Journal of Soil Contamination, 9(1):51–64 (2000)

Arsenic Pollution of a Loam Soil: Retention Form and Decontamination

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A study was conducted to assess the retention form of arsenic in soil and to evaluate the use of phosphate for releasing it from the soil. In this study, a loam soil was artificially polluted with arsenate at pH 5.5, which is one of the pH values at which maximum arsenic adsorption occurred. The soil was kept for 2.5 months under wet conditions to allow for stabilization. The soil was maintained under aerobic condition and losses of arsenic by volatilization were determined to be minimal. The soil was then sequentially extracted with a series of chemicals to identify the soil fractions in which the arsenic was bound. The percentage of arsenic found in the Fe bound-exchangeable, reducible-residual, Al bound exchangeable, residual, calcium bound exchangeable, and easily exchangeable forms was 31.6, 27.3, 25.2, 5.5, 4.9, and 4.7%, respectively. A batch experiment showed that at 20°C, 80% of the bound arsenic was removed by phosphate in the pH range of 5 to 7. A power function model was found to fit the data with a desorption rate constant of 402 mg/kg As h^{-1}.

***KEY WORDS**: soil characterization, arsenic adsorption, soil contamination by arsenic, sequential extraction of arsenic, remediation and kinetic study.*

INTRODUCTION

ARSENIC contamination of groundwater and surface water is mainly due to the earlier use of arsenic pesticides on agricultural land and the release of natural arsenic from soil. The levels of arsenic in uncontaminated soils have been found to be as high as 95 mg/kg, with a global mean of 8.7 mg/kg (Kabata-Pendias and Pendias, 1985). Arsenic compounds such as methylarsonic acids, dimethylcalciumpropylarsonate, calciummethylarsonate, and dimethyl arsenic acid have been used widely as pesticides for over 100 years, but their use is now declining. The major present day uses of arsenic compounds are in the formulation of pesticides, wood preservatives, and as growth promoters for poultry and pigs (O'Nell, 1990). The worldwide usage of arsenic has been estimated recently to be 8000 t/y as herbicides, 12,000 t/y as cotton desiccants, and 16,000 t/y as wood preservatives (O'Nell, 1990).

Arsenic in soil exists mainly in oxidation states of III and V, and the potential mobility (i.e., solubility) of arsenic is based on these oxidation states. As(III) is more mobile in soil when compared with arsenic (V) and hence As(V) compounds may be mobilized if conditions become sufficiently reduced for As(III) compounds to form. In general, As(V) compounds predominate in aerobic soils, whereas As(III) compounds predominate in slightly reduced soils. Arsenic also appears to be more mobile under both alkaline and more saline conditions. Brookins (1988) has provided the various species of arsenic and phosphate under various oxidation-reduction and pH values.

Arsenates are more strongly adsorbed by soils than are arsenites. Arsenates are fixed to soils by adsorption, forming immobile species with soil minerals containing iron, aluminum, calcium, manganese, and other similar minerals. However, arsenic may leach out from soils if the levels of reactive iron, aluminum, and calcium in soils are low or the redox potential is low (Woolson *et al.*, 1971b; Lieberman, 1997). The presence of iron in soils can be most effective in controlling arsenate mobility (Krause and Ettel, 1989; Masscheleyn *et al.*, 1991). Coprecipitation and adsorption of arsenic with iron oxides may be the most common factors affecting its mobility under most environmental conditions. In addition to adsorption, As(V) and As(III) species also can be removed from minerals by substitution with phosphate.

A common method that has been employed to assess the forms in which arsenic is present in soils is the use of serial extractions. Previous investigators have used both single and mixed solvents for As associated with individual elements such as Fe, Al, and Ca. These solvents are presented in Table 1. Many of these solutions have been used to extract phosphorous (P) from soils; indeed, the sequential extraction was designed specifically for fractionation of P (Peterson and Corey, 1966). As and P compounds exhibit analogous behavior with respect to ion exchange; however, phosphate tends to outcompete arsenate for exchange sites (Peters *et al.*, 1999).

TABLE 1
Various Chemicals Previously Used for Sequential Extraction of Arsenic in Soil

Chemical for As extraction	Ref.
1. Ammonium acetate (0.1 and 1 N) Bray P-1 solution (0.03 N NH_4F + 0.025 N HCl)	Jacobs *et al.*, 1970
2. Mixed acid (0.05 N HCl + 0.025 N H_2SO_4 and 0.5 N $NaHCO_3$)	Woolson *et al.*, 1971a
3. 1 N NH_4Cl, 0.5 N NH_4F, 0.1 N NaOH, and 0.5 N H_2SO_4	Woolson *et al.*, 1971b
4. Distilled water, 0.5 *M* HCl	Deuel and Swoboda, 1972
5. 0.05 *M* KH_2PO_4	Woolson *et al.*, 1973
6. 0.1 *M* Na_2HPO_4 (pH 9.1), Na_2HPO_4/NaH_2PO_4 (3:2) (pH 7.0), NaH_2PO_4 (pH 4.5), and H_3PO_4 (pH 1.6)	Yamamoto, 1975

The use of kinetic models in the study of sorption and desorption processes in heterogeneous systems continues to attract considerable interest. Three reasons for the use of kinetic or time-dependent models in soils have been suggested (Skopp, 1986). First, many reactions in soils are slow yet proceed at measurable rates. Slow reactions may be of great importance with regard to plant uptake and precipitation products. Second, nonequilibrium conditions can exist as a result of the physical transport of gases and solutes. Third, information about reaction mechanisms and processes occurring may be obtained from such data. Studies of the kinetics of phosphate reactions with arsenic-contaminated soils are of interest for the mobility of arsenic. Because the chemical behavior of arsenic and phosphorus is similar, the kinetic equations employed to model phosphorus reactions in soils may be useful to study arsenic desorption patterns in contaminated soils. The desorption of arsenic over time, after a change in bulk phase conditions, has been described by different expressions, including a first-order kinetic, a parabolic diffusion law, an Elovich-type equation, and a power function equation (Griffin and Jurinak, 1976; Evans and Jurinak, 1976; Onken and Matheson, 1982; Peryea, 1991).

The objectives of this study were to (1) examine As adsorption on soil; (2) determine the forms of arsenic in an artificially contaminated soil by sequential extraction with a series of different chemicals; (3) determine recovery of total arsenic; (4) examine arsenic release from a contaminated soil using phosphate as a leaching solution and determine the most appropriate kinetic model describing arsenic release.

MATERIALS AND METHODS

Soil Characterization

A relatively large mass of soil contaminated with arsenic was required in this study. To obtain a consistent source of this material, it was decided to artificially contaminate a soil with properties that were representative of a loam soil. Prior to contaminating the soil, a study was performed to determine the optimal pH at which maximum arsenic could adsorb. The soil was commercially available for gardening and was commonly used as an agricultural soil in Japan. The mobility of As is believed to be influenced by the physical and chemical characteristics of the soil (Woolson *et al.*, 1973). The order of mobility of arsenic in different types of soil are (Fuller, 1978): sandy loam > silty clay loam > silty clay > clay. Hence, the particle size, pH, organic matter, particle density, and porosity were studied using standard methods (Klute, 1986).

Adsorption and Contamination of Soil

The soil was dried at room temperature and was contaminated with arsenate at different pH values to identify the optimum pH where maximum arsenate adsorption occurred. In this study, 1 g of loam soil was added to a plastic tube containing 25 ml water that contained 15 mg/l of arsenate. The pH of the solution was then adjusted with 0.5 *M* HCl and/or NaOH. This procedure was repeated with the pH values of the arsenate-dosed liquid adjusted to 1.2, 2.4, 3.1, 6.9, 7.8, and 11.4 before adding soil. The soil suspensions were shaken for 24 h in a shaker at a speed of 100 rpm at 20°C. The mixtures were then centrifuged at 10,000 rpm for 20 min. The corresponding pH of the supernatant was measured, and then the sample was analyzed for arsenic by Inductively Coupled Plasma-Atomic Emission Spectrophotometer (ICP-AES).

Based on the results of this study, a large amount of soil (2 kg) was contaminated by dosing with 5 l of a solution containing 1300 mg of arsenate that was prepared from sodium arsenate ($NaH_2AsO_4{:}H_2O$) at a pH of 5.5 under aerobic conditions. The soil was shaken for 24 h and kept under wet conditions for 2.5 months to stabilize in an aerobic environment that was maintained by mixing from time to time in an open tub. After this, the soil was filtered and dried at room temperature for the subsequent desorption studies conducted in this research. The filtrate samples were directly analyzed for As by ICP-AES. The soil samples were transferred into a 100-ml Erlenmeyer flask and a mixture of 5 ml of concentrated HNO_3 and 7 ml of 9 *M* H_2SO_4 was added. The flask was covered with a watch glass and let stand overnight at room temperature. The mixture was then heated gently for 30 min to remove SO_2; 25 ml of deionized distilled water was added and the heating continued for 2 h. The mixture was cooled and filtered (0.45 μ) into a

100-ml volumetric flask. The flask was then filled with deionized water and analyzed for arsenic by ICP-AES.

Sequential Extraction Procedure

All the experiments were carried out in a single batch extraction. The technique of Manful (1992) was employed for the sequential extraction of soil and is subsequently described.

1. *Extraction of easily exchangeable arsenic:* The easily exchangeable fraction of arsenic was extracted from a 1 g soil sample by shaking the sample for 30 min with 50 ml of 1 *M* NH_4Cl solution. The resulting mixture of soil was centrifuged at 10,000 rpm for 20 min and the supernatant was collected for arsenic determination by ICP-AES.
2. *Extraction of aluminium bound arsenic:* The aluminium-bound exchangeable fraction of arsenic was then extracted from the soil residue using 50 ml of 0.5 *M* NH_4F solution at pH 8.2 with 0.1 *M* NaOH solution. The soil suspension was shaken for 24 h, centrifuged for 20 min at 10,000 rpm, and the supernatant was collected. The soil sample was then washed twice using a 25-ml saturated NaCl solution and centrifuged. The decanted supernatant solutions were then added to NH_4F extract for As determination by ICP-AES.
3. *Extraction of iron bound arsenic:* A volume of 50 ml of 0.1 *M* NaOH was added to the soil residue to determine the iron-bound exchangeable fraction of arsenic. The suspension was shaken for 17 h, centrifuged for 20 min at 10,000 rpm, and the supernatant solution was collected and stored. The soil sample was washed twice using a 25-ml saturated NaCl solution and centrifuged. The supernatant solutions were decanted and added to NaOH extract for subsequent As determination by ICP-AES.
4. *Extraction of residual reducible arsenic:* A 40-ml solution containing 0.3 *M* sodium citrate and 5 ml of 1 *M* $NaHCO_3$ solution was added to the soil residue from the previous extraction. The soil suspension was heated in a water bath at 85°C, 1 g of $NaS_2O_4{:}2H_2O$ was then added and the solution was rapidly stirred for 15 min. The suspension was centrifuged and the supernatant was collected. The residue was washed twice using a 25-ml saturated NaCl solution, and centrifuged. The supernatant solutions were decanted and added to the dithionite-citrate-bicarbonate (DCB) extract for arsenic analysis by ICP-AES.
5. *Extraction of calcium bound arsenic:* A 50-ml volume of 0.25 *M* H_2SO_4 was added to the soil residue from DCB extraction. The solution was shaken for 1 h, centrifuged for 20 min at 10,000 rpm, and the supernatant solution was

collected. The soil sample was then washed twice using a 25-ml saturated NaCl solution and centrifuged. The supernatant solutions were decanted and extracts were combined for arsenic analysis by ICP-AES.

6. *Extraction of residual arsenic:* The soil residue after H_2SO_4 extraction was carefully transferred into a 100-ml Erlenmeyer flask and a mixture of 5 ml of concentrated HNO_3 and 7 ml of 9 *M* H_2SO_4 was added. The flask was covered with a watch glass and let stand overnight at room temperature. The mixture was then heated gently for 30 min to remove SO_2, 25 ml of deionized distilled water was added and the heating continued for 2 h. The mixture was cooled and filtered (0.45 μ) into a 100-ml volumetric flask. The flask was then filled with deionized water and analyzed for arsenic. In a separate experiment the total arsenic in the soil was also determined by this method.

Desorption Studies

The desorption of arsenic by phosphate was studied over a range of pH values. In this study, a series of eight plastic tubes was prepared. A volume of 20 ml of NaH_2PO_4:H_2O(0.5 *M*) was added to each tube and the pH values were adjusted to 2.6, 3.1, 3.7, 4.5, 5.3, 6.3, 8.1, and 10.5, respectively, with 0.5 *M* NaOH and/or HCl solution, keeping a constant volume of 25 ml in each tube by adding water. One gram of arsenic-contaminated soil was added to each tube and the resulting suspensions were then shaken for 70 h at 20°C and at a speed of 100 rpm. The resulting mixture was centrifuged at 10,000 rpm, and each supernatant was analyzed for pH and arsenic content. Soil was also extracted with deionized water over a similar range of pH values to act as a control.

The Kinetics of Desorption

The kinetics of desorption were assessed by studying desorption at different intervals in time. A series of six tubes was prepared, each containing 20 ml of 0.5 *M* NaH_2PO_4:$2H_2O$ solution. After adjusting the pH to 5.5 using 0.5 *M* NaOH, the sample volume was increased to 25 ml using distilled water. One gram of contaminated soil was added to each tube and the soil suspensions were shaken at 20°C at 100 rpm. Individual tubes were then removed from the shaker at intervals of 0.067, 0.50, 2.7, 20, 50, and 70 h, and each sample was filtered with 0.45 μm filter paper. Each filtrate was analyzed for arsenic quantitatively by ICP-AES.

Analysis

All samples containing arsenic were analyzed with an Inductively Coupled Plasma–Atomic Emission Spectrophotometer (ICP-AES), ICPS 1000 II, Shimadzu Corp., Kyoto, Japan. A wavelength of 194 nm was employed and the method had a detection limit of 0.075 mg/l.

RESULTS AND DISCUSSION

Soil Characteristics

The physical and chemical characteristics such as particle size, particle density, porosity, pH, organic matter, and arsenic content for unpolluted and polluted soils are presented in Table 2. The texture of the soil was identified by standard methods using a textural triangle as loam soil. The pH of the uncontaminated and contaminated soil was found to be 5.6 and 5.5, respectively. As previously mentioned, arsenic is relatively mobile in loam soils, and therefore it was expected that moderate to high mobility of arsenic would be observed with the soil under study.

Adsorption

A preliminary experiment was performed to assess the impact of pH on adsorption of As to the soil under study. The degree of adsorption was calculated as a percentage of the total arsenate added and is presented as a function of pH in Figure 1. The adsorption of arsenate on loam soil was found to be 99% in the pH range of 4.0 to 7.3 and decreased substantially at a pH of 2.7.

On the basis of these results, 2 kg of soil was contaminated with 1300 mg of As(V) in 5 l of water. It was found that 99% (1287 mg) of the As(V) was retained

TABLE 2
Properties of the Arsenic-Contaminated Soil

Soil characteristic	Original soil	Contaminated loam
Particle size		
Sand	52.0%	50.0%
Silt	32.8%	31.8%
Clay	15.2%	18.2%
pH	5.75	5.50
Organic matter	2.2%	2.12%
Particle density	2.12 g/cm^3	2.15 g/cm^3
Total porosity	0.45	0.42
Total As	—	1285 mg/kg

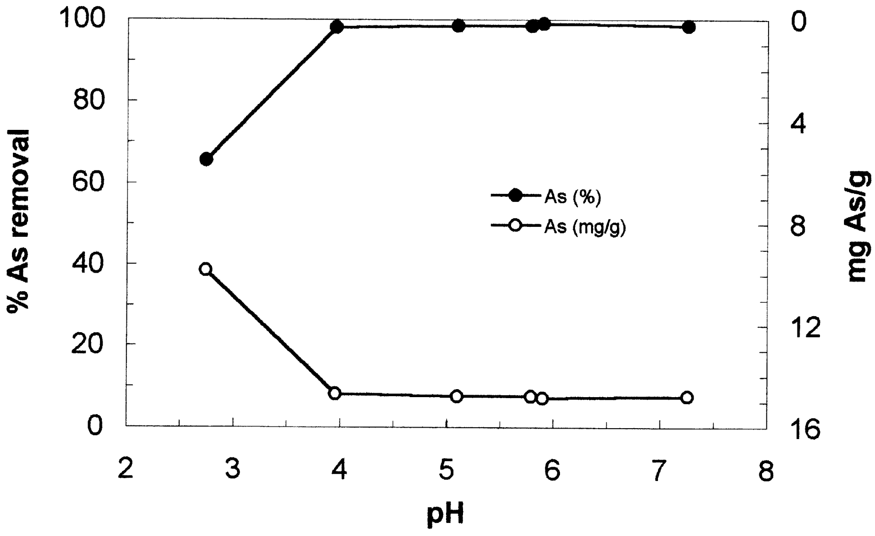

FIGURE 1

Adsorption of arsenate on soil as a function of pH. Amount of soil: 1.0 g and As concentration: 15 ppm.

when the soil was analyzed after 2.5 months at pH 5.5. The arsenic was either adsorbed on the soil particles or reacted with dissolved species of Fe, Al, and Ca ions that were present in the soil solution to form precipitates (Brookins, 1988). Aluminium possesses only one important oxidation state, Al(III) in nature. Under acidic conditions, Al is soluble as Al3+ or AlOH2+, although only Al3+ is shown for convenience (Brookins, 1988). Two types of arsenate adsorption can be identified. First, specific adsorption of arsenate anion on the surface of hydrous oxides of iron and aluminium, for example, iron hydroxide. The second, arsenate anion, can be adsorbed on the surface of oxides of iron or aluminium by a binuclear bridging mechanism (Manful, 1992).

The surface charge properties of soil are strongly influenced by soil pH (Manful, 1992). Acidic soils have large amounts of positive charge and adsorption of the $H_2AsO_4^-$ anion may become important. Arsenate anions are attracted to positively charged colloid surfaces either at broken clay lattice edges where charged Al_3^+ groups are exposed, or on the surfaces of iron and aluminium oxides and hydroxide films (Brookins, 1988). The results of this study demonstrate optimal adsorption of As over the pH range 4.0 to 7.3 and therefore would suggest that adsorption was primarily influenced by the positive surface charge on the soil particles (Manful, 1992). $H_2AsO_4^-$ only protonates significantly at pH values less than 2. Therefore, changes in the degree of ionization should not have been a factor in the observed results (Brookins, 1988).

Sequential Extraction

The results of the sequential extraction study are summarized in Table 3. The following general trends of retention of arsenic were obtained by sequential extractions of the soil under study: exchangeable As-Fe (31.6%) > residual reducible-As (27.3%) > exchangeable As-Al (25.2%) > residual-As (5.5%) > Ca-As (4.9%) > easily exchangeable-As (4.7%). Arsenic in the soil was associated essentially with iron and aluminium with only a small amount associated with calcium. The role of Ca in the fixation process was not as pronounced as the role of Fe and Al (Chukhlantsev, 1956). The use of chemicals such as NH4F and NaOH for the extraction of As bound to aluminium and iron will only release As(V) associated with the elements because the extractions were carried out under aerobic conditions. The addition of reducing agents such as sodium citrate and sodium bicarbonate may release additional As (V) that is present in a reducible form (Manful, 1992).

The fraction of arsenic present in the residual-reducible form was 27.3% and is indicative of that which might be reduced in the soil under anaerobic conditions. Arsenite may be present in various species such as $As(OH)_3$ (pKa 9.2), $As(OH)_4^-$ (pKa 12.1), $AsO_2(OH)^{2-}$(pKa 13.4), and AsO_3^{3-} and is likely to be found when the soil is subjected to anaerobic conditions (Baes and Mesmer, 1976).

The mobility of arsenic in soils is increased under reducing conditions, such as found in a flooded soil, because of the increase in the proportion of arsenite. Arsenite salts are estimated to be around 5 to 10 times more soluble than the corresponding arsenates. Unfortunately, As(III) is both the more available and the more acutely toxic form of the arsenic.

At a particular site, it is important to know how the arsenic is held in the soil before designing a remediation process. Sequential extraction is the most suitable method to study how arsenic is retained in different components of the soil to understand its relative binding strength and hence the solubility, mobility, and bioavailability of arsenic in contaminated soil. Thus, the easily available and reducible fractions of arsenic (totaling 32%) can possibly be leached out first when compared with the other fractions of As. The results of this study yielded a

TABLE 3
Retention Forms of Arsenic in the Soil

As fraction	As (mg/kg)	% As removed
Easily exchangeable	60.8	4.7
Exchangeable Al-bound	323.6	25.2
Exchangeable Fe-bound	406.4	31.6
Reducible	350.5	27.3
Calcium bound	63.5	4.9
Residual	70.5	5.5

minimum value for the As that would be released by a change in oxidation conditions to reducing environment. In a field application it is possible that a greater fraction of the As would be released due to reduction of some portion of the Fe and Al exchangeable fractions. The remaining fraction of arsenic (67.2%) was bound to Fe, Al, Ca, and silicate minerals (residual) and hence under natural conditions is relatively immobile. As shown later, phosphate extraction is a potential remediation approach for this fraction of the As.

pH Dependence of Desorption with Phosphate

The desorption of As from the contaminated soil using a solution of phosphate was examined over a range of pH values. The percentage removal was plotted as a function of pH values and is shown in Figure 2. The removal of arsenic by the phosphate solution was observed to slightly exceed 80% at optimum pH values between 3.9 to 6.4 and then decrease for higher pH values. At elevated pH values, As(V) dissociates to different ionic species ($HAsO_4^{2-}$, AsO_4^{3-}), and the results would suggest that these are not easily exchangeable with phosphate. The avail-

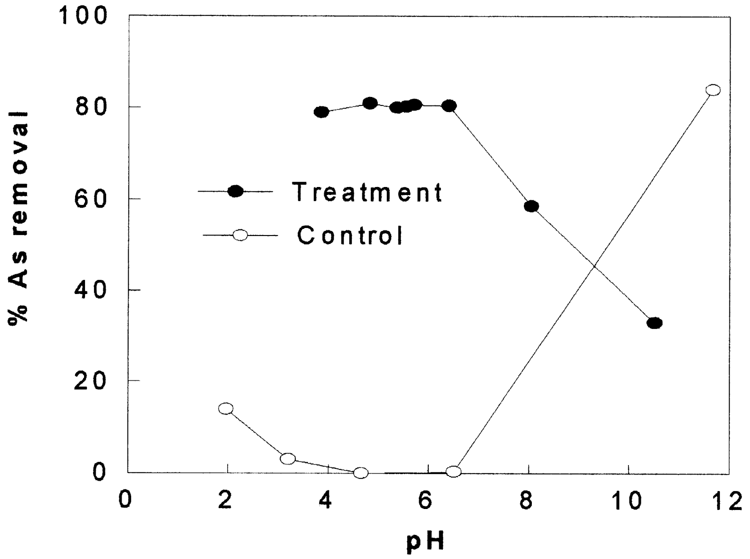

FIGURE 2

Desorption of arsenic by phosphate solution as a function of pH. Amount of soil: 1.0 g, shaking time: 70 h, ● As desorption by phosphate (0.5 M) and ● As desorption by deionized water.

ability of phosphate for desorption reactions likely decreases at elevated pH's due to competing reactions such as precipitation with soil minerals.

The control experiment with deionized water showed that the removal of arsenic over the lower pH range was less than 1%. However, significant desorption was observed in the control at the highest pH values. This desorption was likely due to the soil surfaces becoming negatively charged at the extreme pH examined. The negatively charged anions were then desorbed under these conditions. At elevated pH's desorption increased in the control and decreased in the phosphate-amended solution, suggesting that presence of phosphate interfered with the hydroxide-based desorption process. This was likely due to the increase in ionic strength of the solution that would modify the activity of anions at the soil-water interface.

Arsenate is stable in aerobic soils and was present mainly in this soil. Arsenate has a chemical behavior similar to that of phosphate in soils in that it is chemisorbed by Fe and Al oxides (31.6 and 25.2%, respectively). The ability of phosphate to desorb arsenic in contaminated soil will not only depend on its concentration, but also on the type and nature of the chemical bonds between As and soil particles (O'Nell, 1990).

Phosphate-enhanced desorption of As is a potential treatment technology for As-contaminated soils. The treatment could be carried out *ex situ* by contacting the soil with a phosphate solution and subsequently separating the soil and As-bearing water. If necessary, the pH of basic soils could be adjusted for optimum As removal by using a mixture of phosphoric acid and sodium phosphate solutions.

Evaluation of Kinetic Models

An experiment was conducted to assess the kinetics of desorption when the soil was contacted with a solution containing 0.5 *M* $NaH_2PO4:H_2O$. The results of this experiment are presented in Figure 3a. From Figure 3a, it can be seen that the fraction desorbed increased with time and approached about 80% after 60 h. The extent of desorption at steady state was in agreement with that observed in the prior equilibrium-based experiments. The experimental data were evaluated by employing linearized versions of five kinetic models, namely, the zero and first-order, Elovich, parabolic diffusion, and Power function equations (Table 4). The regression equations relating time and mass adsorbed (XD) are also summarized with r^2 values in Table 4. It was found from the regression analysis of data that only the last three equations fitted well.

The suitability of using the Power, Elovich, and Parabolic equations to describe the desorption data can be assessed by examining Figures 3b,c,d. The power function had the highest value of r^2, and also best described the observed trend in arsenic release from the soil. It is apparent from analyzing the residuals of the Elovich and Parabolic equations that they did not represent the observed trends well. The power function equation constants b and kd were evaluated from the

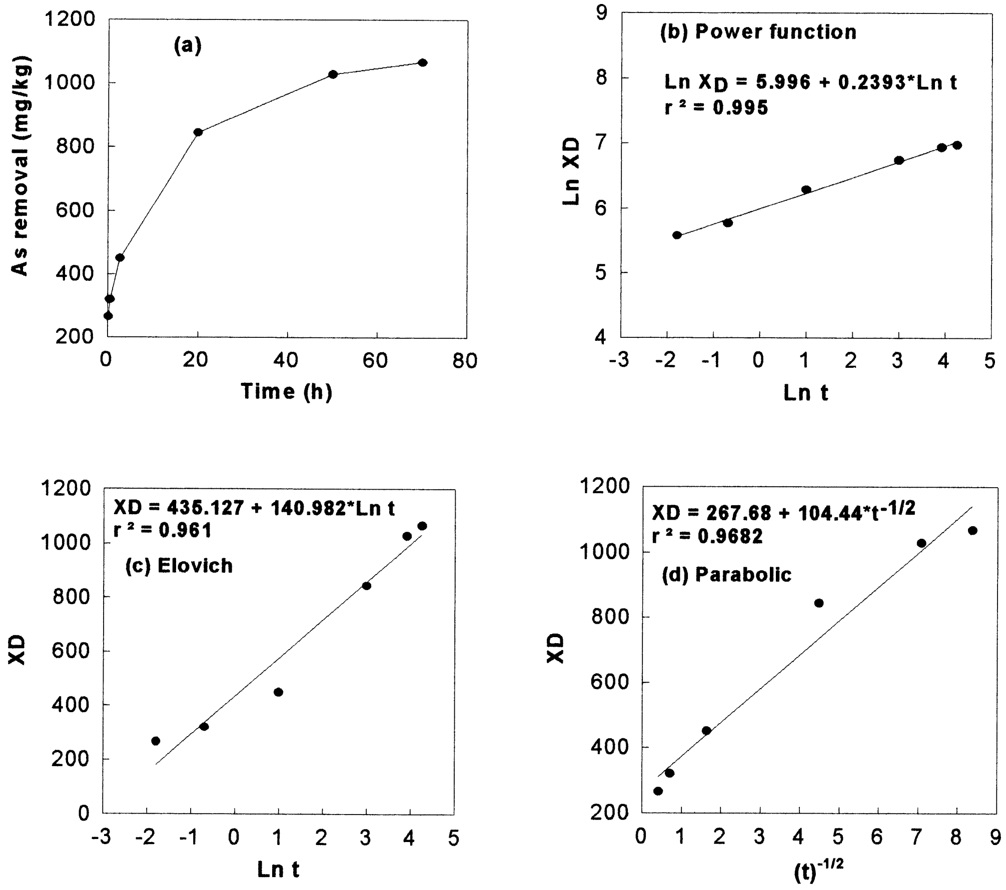

FIGURE 3

Kinetic study of arsenic. (a) removal of As as a function of time with phosphate, (b) power function, (c) Elovich equation, and (d) Parabolic equation. Amount of soil: 1.0 g, pH: 5.5, phosphate concentration: 0.5 M.

slope and intercept of the linear plots and found to be 0.24 and 402 mg/kg h^{-1}, respectively, with an r^2 value of 0.995. A knowledge of the kinetics of desorption is required for designing treatment processes that employ phosphate for desorption of As. The results of this research suggest that the power function model can be used for this purpose for batch completely mixed system.

CONCLUSIONS

It was concluded that 99% of arsenic was adsorbed on loam soil in the pH range of 4.0 to 7.3 during contamination of soil. The results of a sequential extraction test

TABLE 4
Kinetic Equations and Regression Analysis of the Data

Model	Equation	Regression equation	r^2
Zero-order reaction	$X_D = X_{D0} + k_d{*}t$	$X_D = 392.81 + 11.28{*}t$	0.8569
First-order reaction	$\ln X_D = \ln X_{D0} + k_d{*}t$	$\ln XD = 5.92 + 0.02{*}t$	0.7780
Parabolic diffusion	$X_D = X_{D0} + k_d{*}\sqrt{t}$	$X_D = 267.68 + 104.44{*}\sqrt{t}$	0.9682
Elovich equation	$X_D = (1/\alpha){*}\ln(\beta{*}\alpha) + (1/\alpha){*}\ln t$	$X_D = 435.127 + 140.982{*}\ln t$	0.961
Power function equation	$\ln X_D = \ln k_d + b{*}\ln t$	$\ln X_D = 5.996 + 0.239{*}\ln t$	0.9950

Note: Where X_D = amount of arsenic desorption per unit mass of soil, t = reaction time, k_d = desorption rate constant, α = initial instantaneous rate of desorption, β = constant, inversely proportional to ambient rate of desorption, b = empirical constant.

suggested that the arsenic was mainly associated with iron and aluminium. The results obtained for As in the soil under study revealed that it was bound in different fractions in the order of: exchangeable As-Fe > reducible-As > exchangeable As-Al > Residual-As > Ca-As > easily exchangeable-As.

Effective decontamination of arsenic-contaminated soil with a phosphate solution was achieved over a pH ranging from 3.9 to 6.4. It was found that 80% arsenic was removed with a 0.5 *M* phosphate solution after 60 h of equilibration time. The power function equation was found to be the most successful of the kinetic models employed to describe the As desorption data. The rate of desorption was found to 402 mg As/kg h^{-1}.

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