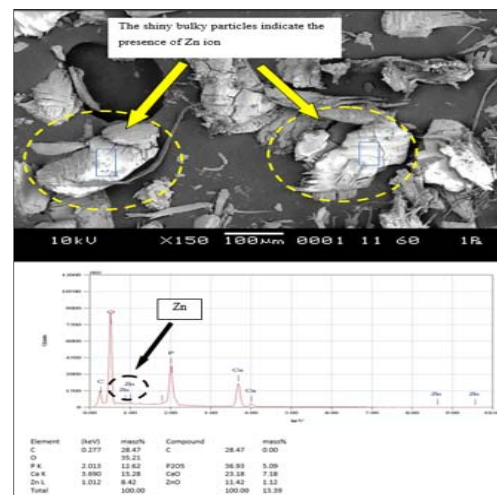


Figure-2. SEM-EDX of Zn ion loaded biosorbent.

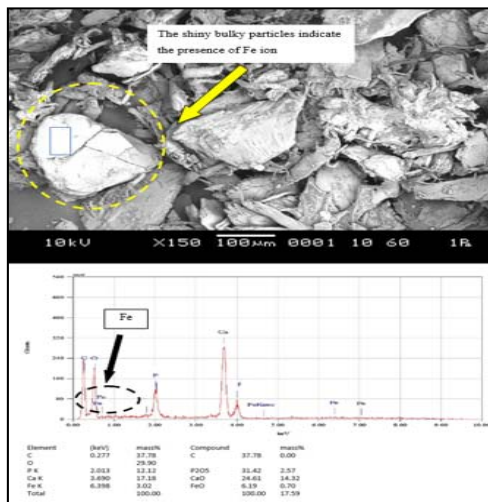


Figure-3. SEM-EDX of Fe ion loaded biosorbent.

FTIR analysis

Figure-4 shows FTIR spectra of fish scales before (treated) and after Fe and Zn ions adsorption studied in the range of 600–4000 cm^{-1} . Previous study shows many functional groups shifted to different frequency level or disappeared after adsorption, indicating the possible involvement of functional groups for uptake of metal cations (Chowdury *et al.*, 2012). FTIR spectra of native biosorbent (Figure 4 a) shows peak at 1718 cm^{-1} between the region 1740 cm^{-1} and 1700 cm^{-1} . Change in the intensity and shift in position of the peaks could be observed in the FTIR spectrum after Fe and Zn ions adsorption on *M. tilapia* fish scales. The shifting of peak of native biosorbent at 1718 cm^{-1} to 1728 cm^{-1} (Figure 4 b), and 1722 cm^{-1} (Figure-4c) characterize carbonyl groups (C=O) stretching from carboxylic acid, ketone, and aldehyde (Pavia *et al.*, 2009; Srividya and Mohanty, 2009).

The sharp peak of native biosorbent observed at 1478 cm^{-1} (Figure-4a) ranging from 1550 cm^{-1} to 1350 cm^{-1} shows a strong band in the infrared spectrum. The peak of native fish scales at 1478 cm^{-1} shift to 1490 cm^{-1} (Figure-4b) and 1498 cm^{-1} (Figure-4c) for Fe and Zn ions loaded biosorbent, respectively. The peaks produced from 1550 cm^{-1} to 1350 cm^{-1} are due to involvement of nitro compound (N=O) group in binding Fe and Zn ions (Pavia *et al.*, 2009).

The characteristic band region at 1350 cm^{-1} to 1000 cm^{-1} suggests the presence of amines group (C-N) in the biosorbent. Figure-4 a of native biosorbent shows peaks at 1176 cm^{-1} . After the biosorption process, the peak shift to 1168 cm^{-1} (Figure 4 b) and 1186 cm^{-1} (Figure 4 c) for Fe and Zn ions loaded biosorbent, respectively.

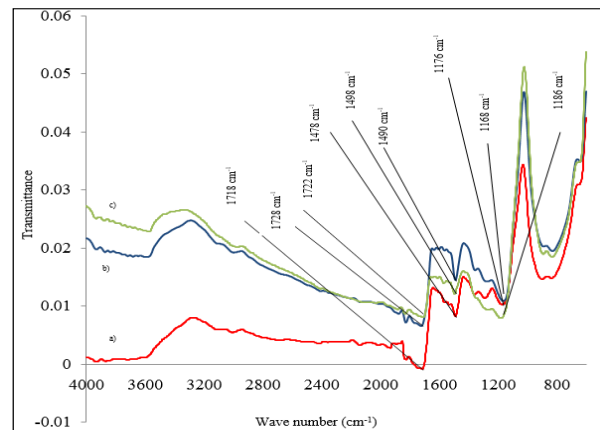


Figure-4. (a) FTIR spectra of native biosorbent, (b) FTIR spectra of Fe ion loaded biosorbent, (c) FTIR spectra of Zn ion loaded biosorbent.

Application of fish scales in domestic wastewater

Application of *M. tilapia* fish scales in domestic wastewater was performed to determine the efficiency of fish scales in heavy metals removal. Table-5 shows removal and metal uptake of Fe and Zn ions under optimum condition of Fe ion. From the results, removal of Zn ion in Fe ion condition shows significantly different in percentage removal compare to batch study (Zayadi and Othman, 2013a). This also explained that the application of Fe ion condition was poor suitable for Zn ion removal. Table-6 shows removal and metal uptake of Zn and Fe ions under optimum condition of Zn ion. Under optimum conditions for Zn ion, the highest removal of Zn and Fe ions were 85.4 % and 53.9 %, respectively. Less adsorption occurred in the actual wastewater sample compared to synthetic solutions due to the presence of other metals. Various pollutant were found in wastewater systems in example organic pollutants, therefore presence of these pollutants normally prevents the removal of other species (Barakat, 2011). In comparison to Fe ion condition, application by using Zn ion condition was well-suited. Optimum condition of Zn ion was best selected and more suitable to apply in wastewater compare to optimum conditions Fe ions due to higher removal of Zn and Fe ions.

Table-5. Removal and metal uptake of Fe and Zn ion under optimum condition of Fe ion.

Heavy metal	Removal (%)	Metal uptake ($\mu\text{g/g}$)
Ferum	57.4-59.3	21.48-24.11
Zinc	57.1-60.0	0.73-0.79

**Table-6.** Removal and metal uptake of Zn and Fe and ions under optimum condition of Zn ion.

Heavy metal	Removal (%)	Metal uptake (µg/g)
Zinc	82.0 – 85.4	41.36 – 46.00
Ferum	52.2- 53.9	781.96-875.94

Kinetic modeling

Batch rate analysis can be used to recognize the practical application of adsorption and design of the batch reactor, and some kinetic models with varying degree of complexity are available to illustrate the kinetics of heavy metal biosorption in batch systems. The sorption kinetics is significant in the treatment of wastewater, as it provides valuable insights into the reaction pathways and mechanisms of sorption reactions. Since biosorption is a metabolism-independent process, it would be expected to be a very fast reaction (Gupta *et al.*, 2001; Gupta *et al.*, 2006; Gupta *et al.*, 2010). Pseudo-first order and pseudo-second order were used in this study to understand the controlling mechanism of heavy metal biosorption.

The pseudo-first order kinetic model assumes that “metal sorption process is first order in nature as it is only dependent on the number of metal ions present at the specific time in the solution” (Lagergren, 1898). Pseudo-first order Lagergren can be presented as:

$$\log (q_e - q_t) = \log q_e - (K_1 t / 2.303) \quad (1)$$

where K_1 (min^{-1}) is the rate constant of the pseudo-first-order adsorption model, and q_e and q_t ($\mu\text{g g}^{-1}$) are the amounts of metal ions adsorbed onto biosorbent at equilibrium and at any time t (min), respectively. q_e and K_1 can be calculated from the slope and intercept of the plot of $\log (q_e - q_t)$ versus t .

Pseudo-second order kinetic model assumes that the metal biosorption process is dependent on the number of metal ions present in the solution as well as the free biosorption sites on the biosorbent surface (Ho and McKay, 2000). The Pseudo-second order equation is expressed as:

$$t / q_t = (1 / K_2 q_e^2) + (t / q_e) \quad (2)$$

where K_2 is the rate constant of the pseudo-second-order biosorption model ($\text{g } \mu\text{g}^{-1} \text{ min}^{-1}$). q_e and K_2 can be calculated from the slope and intercept of the plot of t/q versus t .

The reaction rate constants and correlation coefficients of pseudo-first-order are shown in Table-7, and the pseudo-second-order parameters are listed in Table-8. Based on Table 7, The Lagergren first-order rate constants, K_1 was 0.700 min^{-1} and mass of metal adsorbed at equilibrium, q_e achieved at $0.950 \mu\text{g/g}$ for Zn ion. The

Lagergren first-order constants, K_1 and q_e were determined from the slope and y-intercept of this plot, respectively. In this study, the correlation coefficient, R^2 obtained at 0.708. Study on Fe biosorption shows that the Lagergren first-order rate constants K_1 obtained at 0.016 min^{-1} and mass of metal adsorbed at equilibrium, q_e was achieved at $298.951 \mu\text{g/g}$. The correlation coefficient obtained in this study was 0.847.

Meanwhile, Table-8 shows where the R^2 value of second-order kinetic of Zn ion obtained at 0.999. The pseudo second-order rate constant of biosorption, K_2 and q_e obtained at 0.001 min^{-1} and $49.261 \mu\text{g/g}$, respectively. The result shows value of q_e was close to experimental value, q_{exp} at $45.500 \mu\text{g/g}$. Besides, Table 8 also shows pseudo second-order rate constant of Fe ion biosorption, K_2 and q_e obtained at 0.003 min^{-1} and $25.445 \mu\text{g/g}$, respectively. The value of q_e in pseudo second-order was close to experimental value, q_{exp} at $24.100 \mu\text{g/g}$. R^2 value for the second-order kinetic obtained at 0.998. The pseudo-second order kinetics was best fitted to kinetic data. In comparison with the adsorption rate constants of both models, the second order model provided the best correlation of the data.

Table-7. Pseudo-first order.

Pseudo-first order	Zn	Fe
q_{exp} ($\mu\text{g/g}$)	45.500	24.1000
q_e ($\mu\text{g/g}$)	0.950	298.951
$K_1(\text{min}^{-1})$	0.700	0.016
R^2	0.708	0.847

Table-8. Pseudo-second order.

Pseudo-second order	Zn	Fe
q_{exp} ($\mu\text{g/g}$)	45.500	24.100
q_e ($\mu\text{g/g}$)	49.261	25.445
$K_2(\text{min}^{-1})$	0.001	0.003
R^2	0.999	0.998

Biosorption of Zn and Fe ions of fish scales followed the pseudo-second order kinetics rather than pseudo-first order kinetics. The value of q_e obtained from pseudo-second order kinetic model was in close agreement with experimental value (q_{exp}) whereas the value of q computed from pseudo-first order kinetic model did not agree with the experimental value. A time lag, probably caused by the presence of boundary layer or external resistance controlling at the beginning of the sorption process was argued to be the responsible factor behind the disagreement (Febrianto *et al.*, 2009). This indicates that pseudo-first order kinetics might be insufficient to interpret Zn and Fe ions biosorption.



The R^2 , coefficient of correlation for second-order kinetic model was closer to 1 compared to first-order. Both factors suggest that the sorption of Zn and Fe ions followed the second-order kinetic model and rate-limiting step might involve chemical biosorption process involving valence forces through the sharing or exchange of electrons between sorbent and sorbate (Febrianto *et al.*, 2009).

Sorption isothermal modeling

The analysis of adsorption data is important for developing an equation which accurately represents the results and which could be used for design purposes. The linear regression was used to determine the most fitted model among all written isotherms (Gupta *et al.*, 2010). Several isotherm equations have been widely used for the equilibrium modeling of biosorption systems; there is Langmuir, Freundlich, Brunauer-Emmet-Teller (BET) equations.

The Langmuir monolayer sorption isotherm is based on three assumptions (Cruz *et al.*, 2004). First, the solid surface presents a finite number of energetically uniform identical sites. Second, no interaction exists among adsorbed species, i.e., the amount adsorbed has no influence on the adsorption rate. Third and last, a monolayer is formed when the solid surface reaches saturation (each active site were occupied by one particle). Accordingly, the linearized Langmuir equation is given as:

$$C_e / q_e = (1 / q_{\max} b) + (C_e / q_{\max}) \quad (3)$$

where q_e is the equilibrium sorption capacity ($\mu\text{g g}^{-1}$), and C_e is the equilibrium metal-ion concentration ($\mu\text{g L}^{-1}$). q_{\max} is the maximum amount of metal ion per unit weight of adsorbent to form a complete monolayer on the surface ($\mu\text{g g}^{-1}$), and b is a constant related to the affinity of binding sites with the metal ions ($\text{L } \mu\text{g}^{-1}$) (Langmuir, 1918).

The Freundlich isotherm model assumes that the uptake of metal ions occurs on a heterogeneous surface by multilayer adsorption and that the amount of adsorbate adsorbed increases infinitely with an increase in concentration (Freundlich, 1906). This model is empirical in nature which further assumes that the stronger binding sites are occupied first and that the binding strength decreases with increasing degree of site occupation (Khambhaty *et al.*, 2009). Freundlich (1906) created Freundlich equation and it is an empirical equation based on adsorption on heterogeneous surface. The linearized Freundlich equation is given as:

$$\log q_e = \log K_F + [(1/n) \log C_e] \quad (4)$$

where K_F is the Freundlich constant denoting adsorption capacity ($\mu\text{g/g}$), and q_e is the uptake of metal per unit weight of biosorbent ($\mu\text{g/g}$). C_e is the equilibrium

concentration of metal ions in solution ($\mu\text{g/l}$), and n is the empirical constant indicating adsorption intensity ($1/\mu\text{g}$).

Brunauer-Emmet-Teller (BET) isotherm is an equation for multimolecular adsorption at the adsorbent surface and assumes that a Langmuir isotherm applies to each other. The same kinetics concept proposed by Langmuir is applied to this multiple layering process, that is the rate of adsorption on any layer is equal to the rate of desorption from that layer. These models can provide information of metal-uptake capacities and differences in metal uptake between various species (Brunauer *et al.*, 1938). The linear form of the BET model is given as:

$$q = (K_B C q_m) / \{ (C_s - C) [1 + (K_B - 1) (C/C_s)] \} \quad (5)$$

where q is the amount of metal ions adsorbed per specific amount of adsorbent ($\mu\text{g/g}$), C is the equilibrium concentration ($\mu\text{g/l}$), q_m is the maximum amount of metal ions required to form a monolayer ($\mu\text{g/g}$), and K_B is the BET constant (Brunauer *et al.*, 1938).

The corresponding constants and correlation coefficient (R^2) associated with each linearized model are given in Table-9, for Zn and Fe ions. Based on Table 9, the maximum achievable uptake of Zn ion, q_{\max} was obtained at $72.993 \mu\text{g/g}$, adsorption constant, b was $2.017 \text{ L } \mu\text{g}^{-1}$, and R^2 value for the Langmuir model achieved at 0.997. Meanwhile, for Fe ion, the maximum achievable uptake, q_{\max} was obtained at $55.249 \mu\text{g/g}$ and adsorption constant, b was $0.004 \text{ L } \mu\text{g}^{-1}$. The R^2 value for the Langmuir model achieved at 0.990.

Table-9. Langmuir isotherm.

Langmuir	Zn	Fe
R^2	0.997	0.990
$q_{\max} (\mu\text{g/g})$	72.993	55.249
$b (\text{L } \mu\text{g}^{-1})$	2.015	0.004

The Freundlich constants are shown in Table-10. The rate constants of Freundlich isotherms namely, K_F and n can be evaluated from the slopes and intercepts. For Zn ion, K_F and n value obtained from a plot of Freundlich isotherms were $49.023 \mu\text{g/g}$ and 4.503 l/mg , respectively. The correlation coefficient value was found to be 0.890. Besides, biosorption of Fe ion for K_F and n value obtained from a plot of Freundlich isotherms were $2.236 \mu\text{g/g}$ and 2.222 l/mg , respectively. Moreover, the correlation coefficient value was found to be 0.957.

**Table-10.** Freundlich isotherm.

Freundlich	Zn	Fe
R^2	0.890	0.957
n (1/mg)	4.503	2.222
K_F (μg/g)	49.023	2.236

The reaction rate constants and correlation coefficients of BET are shown in Table-11. The maximum amount of Zn ion, q_m was 53.19 μg/g and BET constant, K_B obtained was 62.667 μg/g. From the analysis of BET equation, the correlation coefficient, R^2 for BET model achieved at 0.979. The maximum amount of Fe ion, q_m was 15.848 μg/g and BET constant, K_B obtained was 3.108 μg/g. From the analysis of BET equation, the correlation coefficient, R^2 for BET model achieved at 0.374.

Table-11. BET isotherm.

BET	Zn	Fe
R^2	0.979	0.374
K_B (μg/g)	62.667	3.108
q_m (μg/g)	53.192	15.848

These results depict that Langmuir model better fits the adsorption process of Zn and Fe ions by fish scales in comparison to the Freundlich and BET model due to the high value of correlation coefficient, R^2 . Thus, the results of the present study indicate that biosorption of Zn and Fe ions onto fish scales of *M. tilapia* is monolayer where the solid surface presents a finite number of energetically uniform identical sites. Langmuir equation relates the coverage of molecules on a solid surface to concentration of a medium above the solid surface at a fixed temperature. Langmuir model also assumed that there are no interactions among adsorbed species and a monolayer is formed when the solid surface reaches saturation (Cruz *et al.*, 2004; Febrianto *et al.*, 2009).

CONCLUSIONS

The results prove that *M. tilapia* fish scales have high possibility and efficiency in removing Zn and Fe ions in wastewater. It is a promising biosorbent and poses as an environmental friendly adsorbent to society and environment.

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