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Full Length Research Paper

Utilization of fly ash linear materials as an adsorbent of hazardous chemical compounds

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In Japan, due to the public resistance of the nuclear power plants, the general trend is to generate power by using the coal. This means that huge amount of fly ash will be accumulated in the power plants due to the lack of safe reclamation sites. Accordingly, this paper presents an experimental study that evaluates the adsorption characteristics of fly ash when used as a filter medium in places where the groundwater is likely to be polluted. Previous studies show that fly ash is a good adsorbent of harmful chemicals. In this paper, some of the most harmful chemicals were allowed to pass through a fly ash packed column at different lengths with the aid of micro pump that can regulate the discharged volume in specific intervals of time. An ultraviolet (UV) spectrometry, atomic absorption spectrometry and capillary ion analysis were done to evaluate the adsorption efficiency of the fly ash. The harmful chemicals used in this research were mercury, sodium cyanide, and tetrachloroethylene. After analyzing the outcome of these harmful chemicals results show that the fly ash is a good adsorbent and can decrease the concentration of the harmful chemicals to some acceptable values. Results also show that, for the scope of this study, adsorption efficiency increases as a result of the increased mass transfer units in proportionality with the length of the columns.

Key words: Adsorption, fly ash, hazardous chemicals, packed column, adsorbent.

INTRODUCTION

In Japan about 20% of the electrical power is generated by coal thermal power plants. Furthermore, the number of these coal thermal power plants is expected to increase in the coming years yielding about 10,000 Gg of coal ash every year (Takahashi et al., 1996). Now, even though there is a big amount of coal ash used in the cement manufacturing industry (San Juan, 1996) there is a real need to utilize this huge amount of coal ash wastes.

Geotechnical engineering has found its way to make this material applicable in some areas of earth works such as light fill material (Huang and Lovell, 1993; Tanabashi et al., 1996). From this point of view this paper aims at utilizing the coal ash as a linear material that can be used in adsorbing some harmful chemicals from the leaching of the wastes before it reaches the groundwater. The chemicals used in the research were mercury (Hg), tetrachloroethylene, and cyanide (CN). Recently, Rice-Husk Ash (RHA) is being used as an adsorbent of Hg(II) from effluent solutions (Taiwari et al., 1995).

Bentonite was also used for the same purpose in an attempt to study the efficiency of bentonite in the reduction of benzene (James Peter, 1994). Due to the high cost of powder activated carbon (PAC) and other purification materials, this research was carried out in order to perform a comprehensive evaluation of coal ash and its utilization in treating and purifying some waste solutions.

Chemicals and physical characteristics of coal ash

The coal ash used in this study was obtained from Omura Power Plant, Nagasaki Prefecture, Omura City, Japan. The chemical composition of this coal is shown in Table 1.

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Table 1. Chemical composition of coal ash.

Compound	SiO_2	Al_2O_3	Fe_2O	MgO	Na_2O	K_2O	SO_3	TiO_2	CaO	Ig.Loss
(%)	62.1	22.45	4.20	1.28	1.65	2.22	0.22	0	1.80	3.74

Table 2. Physical characteristics of Omura coal ash.

Characteristics	Values
Specific gravity, Gs	2.243
Permeability coefficient, K	$9.47*10^{-5}$ m/s
Natural water content, w	0.32%
Uniformity coefficient Uc	2.2
Maximum dry density,γ	1.31g/cm^3

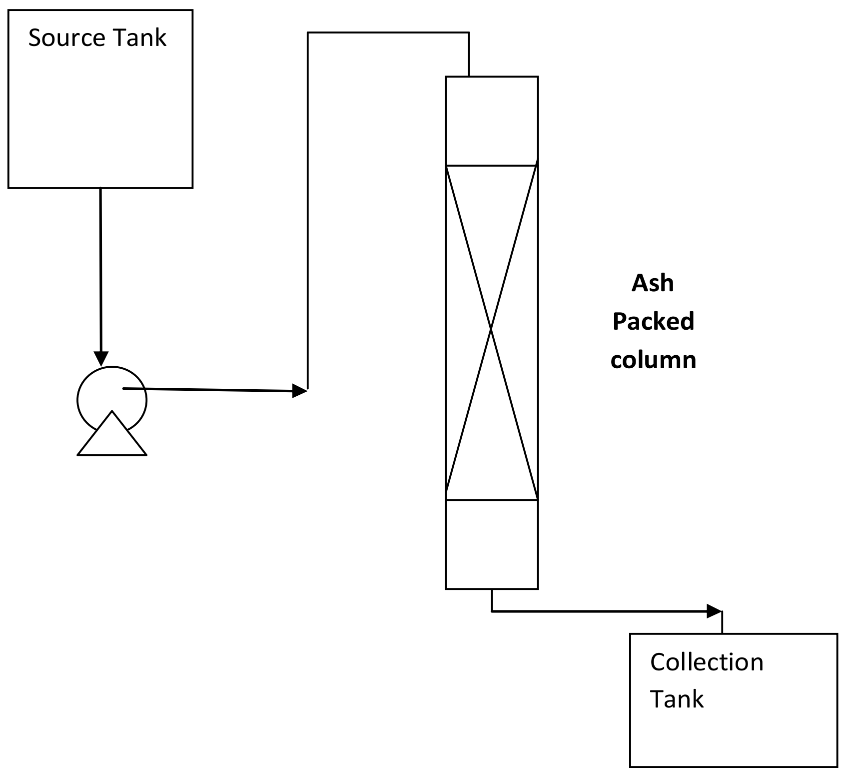

Figure 1. Schematic diagram of the experimental set-up.

This coal ash can be used as a linear material due to its low permeability and also because of the chemical compounds it contains which have the ability to adsorb some harmful chemicals. The physical characteristics of Omura coal ash are shown in Table 2.

MATERIALS AND METHODS

Sample solutions

Standard solution of the test materials were prepared by dissolving the proper amount of tetrachloroethylene, sodium cyanide and mercury in water to give concentration of 30, 16.6 and 0.3 (parts per million) ppm respectively. For the evaluation of the adsorption ability of coal ash, Figure 1 shows a schematic diagram for apparatus set used in this experiment. Coal ash packed glass columns of 2, 4 and 6 cm length and 1.0 cm in diameter were used. The test materials were placed in a source tank from which the micro pump withdraws at a flow rate of 1.5 ml/min. The elute was collected at the outlet of the columns after 10 min period of each trial and the concentration of the test material were analyzed by atomic absorption spectrometry, UV-spectrometry, and capillary ion analysis. The above mentioned procedure was repeated for four times successively. Finally, distilled water was also analyzed before

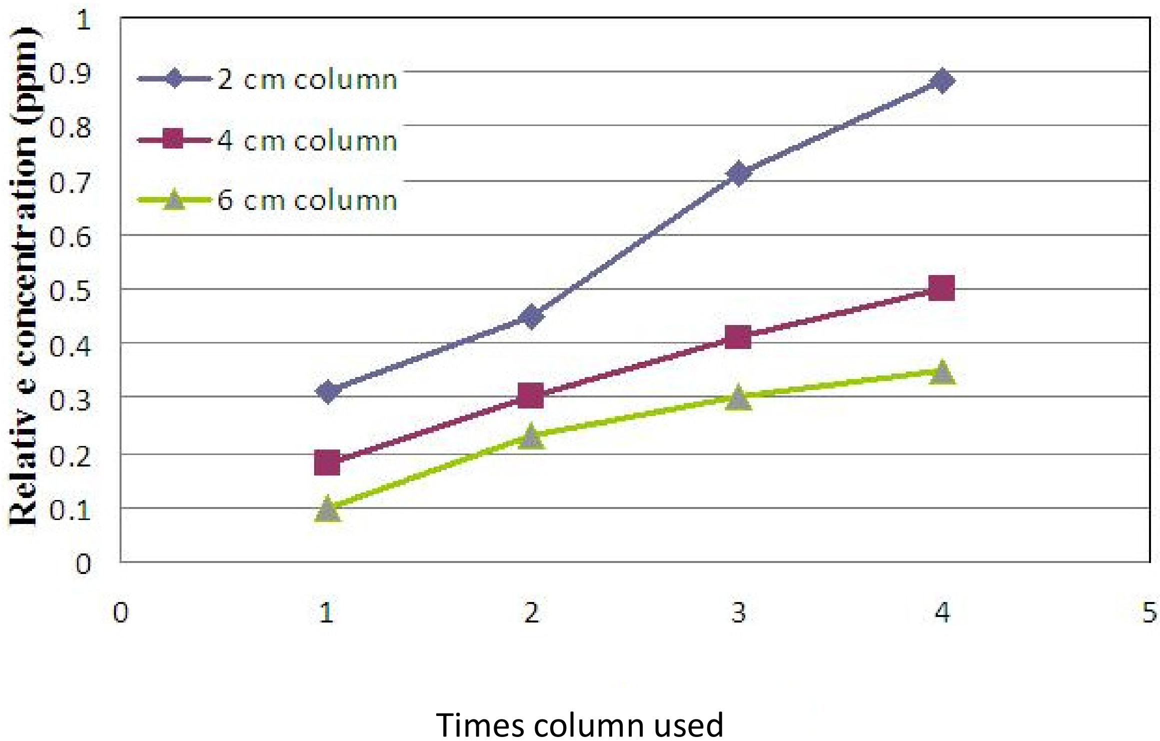

Figure 2. Adsorption of Mercury (Hg).

and after passing through the coal ash column in order to determine the effect of the coal ash on the clean water.

RESULTS AND DISCUSSION

Adsorption of mercury (Hg)

Figure 2 shows the results of the atomic absorption spectrometry of mercury after passing through the coal ash packed columns for four successive times at a flow rate of 1.5 ml/min. the Y-axis shows the relative concentration of each trial divided by the original concentration of the mercury used ($C_{Hgoutlet}/C_{Hg\ initial}$). These results indicate that the coal ash has the potential and the ability of adsorbing mercury even though there is no linear relationship between the coal ash column length and the concentration. However, the concentration of the mercury was reduced to about 0.03 ppm by using the 6 cm coal ash packed column for the first two times compared with 0.30 ppm the original concentration. This is considered to be a good indication that coal ash could be used to purify mercury-polluted solutions.

Adsorption of tetrachloroethylene

Tetrachloroethylene is a well known pollutant of the shallow ground water and it causes severe health problems to human beings. It is used mainly in the dry-cleaning industry. Thus, it was a main target of this research. Figure 3 shows the results of the tetrachloroethylene before and after passing through the coal ash packed glass columns. Results indicate that the coal ash is capable of reducing the tetrachloroethylene concentration to about zero especially when using the 6 cm coal ash packed columns. Figure 3 also shows that the 6 cm column can adsorb tetrachloroethylene for four consecutive times. Therefore coal ash can be considered as a promising material in the field of purification of tetrachloroethylene or some other similar compounds that have mostly the same chemical structures specially tetrachloroethylene.

Adsorption of cyanide

Figure 4 shows the results of the ion capillary analysis of the cyanide from the outlet after passing through the coal ash packed columns. The general trend with the adsorption of cyanide in three different columns with different heights is that the adsorption efficiency of cyanide increases as a result of the increased mass transfer units.

Testing of distilled water

For the coal ash to be successfully used in the removal of harmful chemicals, its effect on the ordinary water must

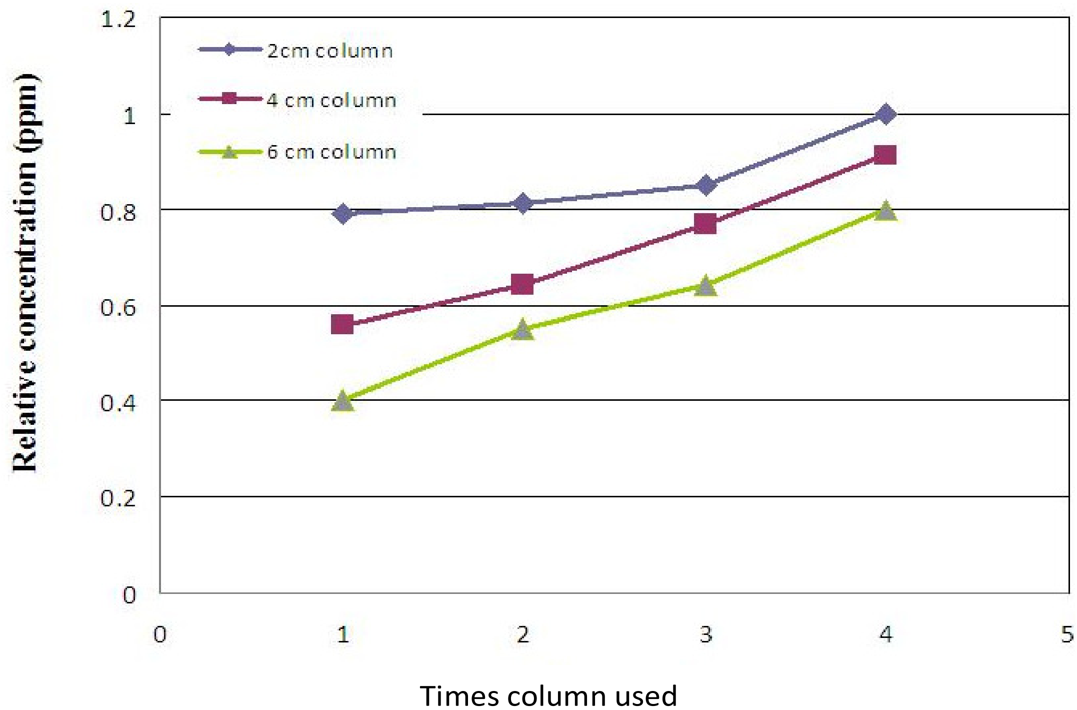

Figure 3. Adsorption of tetrachloroethylene.

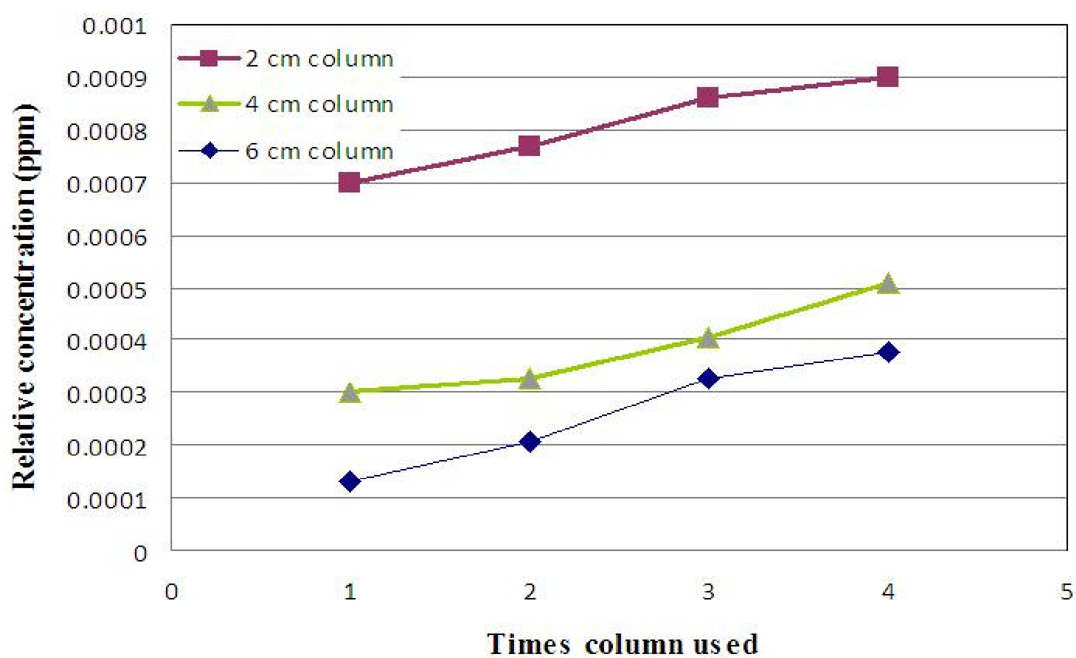

Figure 4. Adsorption of cyanide (CN).

also be evaluated. For this purpose the same procedure used for the chemicals was conduced by using pure water. As a first step the concentration of the main heavy metal ions in the pure water was determined. These heavy metal ions are Cr, Cd, Pb, Cu, Fe, and Mn.

The concentrations of these heavy metal ions in the pure water were found to be 0.08504, 0.00431, 0.01464, 0.0723, 0.08145, 0.02732 and 0 ppm respectively. The results of passing water through the coal ash packed columns of different lengths are shown in Tables 3, 4 and 5.

Table 3. Results of distilled water testing after passing through 2 cm coal ash packed column.

	Cr^{3+}(ppm)	Cd^{2+}(ppm)	Pb^{2+}(ppm)	Cu^{2+}(ppm)	Fe^{2+}(ppm)	Mn^{2+}(ppm)	Zn^{2+}(ppm)
St.ppm	0.08504	0.00431	0.01464	0.01723	0.08145	0.02732	0
Trial 1	0.08393	0.00406	0.01686	0.02250	0.02227	0.02990	0.02800
2	0.09796	0.00381	0.00692	0.01846	0.10618	0	0
3	0.10439	0.00457	0.01690	0.01461	0.10015	0	0
4	0.0132	0.00681	0.02757	0.01666	0.08628	0	0

Table 4. Results of distilled water testing after passing through 4 cm coal ash packed column.

	Cr^{3+} (ppm)	Cd^{2+}(ppm)	Pb^{2+}(ppm)	Cu^{2+}(ppm)	Fe^{2+}(ppm)	Mn^{2+}(ppm)	Zn^{2+}(ppm)
St.ppm	0.08504	0.00431	0.01464	0.01723	0.08145	0.02732	0
Trial 1	0.00864	0.00754	0.02290	0.03253	0.14541	0.04280	0
2	0.04156	0.00691	0.01919	0.01332	0.07394	0	0
3	0.04604	0.00868	0.03406	0.01592	0.05165	0	0
4	0.05205	0.00856	0.02906	0.02002	0.11265	0	0

Table 5. Results of distilled water testing after passing through 6 cm coal ash packed column.

	Cr^{3+} (ppm)	Cd^{2+}(ppm)	Pb^{2+}(ppm)	Cu^{2+}(ppm)	Fe^{2+}(ppm)	Mn^{2+}(ppm)	Zn^{2+}(ppm)
St.ppm	0.08504	0.00431	0.01464	0.01723	0.08145	0.02732	0
Trial 1	0.10579	0.01010	0.01693	0.01919	0.15032	0.04231	0
2	0.08223	0.00743	0.02002	0.01632	0.00577	0	0
3	0.07144	0.00719	0.03701	0.01992	0.05648	0	0
4	0.06623	0.01069	0.02249	0.02702	0	0	0

These results indicate that there are no major changes took place when passing water through the coal ash packed columns and water seems to be still drinkable. The only two major changes occurred at the first trial of the 4 cm coal ash packed column since there is a little increase in the concentration of the Fe. However this result can be neglected because this was not observed in the other trials of the same column or even in the other columns. This is also the case where there was an increase in the Cd at the fourth trial of the 6 cm coal ash packed columns. This result must be considered seriously again and if confirmed some solutions must be provided.

Conclusions

This paper has suggested a new idea about the utilization of the coal ash in the field of harmful chemical treatment. Results indicate that the coal ash has a good ability to adsorb and retain some of the most harmful chemicals. However, this is considered as a first step toward the understanding of the coal ash linear materials and its efficiency of adsorbing chemicals and if not it will help in extracting some useful heavy metals from the coal ash.

The general trend in the three columns with the adsorption of three different chemicals is that the adsorption efficiency increases as a result of the increased mass transfer units in proportionality with the length of the columns.

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