ASSESSMENT OF POTENTIAL FUNGAL SPECIES ISOLATED FROM ZINC INDUSTRIAL SEDIMENT WASTES FOR LEAD SORPTION

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ABSTRACT

Different isolates of native fungal species of zinc industry sediments were used for biosorption experiments. All isolates which were isolated from industrial sediments were tested for metal tolerance against the Pb 0.00-2000mg/L. The degree of tolerance against Pb was measured by minimum inhibitory concentration (MIC) in the presence of Pb. Four isolates PZ1, PZ2, PZ3 and PZ4 showed the highest tolerance against the tested heavy metals. Analysis of morphological character and sequencing of ITS-rDNA revealed that four isolates were belongs to ascomyete Aspergillus fumigatus. It was shown that A.fumigatus PZ1 had the highest and A.fumigatus PZ4 possessed the lowest metal tolerance. Sorption experiment was conducted using living and dead biomass of those four isolates for Pb sorption under batch condition. The highest sorption amount was observed for live and dead biomass of A. fumigatus PZ1, being about 1.36 mg/g, 0.37 mg/g, respectively. The maximum Pb removal efficiency (RE) observed by live biomass of A. fumigatus PZ1 was about 76.73% and 95.35% by dead biomass of A.fumigatus PZ2. Kinetic study by four isolates revealed that sorption processes were best described by Pseudo Second order model for Pb ions. The results of four isolates sorption assessment were obtained through the TOPSIS method. Live biomass of A.fumigatus PZ1 and dead biomass of A.fumigatus PZ4 showed the highest ranking for lead sorption. This experiment concluded that A.fumigatus PZ1 live biomasses which are adapted in zinc industries sediment waste for long term may be used as a bioindicator for monitoring similar sites.

KEYWORDS:
Pb, biosorption, monitoring, isotherm, bioindicator

INTRODUCTION

Zinc industries wastes contain high percentage of heavy metals, such as Pb, Zn and Cd, which are the final products of leaching and purification processes. All filter cakes of zinc processes contain high amounts of heavy metals, such as cadmium sulfate with solubility of 76.7g/100ml, zinc sulfate 57.7 g/100ml, and lead sulfate 0.0404 g/100 ml in water at 25°C [1]. Solubility of this waste in water caused heavy metal to be bio available and it is the main source for contamination of agricultural, land and surface water.

Some of microorganisms were used as sentinels or biological indicators in order to assess metal pollution in aqueous ecosystem [2]. The initial focus of biomonitoring was on bacteria, but now the range of taxa has been introduced to enfold other microscopic organisms, such as algae, fungi and protozoa [3]. Several techniques, such as chemical precipitation, electrolysis, oxidation/reduction, ion-exchange, and membrane filtration, have been used for metal removal [4]. Removing heavy metals in low concentrations of aqueous solution using physicochemical processes requires sophisticated technologies and high costs. During the past decades, it has been demonstrated that, among the biosorbents, the fungi appeal to the researchers most, due to their higher ability to remove high concentrations of heavy metals from yeast, bacteria and algae [5]. Advantages of heavy metal removal by microorganisms include: low cost, high efficiency, no need for landfill, low-cost transportation, no need for skilled workforce, reduction in chemicals, reusability, specific method for metal recovery also reduction in toxic metals in the environment. They can adapt and grow in environments with high metal concentrations [6]. Fungi and yeast require some heavy metals, such as cooper, zinc, cobalt, manganese as nutrients for growth. Dead and live biomasses of fungi and yeast are able to accumulate toxic metals; cadmium and lead to recover precious metals; silver and gold [7]. Metal uptake by the fungus depends on: first, environmental factors, such as nutrients, oxygen, moisture, pH, temperature, light [8, 9] metal...
concentration, metal species, sorbent species, ionic potential of adsorbent, fluidity of solvent also surface area, porosity, chemical bond; C, H, N, S of adsorbent, second, microorganism-dependent factors, such as sporulation, fungi species, age, gender, genome, species competition [10], diversity [11]. *Acinetobacter sp.* was tested under the stress of lead ions. Then the results of SEM and TEM analysis noted that the amino, carboxy1, and hydroxyl groups were the most ionizable and functional group that interact with lead ions[12]. Biosorption of copper and cadmium by *Rhizopus arrhizus* and *Aspergillus niger* was studied as a function of initial pH and metal ion concentration. The conclusion showed that *R. arrhizus* had higher sorption than *A. niger* for removal of Cu(II) and Cd(II) ions from wastewater[13].

Potential of fungal strains isolated from tanning effluent were evaluated for copper resistant and heavy metal removal from industrial wastewater at a laboratory scale. The heavy metal uptake was determined for each isolate. Findings revealed that *Gliocladium viride* sp found to be highly copper tolerant fungus and exhibited greater growth than other fungal species and *Gliocladium viride* species had greater Cu removal efficiency (96.98 %) than other fungal species [14]. Studying the tolerance of lead by the *Enterobacter aerogene* proved that the bacteria had different response to species of heavy elements [15]. Presence biological responses to a metal stress at the organism level mark a tool for metal ecotoxicity assessment [16].

The objective of this experiment was to investigate the biosorption of Pb by using several native fungi species which were adapted with zinc industries waste. Specifically, in this experiment, dead and live biomasses of several fungi species which had a high biomass growth rate were used for Pb sorption to be examined in aqueous solution.

**MATERIALS AND METHODS**

**Sampling.** Six sediment samples were collected from top of the stream bed (about 0-10 cm), which are contaminated by zinc industrials wastes which located at 5 km south of Zanjan town in north west of Iran and kept dry, in sterile plates at the temperature of 4 °C and were analyzed in the laboratory of Environmental Department of Zanjan Province, Iran. The wastes have been emitted from zinc industrial wastes for more than 15 years.

**Isolation of fungi.** Fungal population was determined by serial dilution method on media agar. The YGC agar media were prepared using *Yeast Extract Glucose Chloramphenicol (37 g/l, pH 5)* and distilled water sterilized in an autoclaving at 121°C and 124 kPa for 15 min, cooling down to room temperature were transferred to plates in the microbiology hood space. Sediment samples were diluted in sterile water with 50 mg/l Pb (NO3)2 and transferred to YGC agar surface for growth and incubated at 28 ± 1 °C for 5 days. Having grown the fungi for pure cultures preparation, a colony was obtained from growing fungi species and then placed on the surface of YGC agar plates. After inoculation incubated at 28 ± 1°C for 5 days. Single spore technique was used to prepare fungal isolates [18].

**Morphological characterization and identification of fungal isolates.** For micro-morphological observations used from MEA colonies and for description of colony criteria used from CYA colonies [19]. To identify the fungal isolates culture media PDA (Potato dextrose agar), MEA (Malt extract agar) and CYA (Czapek Yeast Extract Agar) were used. Growth rates were determined after 7 day of incubation on MEA and CYA media at 25 °C and 37 °C in the dark.

**Molecular studies.** Genomic DNA was extracted from seven-day-old colonies according to the procedure described by Liu et al. [20] with some variation. The ITS-rDNA was sequenced directly from PCR products using primer pair ITS1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS4 (5'-TCCCTCGCTTATGATGATG-3') [21].

**Screening fungal isolates for lead tolerance.** Metal resistance was determined by the minimum inhibitory concentration (MIC) against the isolated fungi. Different concentrations of Pb (NO3)2, (0.00, 250, 1000, 2000 mg/l) with YGC agar, prepared and inoculated with spore suspension of different isolates and three replicates of each concentration were used. The plates were incubated at 28 ± 1°C for five days. After incubation, the lowest concentration of lead which inhibited growth rate of fungi was defined as the minimum inhibitory concentration of the heavy metal (MIC) which inhibited visible growth of fungi [5]. The isolates showed better growth rate after incubation were considered concerning tolerance to metals.

**Live Biomass Experiment.** The removal of lead by live biomass of *A. fumigatus* strain was examined in four 250 mL Erlenmeyer flask containing 150 mL culture media (SDB). The medium was contaminated with Pb solution and maintained to have 20 ppm. Then, a 5-mL sample of each 4 flasks was picked up using a test tube and one drop of HNO3 normal was added to each in order to analyze Pb (initial metal concentration C0). PH of all 4 flasks were adjusted in pH 5 and then put in autoclave and sterilized. Later they were
cooled down at about room temperature then a colony of four fungus species was taken and transferred to 4 flasks and placed on orbital shaker (at 150 rpm) at 28±1 °C. For 7 days, all samples were filtrated and supernatant fraction was analyzed for the remaining Pb concentration (Cf) and all biomass washed and was dried in the oven at 50 °C and weighed to measure the mass of biomass (w). The (Ci) initial and final (Cf) metal concentrations were determined before and after the process. All of the experiments were replicated twice.

**Dead Biomass Experiment.** Live biomass of four isolates were prepared by (SDB) culture media and after the growth period, the biomass was harvested from the medium and washed twice with distilled water, inactivated using incubator at 121 °C and then dried at 50 °C for 24 h. Initial batch adsorption experiments of four isolates were carried out with (0.13-0.19) mg of dried biomass in a 100-ml solution at pH 5 and different lead concentrations (5, 10, 15, 20 mg/l). All of the experiments were replicated twice. Then, a 5-ml sample of each 4 flasks in test tube was obtained and kept in refrigerator to analyze Pb (initial metal concentration Ci). All 4 flasks were placed on orbital shaker (150 rpm) at 28±1 °C for 20 hours. After 20 hours, all samples were filtrated and supernatant fraction analyzed for analyzing Pb (final metal concentration Cf).

**Preparation of Heavy Metal Solution.** Stock solution (1000 mg/l) of Pb was prepared using salts of Pb (NO3)2. The concentration range varied between 5, 10, 15, 20 mg/l for single metal solution. pH was adjusted with dilute 0.1 N HCl or 0.1 N NaOH. Metal uptake was calculated through a method used by Zhang et al. [22]:

$$q = \frac{(C_i - C_f) \times V}{W}$$  \hspace{1cm} (1)

The sample was analyzed using direct air-acetylene flame, spectrophotometer AA 110 VARIAN in laboratories of Environmental Department of Zanjan Province as a method mentioned in published paper by Joseph W. [23]:

**Adsorption Efficiency.** Removal efficiency of metal ion by biosorbent was calculated as Anbia et al. [24]:

$$RE = \frac{(C_i - C_f) \times 100}{C_i}$$  \hspace{1cm} (2)

**Adsorption Models.** In order to compare the data obtained, two types of sorption models were used.

**Fungal identification.** After combining morphological criteria and sequencing of the ITS-rDNA, Aspergillus fumigatus Fresenius, Beitr was identified

**Minimum Inhibitory Concentration (MIC).** Samples of zinc waste sediment as well as seven fungal isolates were isolated. Four isolates belonging to Aspergillus fumigatus, namely, AspZ1, AspZ2, AspZ3, AspZ4, which were dominated in all the sediment samples were selected. These four fungi species were evaluated for minimum inhibitory concentration (MIC), contrary to different concentrations of Pb ions based on section 2.4. The MIC values were measured by radial growth rates of fungi in media which polluted by Pb ions. The effects
Lead concentration (mg/l)
Radial growth (cm)
0 250 500 1000 2000
0 2 4 6 8
AspZ1
AspZ2
AspZ3
AspZ4

FIGURE 1

of Pb ions on radial growth rate of different isolates are shown in Fig. 1.

Four isolates revealed different tolerance towards lead ions. Similar to this study Price et al. [26] studied the abilities of fungi in copper and zinc removal. The results showed that *Aspergillus niger* was the best suited for metal removal, as compared to other fungi. Metal concentrations and type of fungal species are the main factors which exert effects on metal tolerance. The highest metal resistances against lead ions showed 2000 ppm for the isolate *A. fumigatus* Z1 in solid media of YGC agar.

**TABLE 1**
Lead uptake capacity and removal efficiency of Pb by live biomasses of four isolates of *Aspergillus fumigatus*.

<table>
<thead>
<tr>
<th>Fungal isolates</th>
<th>$C_i$ (mg/l)</th>
<th>$C_f$ (mg/l)</th>
<th>V (L)</th>
<th>W (g)</th>
<th>$q_{max}$ (mg/g)</th>
<th>RE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AspZ1</td>
<td>15.9</td>
<td>3.70</td>
<td>0.14</td>
<td>1.26</td>
<td>1.36</td>
<td>76.73</td>
</tr>
<tr>
<td>AspZ2</td>
<td>15.9</td>
<td>5.98</td>
<td>0.14</td>
<td>1.22</td>
<td>1.14</td>
<td>62.39</td>
</tr>
<tr>
<td>AspZ3</td>
<td>15.9</td>
<td>5.94</td>
<td>0.14</td>
<td>1.31</td>
<td>1.06</td>
<td>62.64</td>
</tr>
<tr>
<td>AspZ4</td>
<td>15.9</td>
<td>12.5</td>
<td>0.14</td>
<td>1.14</td>
<td>0.42</td>
<td>21.38</td>
</tr>
</tbody>
</table>

Biosorption of Pb by live biomasses of different fungal isolates. The average of residual concentrations of Pb with four fungi species after 7 days of incubation is given in Table 1. Maximum sorption $q_{max}$ occurred at 15.9 mg/l initial concentration for live biomass of fungal *A. fumigatus* Z1 (1.36 mg/g), and (1.14mg/g) by fungi *A. fumigatus* Z2, (1.06 mg/g) by fungi *A. fumigatus* Z3, and less tolerance 0.42 mg/g by fungi *A. fumigatus* Z4. Within all examined metals, the removal efficiency for Pb was the highest at 76.73 % for fungal *A. fumigatus* Z1, and the lowest removal efficiency occurred for fungal *A. fumigatus* Z4, as 21.38%. Fungal biomasses dry weight max obtained 16.66 and 3.33 g/l for *A. fumigatus* Z1 and *A. fumigatus* Z4, respectively.

**TABLE 2**
Linear regression, ($q_{max}$), RE and $R^2$ of dead biomasses of four *Aspergillus fumigatus* isolates.

<table>
<thead>
<tr>
<th>Fungal isolates</th>
<th>Linear regression equation</th>
<th>$q_{max}$ (mg/g)</th>
<th>RE (%)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AspZ1</td>
<td>y=0.0131x + 0.1411</td>
<td>0.16</td>
<td>0.37</td>
<td>90.84</td>
</tr>
<tr>
<td>AspZ2</td>
<td>y=0.0104x + 0.0323</td>
<td>0.07</td>
<td>0.22</td>
<td>95.35</td>
</tr>
<tr>
<td>AspZ3</td>
<td>y=0.0135x + 0.1956</td>
<td>0.18</td>
<td>0.35</td>
<td>92.60</td>
</tr>
<tr>
<td>AspZ4</td>
<td>y=0.0057x + 0.2626</td>
<td>0.26</td>
<td>0.33</td>
<td>88.71</td>
</tr>
</tbody>
</table>


**FIGURE 2**
Based on this experiment, the maximum amount of sorption occurred as 0.37 mg/g by dead biomasses of fungi *A. fumigatus* Z1 with RE 90.84% and lowest metal uptake, 0.22 mg/g with maximum RE 95.35% by dead biomasses of fungi *A. fumigatus* Z2.

**Adsorption isotherm models.** Adsorption capacity of fungal dead biomasses was determined using an adsorption isotherm; it is an equation relating the amount of solute adsorbed to the solid and the equilibrium concentration of the solute in solution at a given temperature. There are types of models for predicting sorption equilibrium, Langmuir [27] and Freundlich models are known to be used for single solute system [28]. In order to obtain adsorption isotherm, the data from laboratory experiment were set as these two models.

The predicted shapes of the isotherm, at the highest and lowest concentrations are shown in Fig. 3 and Fig. 4. The maximum correlation coefficient ($R^2$) of the Langmuir model for adsorption Pb indicated 0.996 by fungi *A. fumigatus* Z4.

The results revealed that the most lead sorption in four fungi species was fitted by Freundlich model in this experiment Fig. 3.

**FIGURE 3**

**FIGURE 4**

**TABLE 3**

<table>
<thead>
<tr>
<th>Fungal isolates</th>
<th>Langmuir isotherm</th>
<th>Freundlich isotherm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_{max}$</td>
<td>$K_L$</td>
</tr>
<tr>
<td>AspZ1</td>
<td>0.633</td>
<td>0.04</td>
</tr>
<tr>
<td>AspZ2</td>
<td>0.966</td>
<td>0.02</td>
</tr>
<tr>
<td>AspZ3</td>
<td>0.640</td>
<td>0.03</td>
</tr>
<tr>
<td>AspZ4</td>
<td>0.370</td>
<td>0.16</td>
</tr>
</tbody>
</table>
The maximum correlation coefficient ($R^2$) of the Freundlich model Freundlich showed 0.951 by fungi A. fumigates Z2. In all cases, the value fell between 0 and 1, which indicates favorable biosorption.

Larger values of $k$ mean greater capacities of adsorption fungi sp [29] The amount of $q_{max}$ for adsorption of Pb relating to the energy of adsorption in Langmuir model and the amounts of metal ions required to form a monolayer, ($q$) obtained by Langmuir models which are presented in Table 3.

The maximum values of $n$ and kf of Freundlich model were found to be 5.26 and 0.196 for fungi A. fumigatus Z4, respectively.

**Adsorption kinetic.** In this part, four fungi dead biomasses were compared through varying the contact time from 0 to 120 min at an initial lead concentration (100 mg/L), stirring speed (125 rpm), temperature (28±1 °C) and pH 5. To use the kinetic mechanism the pseudo first order [30] and pseudo second order [31] models were used and reliability of these models were checked using linear equation validity plots. These models were verified by linear equation of Log ($q_e - q_t$) vs t, and $t/q_t$ vs $q$, respectively. The first order equation is described by

$$\log (q_e - q_t) = \log q_e - \frac{k_1}{2.303}t$$

The pseudo second-order equation was used as

$$\frac{t}{q_t} = \frac{1}{k_2q_e^2} + \frac{1}{q_e}$$

Where $q_e$ is the amount of lead ion absorbed at equilibrium (mg metal/g sorbent), $q_t$ is the amount of lead ion on the surface of the fungi biomasses at any time, t (mg metal/g sorbent) and $k_1$ is the pseudo-second order sorption constant (1/min) and $k_2$ is the pseudo-second order sorption constant (mg/(g.min)).

In the present experiment, kinetic study showed that the major removal occurred in the first 10 minutes and all the metal removal processes were completed in 30 minutes Fig. 5.

Experiment data were fitted by two models and each set of data were fitted using the model Table 4. The experimental data can be used to determine the metal binding rate.

![Figure 5](image.png)

**FIGURE 5**  
A. Pesudo first; B. Pseudo second order kinetic, and C. Rate of adsorption in first 10 minutes by four Isolate, A. fumigatus Z1, A. fumigatus Z2, A. fumigatus Z3 and A. fumigatus Z4 .

**TABLE 4**  
The pseudo-first and pseudo-second order kinetics parameters for biosorption Pb by dead biomass of four Aspergillus sp. isolates.

<table>
<thead>
<tr>
<th>Fungal isolates</th>
<th>Pseudo first order parameter</th>
<th>Pseudo second order parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$q_e$ (mg/g)</td>
<td>$K_1$ (1/min)</td>
</tr>
<tr>
<td>AspZ1</td>
<td>10.48</td>
<td>0.006</td>
</tr>
<tr>
<td>AspZ2</td>
<td>11.07</td>
<td>0.007</td>
</tr>
<tr>
<td>AspZ3</td>
<td>8.53</td>
<td>0.009</td>
</tr>
<tr>
<td>AspZ4</td>
<td>18.39</td>
<td>0.004</td>
</tr>
</tbody>
</table>

The coefficient of determination and rate constants were calculated and are given in Table 5.

The plots according to the Equation (8) showed that pseudo second order was the best fit for this group of fungi species. The rate of adsorption by isolate A. fumigatus Z2 was very fast in 10-minute contact time and other fungi.
biomasses adsorption forms were set as AspZ2>AspZ3>AspZ4>AspZ1

CONCLUSION

Analysis of zinc industry wastes revealed that it contains high percentages of heavy metals, such as lead, cadmium and zinc. These heavy metals are more considerable and the most important sources of environmental pollution. In the first step of this research after fungi isolation in media, all fungal isolates which grew were evaluated for metal tolerance using Minimum Inhibitory Concentration technique. Accordingly, four Aspergillus sp. isolates which were higher resistance to Pb ions were selected. The results of maximum resistance to Pb showed for A. fumigatus Z1 (2000) mg/l, A. fumigatus Z2 (1500) mg/l, A. fumigatus Z3 (1000) mg/l and A. fumigatus Z4 (800) mg/l. In the second step, live and dead biomasses of four isolates, which were high resistance to Pb, were evaluated for sorption experiment. All of pH, temperature, contact time, nutrient amount, samples volume, biomass dosage and fluidity of solution were constant. Comparing metal sorption of four Aspergillus sp. isolates showed that there had been a competition between fungi live species for metal uptake. Physicochemical property of biomasses and types of metal ions, as well as the type of fungal isolates and their interactions with metals are important for biosorption [32]. Gadd reported that difference in metal uptake by organism its chemical composition of cell wall leading various types of interaction of metals with fungi[33].

The maximum lead removal by live biomasses was observed for the A. fumigatus Z1, as 1.36 mg/g and minimum removal by dead biomass for the A. fumigatus Z2, 0.152 mg/g, on average. Fungi live biomass sorption experiment revealed that as for A. fumigatus Z1, in terms of time, sorption rate depends on fungus growth.

For assessing sorption by different live and dead biomasses of four fungal isolates, first, fungal sorption criteria were determined, later, a pilot study was conducted on ranking fungal isolates based on fuzzy TOPSIS technique. This technique method (for order preference by similarity to an ideal solution) which is one of the most frequently used classical MCDM methods was developed by Hwang et al. [34]. Using TOPSIS model provides a broader principle of compromise for solving multiple criteria decision making problems [35].

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<tr>
<td>Fungal live criteria</td>
<td>Metal tolerance</td>
<td>Sorption experiment</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>CGN (n)</td>
<td>MIC (cm)</td>
<td>DBW (g)</td>
<td>q&lt;sub&gt;max&lt;/sub&gt; (mg/g)</td>
<td>RE (%)</td>
<td></td>
<td></td>
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<tr>
<td>Alternative</td>
<td>Weight</td>
<td>0.2</td>
<td>0.2</td>
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<td>0.2</td>
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<tr>
<td></td>
<td>AspZ1</td>
<td>8</td>
<td>0.5</td>
<td>2.5</td>
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<td>76.73</td>
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<td>AspZ2</td>
<td>4</td>
<td>0.1</td>
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<td>1.14</td>
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<td>AspZ3</td>
<td>2</td>
<td>0.2</td>
<td>1</td>
<td>1.06</td>
<td>62.64</td>
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<td>AspZ4</td>
<td>3</td>
<td>0.15</td>
<td>0.5</td>
<td>0.42</td>
<td>21.38</td>
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<tr>
<td>Fungal dead Criteria</td>
<td>Sorption experiment</td>
<td>Freundlich isotherm</td>
<td>Pesudo Second Kinetic experiment</td>
<td></td>
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<tr>
<td></td>
<td>q&lt;sub&gt;max&lt;/sub&gt; (mg/g)</td>
<td>RE (%)</td>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
<td>K&lt;sub&gt;F&lt;/sub&gt;</td>
<td>n</td>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Alternative</td>
<td>Weight</td>
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<tr>
<td></td>
<td>AspZ1</td>
<td>0.37</td>
<td>90.84</td>
<td>0.73</td>
<td>0.075</td>
<td>1.73</td>
<td>0.820</td>
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<tr>
<td></td>
<td>AspZ2</td>
<td>0.22</td>
<td>95.35</td>
<td>0.92</td>
<td>0.017</td>
<td>1.12</td>
<td>0.951</td>
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<tr>
<td></td>
<td>AspZ3</td>
<td>0.32</td>
<td>92.60</td>
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<td>0.072</td>
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<td>0.828</td>
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<td></td>
<td>AspZ4</td>
<td>0.33</td>
<td>88.71</td>
<td>0.96</td>
<td>0.196</td>
<td>5.26</td>
<td>0.941</td>
</tr>
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</table>
TABLE 7

<table>
<thead>
<tr>
<th>Fungal dead ranking</th>
<th>Fungal live ranking</th>
</tr>
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<tbody>
<tr>
<td>0.899</td>
<td>0.468</td>
</tr>
<tr>
<td>AspZ4</td>
<td>AspZ1</td>
</tr>
<tr>
<td>0.341</td>
<td>AspZ3</td>
</tr>
<tr>
<td>0.249</td>
<td>AspZ2</td>
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<tr>
<td>1.00</td>
<td>0.355</td>
</tr>
<tr>
<td>AspZ1</td>
<td>AspZ2</td>
</tr>
<tr>
<td>0.3269</td>
<td>AspZ3</td>
</tr>
<tr>
<td>0.102</td>
<td></td>
</tr>
</tbody>
</table>

For proposed model, five criteria were considered for live fungi to be set including; Colony Growth Number (CGN) in media, Minimum Inhibitory Concentration (MIC) of metal tolerance, Dry Biomasses Weight (DBW), maximum sorption capacity \( q_{\text{max}} \) and Removal Efficiency (RE) of sorption experiment.

For dead fungi biomasses nine criteria were set including; (maximum adsorption capacity \( q_{\text{max}} \), Removal Efficiency (RE) and Coefficient of Determination \( R^2 \) of sorption experiment), (constant \( k_f \), \( n \)) and Coefficient of Determination \( R^2 \) of Freundlich isotherm), (Adsorption Rate in first 10 minute (AR), amount of lead sorbed at equilibrium \( q_e \)) and kinetic constant \( K_2 \) of pseudo second kinetic experiment.

The results of ranking by live fungi indicate that *A. fumigatus* Z1 had the highest rank with 1.00 and *A. fumigatus* Z4 had the lowest amount with 0.102. Ranking dead fungi biomasses also showed that *A. fumigatus* Z4 with 0.899 highest and *A. fumigatus* Z2 with 0.249 lowest ranking. Based on this experiment, through using TOPSIS model live biomasses of *A. fumigatus* Z1 and dead biomasses of fungi *A. fumigatus* Z4 had the maximum ranking.

Similarly, Al-Garni, A. [36] reported that removal of cadmium by *A. fumigatus* in aqueous solution showed that dry biomass of *A. fumigatus* was the most impressive for Cd, sorption and these indicated that biosorption of Cd by the fungi was dependent in the fungal species also biosorption experiment by [5] showed that *Rhizopus sp.* accumulated 4.33 mg of Cr and 2.72 mg of Cd per g of biomass.

The noteworthy finding of this experiment was that the population of *A. fumigatus* Z1 which was dominated in zinc waste sediment samples showed high growth in metal tolerance against kind of lead ions is the best candidate for metal uptake, another it is the potential of fungi for using fungi as a biomarker for metal exposure in the environment. Furthermore, study on live fungi showed that *A. fumigatus* Z1 is more tolerant against the types of lead salt. Reaction of live fungi against metals will be concluded to accumulation by fungi or change their genome and species, it is one key for detection of metals which will be used for mines assessment.

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