Adsorption of Cyanide Ion from Aqueous Solutions by \textit{Saccharomyces cerevisiae} Biomass

Venty Suryanti\textsuperscript{a}, Fitria Rahmawati\textsuperscript{a}, Yudha Anggara Haeqal\textsuperscript{a}

Abstract

Cyanide compounds are extremely toxic to humans. Cyanide compounds are occurs in the wastes generated from various industries and can be treated by adsorption and biodegradation. The adsorption of cyanide from aqueous solutions by \textit{Saccharomyces cerevisiae} biomass has been studied by investigating the effect of initial pH solutions and time of contact between the biomass and the solutions. The biomass was previously treated with sodium chloride in order to increase the adsorption capacity. Batch adsorption experiments were performed to study the adsorption potential of the biomass. Total cyanide was determined by Prussian Blue colorimetric method at 591 nm where all spectrometric measurements were carried out using UV-VIS spectrophotometer.

The adsorption optimum was obtained at pH 11 and 10 minutes of time of contact where the adsorption capacity was found to be 17.7 mg/g. The FT-IR spectra revealed that the ability of biomass to bind cyanide has been attributed to the presence of various functional groups on the surface of biomass which can attract cyanide. Isotherm studies showed that cyanide adsorption by \textit{S. cerevisiae} biomass can better be described by Langmuir isotherm compared to Freundlich isotherm. Interaction occurred between \textit{S. cerevisiae} biomass and cyanide ion is the chemical interaction. Desorption studies indicated that there are considerable amounts of desorption of cyanide (30%). Thus, cyanide adsorption by \textit{S. cerevisiae} biomass is not completely reversible. The present investigations revealed that \textit{S. cerevisiae} biomass can be used as an alternative method for removal of cyanide from wastewaters.

Keywords: adsorption, aqueous solutions, biomass, cyanide, \textit{Saccharomyces cerevisiae}, wastewater

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Introduction

Cyanides are used in a number of chemical synthesis and metallurgical processes and therefore, they are present in their effluent waters. Cyanides are highly toxic. Hence, cyanides must be destroyed or removed from wastewater prior to discharge. The current methods for treating cyanides are adsorption and biodegradation (Ebbs, 2004; Dash, \textit{et al}., 2009a; David, 2006; Desai, \textit{et al}., 1998; Huff, \textit{et al}., 1978; Roshan, \textit{et al}., 2006). The appropriate treatment method can be chosen based on the benefit, cost and concentration of cyanide ion in wastewater (David, 2006). Therefore, it is still necessary to develop processes for removal of cyanides from wastewater.

Various materials have been used as adsorbents, such as activated carbon, minerals, zeolites, clays and synthetic materials which include \textit{Al}_2\textit{O}_3 and \textit{SiO}_2 in the removal of heavy metals and toxic materials from wastewater (Hang and Cheng, 1997). An emerging field of interest is employing plants or bacteria biomass to uptake heavy metals and toxic materials for the remediation of the environment. This technology is effective, environmentally friendly and inexpensive (Kiran and Chandrajit, 2011). The aim of this investigation is to study the possibility of using \textit{Saccharomyces cerevisiae} biomass for removing cyanide ion from aqueous solution. The important parameters that influence adsorption such as the effect of initial pH solutions and time of contact between the biomass and the solutions were investigated. The adsorption data have been interpreted using Langmuir and Freundlich isotherms. Desorption and reversibility of adsorption processes have also been examined.
Methodology

All the chemicals used in the experiment were of analytical grade (E-Merck) and prepared by distilled water. A laboratory strain of S. cerevisiae (FNCC 3044) was routinely maintained on potato dextrose agar (Oxoid), for experimental purposes, S. cerevisiae cells were cultured on a rotary shaker agitated at 125 rpm at room temperature in 10 mL of peptoneglucose yeast extract (Oxoid) and incubated for 24 h. The bacteria were then transferred to 1 L of the same growth medium and incubated for another 24 h at room temperature. After incubation, the biomass was harvested by centrifugation at 8,000 g for 10 minutes and the harvested biomass was washed with generous amounts of distilled water. Biomasses were then treated with alkali chemical (NaOH). The biomass was washed with generous amounts of distilled water and then dried at 60°C for 12 h in a drying oven. Dried biomass was ground in a mortar and pestle.

The cyanide solution was prepared by dissolving sodium cyanide in distilled water. Effects of pH on adsorption were studied for pH 6–13, where the pHs of the suspensions were adjusted using NaOH or NH₄OH. The pH of the solutions was measured using pH meter model 710 A, Orion Boston USA. All adsorption studies were conducted in 50 mL flasks containing 25 ppm of S. cerevisiae biomass was ground in a mortar and pestle.

Results and Discussion

The experiments were conducted to investigate the effects of various process parameters on removal of cyanide from the synthetic solution. NaOH-pretreated S. cerevisiae biomass (0.1 g) was contacted with synthetic solution containing cyanide for 0–30 minutes, with an initial pH value of the solutions ranging from 6 to 13. The influence of pH and effect of time of contact on the extent of adsorption of cyanide is shown in Figure 1.

Effect of pH

pH of the solution affects the surface charge of the adsorbent, degree of ionization along with speciation of different pollutants (Adhoum and Monsen, 2002). A little adsorption occurred at pH 6.0 (Figure 1a). A steady increase in the adsorption of cyanide was observed in the pH range of 8.0–11.0. Maximum adsorption occurred in the pH 11 and adsorption was almost constant at higher pHs. We could conclude that pH of 11 is optimum for the adsorption of cyanide.

At low pH value (pH 6), cyanide exists as HCN which is a weak acid and highly soluble in water. This affinity of water at low pH prevents its adsorption onto biomass. At a higher pHs (in the alkaline conditions), the deprotonation on biomass surface provides functional groups, for chemisorptions, on its surface that can undergo ion exchange type of interaction with cyanide ions. Dash reported the adsorption of cyanide on activated carbon and showed that maximum adsorption occurs at pH 9.2 for NaCN (Dash, et al., 2009b). Guo studied the effects of pH on dilute cyanide solutions and observed that effect of pH was very less pronounced in adsorption but had a marked effect on the stability of cyanide (Guo, et al., 1993).

Effect of time of contact

The contact time between the adsorbent and the pollutants is of significant importance in the treatment of effluent by adsorption. An establishment of
equilibrium in short period by rapid uptake of the pollutants signifies the efficiency of the adsorbent being used in the effluent treatment. It was shown in Figure 1b that cyanide removal is a rapid process where similar cyanide adsorption was observed for time of contact of 10, 20 and 30 minutes. We could conclude that time of contact of 10 minutes is optimum for the adsorption of cyanide.

Generally in physical adsorption most of the adsorbent media are adsorbed within a short time of exposure (Adam, 2003). However chemisorptions requires a longer contact time for achieving a strong chemical bond and hence attaining equilibrium. The adsorption results show that the uptakes of cyanide was fast at the initial stage of contact time and the rate of adsorption was found to be nearly constant at time of contact of 10 minutes and above. This phenomenon is because of availability of large number of vacant sites in the initial stages of adsorption and competition for the remaining active surfaces in the later stages (Abbas, et al., 2014). The results showed that the adsorbent media had a limited number of active sites, which would have become saturated at a certain time.

Infra-red spectral analysis

The FT-IR spectra of the NaOH-pretreated biomass sample showed the presence of various functional groups of the S. cerevisiae biomass. The unique ability of biomass to bind cyanide has been attributed to the presence of various functional groups on the surface of biomass which can attract cyanide. The absorption peak and their corresponding functional groups of the un-contacted biomass sample and contacted biomass with cyanide solution are shown in Table 1.

### Table 1. IR absorption bands and the corresponding functional groups.

<table>
<thead>
<tr>
<th>Wave number (cm⁻¹)</th>
<th>Un-contacted biomass sample</th>
<th>Contacted biomass with cyanide solution</th>
<th>Functional groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>3421</td>
<td>3421</td>
<td>-OH, -NH</td>
<td></td>
</tr>
<tr>
<td>2923</td>
<td>2927</td>
<td>-CH</td>
<td></td>
</tr>
<tr>
<td>2854</td>
<td>2854</td>
<td>-CH</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>2083</td>
<td>C≡N</td>
<td></td>
</tr>
<tr>
<td>1735</td>
<td>-</td>
<td>C=O</td>
<td></td>
</tr>
<tr>
<td>1651</td>
<td>1654</td>
<td>C=O</td>
<td></td>
</tr>
<tr>
<td>1562</td>
<td>1542</td>
<td>-NH</td>
<td></td>
</tr>
<tr>
<td>1458</td>
<td>1400</td>
<td>COO⁻</td>
<td></td>
</tr>
<tr>
<td>1041</td>
<td>1049</td>
<td>C=O</td>
<td></td>
</tr>
</tbody>
</table>

The new absorption peak at 2083 cm⁻¹ can be attributed to the CN group which appeared after contacting biomass with cyanide solution representing the binding of biomass and the cyanide.

Adsorption Isotherm

Adsorption isotherm plays a crucial role in the predictive modelling procedures for the analysis and design of an adsorption system. The adsorption data of cyanide were tested with Langmuir and Freundlich isotherm models within initial cyanide ion concentration range from 50 to 100 ppm (Figure 2). Isotherm studies showed that adsorption of cyanide by S. cerevisiae biomass can better be described by Langmuir isotherm (R² = 0.9166) compared to Freundlich isotherm (R² = 0.8893). The Langmuir equation is the suitable modelling tool to satisfactorily describe adsorption of cyanide by biomass by providing the higher squared correlation coefficients. Thus, it can be concluded that interaction occurred between S. cerevisiae biomass and cyanide ion is the chemical interaction.

Desorption and Reversibility Studies

Desorption and reversibility of adsorption processes were investigated. The desorption study was conducted at the optimum conditions at pH 11 and time of contact of 10 minutes. Desorption studies indicated that there were considerable amounts of desorption of cyanide (30%). Thus, cyanide adsorption by S. cerevisiae biomass was not completely reversible.

Conclusions

The NaOH pre-treated S. cerevisiae biomass showed a good ability to remove cyanide ion from aqueous solution using batch adsorption experiments. So, it could be recommended for removal of cyanide ion from wastewater. The adsorption optimum was obtained at pH 11 and 10 minutes of time of contact.
where the adsorption capacity was found to be 17.7 mg/g. The ability of biomass to bind cyanide has been ascribed to the presence of various functional groups on the surface of biomass. The Langmuir equation is the suitable modelling tool to satisfactorily describe adsorption of cyanide by biomass, indicating that interaction occurred between S. cerevisiae biomass and cyanide ion is the chemical interaction. Desorption studies revealed there are considerable amounts of desorption of cyanide (30%) indicating that the cyanide adsorption by S. cerevisiae biomass is not completely reversible.

References


Presentation Discussion
Questions from:
- Umar: How can Cyanida in pH 6 dangerous?
- Indriana: Describe a simple view of the solvent that used in this study

Answer to:
- Umar:
- Indriana: Compare another adsorben make more be sure and more good product.