

An Interactive Behavior of Soil Moisture Influences the Concentration of Arsenic in the Acidic Soil of the Plow Layer of the Central Region of Thailand

Patarapong Kroeksakul^{1*}, Phattharapol Srisuwan¹, Thatthep Uaesukpakdee¹, Jakkrapong Panichpaisarn¹

¹ Department of Environment in Faculty of Environmental Culture and Ecotourism, Srinakharinwirot University, Bangkok, 10110, Thailand

* Corresponding author's e-mail: patarapong@g.swu.ac.th

ABSTRACT

This article investigates trends in changing values of arsenic concentration in the plow layer under different conditions of soil moisture in the central region of Thailand. The study consists of two experiments: (1) examining the relationship between the vertical dynamics of As and soil moisture, and (2) exploring the effects of soil surface water evaporation on As speciation transformation and vertical dynamics. The experiments were conducted at the greenhouse facility of the Faculty of Environmental Culture and Ecotourism at Srinakharinwirot University. The evaporation rate of the greenhouse was measured to be 0.000104 mm/m²/h, and the soil permeability coefficient was 0.0014 cm/s. The effects of soil moisture on the vertical distribution of arsenic was found to be significant ($p < 0.05$), particularly on day one, in the layer 0–10 cm. In layers 11–20, 21–30, and 31–40 soil with 40% moisture showed higher concentrations of arsenic than soil with moisture levels of 10% and 20% ($p < 0.05$). The pattern of As available for vertical movement in the plow soil layer showed great variability, especially in the 11–20 cm, 21–30 cm, and 31–40 cm layers. The most notable increase was observed at a 40% moisture content. The principal component analysis (PCA) test found that PC1 was most influential on the soil layers 21–30 cm and 31–40 cm, while PC3 highlighted arsenic concentrations in layers 0–10 cm and 41–50 cm. The movement of arsenic through evaporation from below the plow showed great variability between layers with the most stable concentrations being observed on the 14th day. However, the research showed that arsenic moves vertically in acidic soil rather than evaporating to the soil surface.

Keywords: plow layer, arsenic, acidic soil, soil behavior.

INTRODUCTION

Heavy metal contamination in soil in agricultural areas is an important problem that affects food safety, ecosystems, and people's health. In general, the problem of heavy metal contamination in soil is mainly caused by (1) parent soil (Alloway, 2013; Bardl, 2005) and (2) land use activities such as the release of certain types of contaminated heavy metals from industry, mining activities, or use fertilizers certain chemicals in agriculture (Alengebawy et al., 2021; Rashid et al., 2023). Recent studies have found atmospheric metal contamination from transportation sources (He et al., 2023) and industrial sources (Ghosh et al., 2023). Heavy metals that are dispersed

in the atmosphere will eventually fall to the ground and concentrate there (Jeričević et al., 2012; Sharifi et al., 2023), and arsenic (As) is a heavy metal found in the environment, especially in topsoil around industrial areas and municipal landfills (Nriagu et al., 2007; Hu et al., 2021).

As is a heavy metal found in the soil so it can contaminate in the food chain through biological processes (Gogoi et al., 2024; Baruah et al., 2021). The As found high concentration in loess, glacial tills, peats and acid sulphate soils may have contamination levels as high as 50 mg/kg of soil and sediment in delta regions (Polya and Lawan, 2015; FAO and UNEP, 2021). However, As can flush from soil in acid conditions (Tokunaga and

Hakuta, 2002), so data should be compared to that of other elements that have a positive relationship with highly acidic soil conditions (Gersztyn et al., 2013; Gao et al., 2023).

The soil acidity in central region of Thailand is extreme acidic with an average pH of between 3 and 5 (Jutakanoke et al., 2023; Natural Resources Conservation Service, 1994). This is caused by soil sources in the central plains of the country. The deposit of brackish water sediments results in the creation of pyrite that, in dry conditions, is oxidized until sulfuric acid is created. So pyrite is the chemical change agent responsible for the formation of acidic soil (Land Development Department, 2007). The centrally acidic land is an important rice growing area, where irrigation enables farmers to harvest eight crops in three years (2.66 cropping per year) in a usual conditions (not drought or flooding). Soil moisture has a positive correlation with soil pH. High moisture results in an increase in soil pH (Zárate-Valdez et al., 2006; Vogel et al., 2023), and relate to the migration of elements in soil (Shi et al., 2019).

As can pollute the air through industrial combustion and fossil fuel combustion, so it can be distributed to remote areas where it may fall to the ground (Upadhyay et al., 2019; Patel et al., 2023), resulting in heavy metal residues in the soil layer or the tillage layer, before further storage or incorporation into the soil (Ogunkunle and Fatoba, 2014; Aksu, 2015; Wan et al., 2011). However, the tillage layer is important for microorganisms, and heavy metals can penetrate into soil layers through both physical and biological mechanisms (Soon and Arshad, 2005).

The plow layer of soil is important for agriculture, and is affected by soil erosion. It is where heavy metals have the greatest effect on agricultural production, especially in the acidic zone of central Thailand. This study examined trends in As changes in plow layer stability under conditions of soil moisture. Leaching was used to duplicate soil moisture and As was chosen because it shows heavy metal activity. The result of this study support As transformation or stocking in the plow layer of acidic soil to prediction As in central Thailand.

MATERIALS AND METHODS

Experiment A: behavior of As vertical dynamic relative to soil moisture

Experimental design and implementation

Soil was put into a tube to a depth of 48 cm and topped up with 2 cm of soil contaminated with As at a concentration of 2 mg/kg. At the start of the experiment, a specific amount of water was slowly added to the soil samples in the tube to allow the water to uniformly permeate downward. Moisture content tests were conducted in 10% 20% and 40% of soil volume.

Sampling methods

Soil samples for testing were collected from each tube one, three, five, seven, and 14 days after the commencement of experiment. However, the soil samples were collected hierarchically using a soil drill with an inner pipe. Three samples points

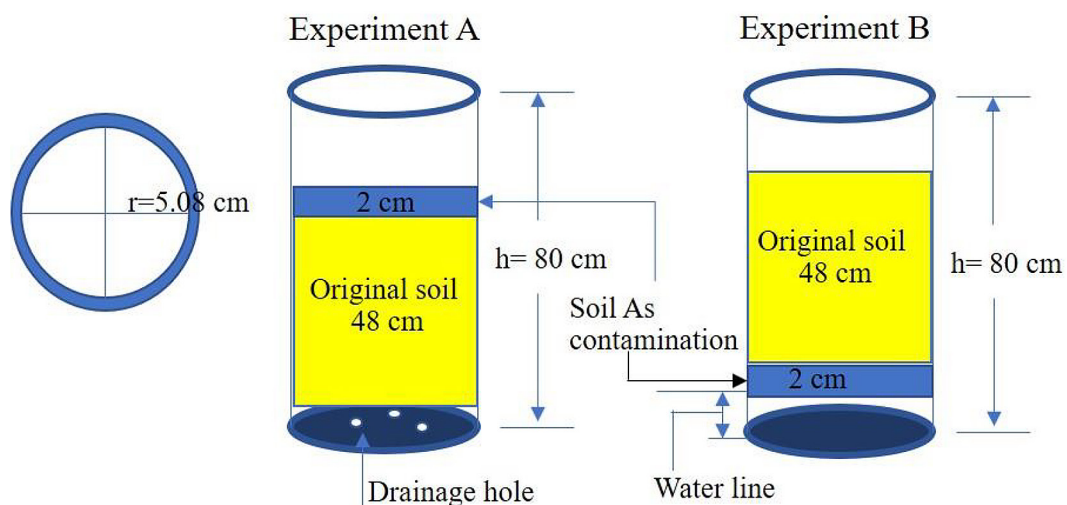


Figure 1. The tube size, soil filling pattern, and water line setting in the water evaporation experiment

were collected for each layer. The soil in the tube layers divided into four distinct layers, namely 0–10 cm, 21–30 cm, 31–40 cm, and 41–50 cm.

Experiment B: behavior of soil surface water evaporation on As speciation transformation and vertical dynamic

Experimental materials

The original soil samples and methods for the preparation of the As contaminated soils were the same as those used in experiment A.

Experimental design and implement

Deionized water was introduced into the tube with the following soil moisture levels: 20 mm of soil at 40% moisture, 10 mm of soil at 20% moisture, and 5 mm of soil at 10% moisture. Then 162 ml of soil with As contamination 2 mg/kg volume was added, and the tube was filled with general soil until it reached 50 cm. The tube size, soil filling pattern, and water line settings for water evaporation in both experiment are shown in Figure 1.

Soil condition and the heavy metal controls

Topsoil was obtained from the top 20 cm of soil in the Ongkharak sub-district, Ongkharak District, Nakhon Nayok province (UTM Zone 47 712029.21 E 1559673.11 N) and dried in a greenhouse for 14 days after being sieved through a No. 20 sieve with a 0.85 mesh size. The soil had an average pH of 3.8 ± 0.17 , average electrical conductivity (EC) of $107 \pm 20 \mu\text{S}/\text{cm}$, soil moisture average of $4.79\% \pm 0.021$, bulk density average of $0.025 \pm 0.006 \text{ cm}^3$, organic carbon average of $281 \pm 130 \text{ mg C}/\text{ha}$, organic matter average of $6093 \pm 2355 \text{ mg}/\text{kg}$. The soil was winnowed with a No. 20 sieve, to ensure that the soil pellets used for testing were smaller than 0.85 mm. A 99% arsenic trioxide (As_2O_3) (Loba Chemie PVT. LTD., India), was used, and adjusted in the soil 5 ppm.

Environmental conditions in the greenhouse

The greenhouse used is at the Faculty of Environmental Culture and Ecotourism of Srinakharinwirot University in Ongkharak district, Nakhon Nayok province limit UTM Zone 47 714327.25 E 1559966.62 N. The temperature range was 29.8–38 °C with an average of $34.3 \pm 1.96 \text{ °C}$, the humidity range was 30–78% with an average of average

55($\pm 11.5\%$). The evaporation rate ($\text{ml}/\text{m}^2/\text{h}$) in the greenhouse was calculate using:

$$ER = (Vol_1 - Vol_2)/T \quad (1)$$

where: ER – evaporation rate ($\text{ml}/\text{m}^2/\text{h}$), $Vol_1(\text{ml})$ – initial of water volume in a 45 mm-wide 500 ml glass cylinder, and the $Vol_2(\text{ml})$ – final of water volume in the 45 mm-wide 500 ml glass cylinder. The ER was 0.000104 $\text{mm}/\text{m}^2/\text{h}$ in the greenhouse between February and March 2004.

Soil sample permeability

The soil permeability was calculated using:

$$K = Q \cdot L / A \cdot h \cdot t \quad (2)$$

where: K – soil permeability coefficient (cm/s), Q – water seepage through the sample (cm^3), L – length of soil sample (cm), A – cross-sectional area of soil sample (cm^2), h – length of water flow through soil sample (cm), and t – infiltration time through soil sample (seconds). So the input data formulation was $Q = 9.53$, $L = 50$, $A = 81$, $h = 80$, $t = 52$.

$$K = 9.53 \cdot 50 / 81 \cdot (80 \cdot 52) \quad (3)$$

The soil permeability coefficient was found to be 0.0014 cm/s

Soil extraction and As analysis

Fifty milliliters of AR (Aqr Regia), a nitro-hydrochloric acid solution made up of a 3:1 ratio of hydrochloric acid (HCl, Beker Analyzed, Taiwan) to nitric acid (HNO_3 , QR&C, New Zealand), was combined with a two to one gram soil sample. The mixture was heated to 500 °C in a SpeedDigester K-425 BUCHI (Switzerland) until it was completely dry. After rinsing the residue with 1% HNO_3 , it was sieved using Whatman No. 1 paper. The supernatant was poured into a 50 mL volumetric flask, 1% HNO_3 was added (ICP-OES), and then the inductively coupled plasma optical emission spectroscopy examination began. A series PlasmaQuant 9100 (Germany) was used for this analysis. Quality assurance and quality control (QA/QC) procedures ensured that all 40 samples, as well as duplicates and blanks, were collected, processed, and examined in the laboratory. The samples were compared to an arsenic (As) ICP Standard by Loba Chemie PVT. LTD (India).

Data analysis

Data were analyzed using one-way analysis of variance (ANOVA), and differences in data were compared using the least significant difference (LSD) test in $p < 0.05$ between data components. Principal component analysis (PCA) evaluated the correlation matrix component of factors of related arsenic concentration in acidic soil of the central region, and correlation analysis was done using Pearson's correlation coefficient ($p < 0.05$). Finally, all analyses were conducted using the program SPSS v.22 (IBM; Armonk, NY, USA) and SigmaPlot v.12.0 (Systat; Chicago, IL, USA).

RESULTS AND DISCUSSION

Soil moisture behavior in relation to arsenic vertical distribution

The soil sample had a soil permeability coefficient of 0.0014 cm/s. It was silty clay, so the permeability was slow (Evirgen et al., 2015, Yusuf et al., 2023). The quantity of As concentration

on day one in the layer 0–10 cm between moisture and soil is significant ($p < 0.05$). In the layers 11–20 and 31–40, the 40% moisture sample had a higher As concentration than the 10% or 20% samples ($p < 0.05$). On days three, five, seven, and 14, all moisture conditions had high variants, especially layers 11–20, 21–30, and 31–40 ($p < 0.05$). The As content in experiment A is shown in Table 1. However, on days seven and 14, the As concentrations in layers 0–10 and 41–50 of all the moisture conditions were not significant, as shown in Figure 2. Although the As moves in accordance with water as it penetrates the soil's surface, it also moves in tandem with iron due to other variables (Smedly and Kinniburgh, 2002; Takahashi et al., 2004). So, the As moves well at a depth of 50–60 cm from the soil (Huq et al., 2003).

The pattern of arsenic available for moving and vertical drive in soil

The arsenic available to move vertically is an expression of As contamination in the ground

Table 1. Vertical distribution and As concentration in soil in experiment A

Date	Layer (cm)	Moisture 10%	Moisture 20%	Moisture 40%
Day 1	0–10	0.649 (± 0.026) ^a	0.515 (± 0.026) ^b	0.751 (± 0.031) ^c
	11–20	0.155 (± 0.106) ^a	0.91 (± 0.152) ^b	0.719 (± 0.016) ^b
	21–30	0.145 (± 0.105) ^a	0.37 (± 0.314) ^a	0.791 (± 0.024) ^b
	31–40	0.148 (± 0.109) ^a	0.591 (± 0.548) ^a	1.81 (± 0.017) ^b
	40–50	0.789 (± 0.047)	0.874 (± 0.741)	0.72 (± 0.020)
Day 3	0–10	0.628 (± 0.429)	0.809 (± 0.047)	0.905 (± 0.862)
	11–20	0.637 (± 0.008) ^a	0.555 (± 0.022) ^b	1.97 (± 0.036) ^c
	21–30	0.530 (± 0.025) ^a	0.505 (± 0.025) ^a	2.89 (± 0.037) ^b
	31–40	0.847 (± 0.030) ^a	0.389 (± 0.197) ^b	5.74 (± 0.051) ^c
	40–50	0.246 (± 0.156)	0.787 (± 1.10)	0.568 (± 0.056)
Day 5	0–10	0.394 (± 0.326) ^a	2.18 (± 0.063) ^b	0.296 (± 0.328) ^a
	11–20	2.94 (± 0.076) ^a	0.857 (± 0.131) ^b	0.325 (± 0.052) ^c
	21–30	0.892 (± 0.031) ^a	0.109 (± 0.083) ^b	1.29 (± 0.064) ^c
	31–40	1.15 (± 0.040) ^a	0.814 (± 0.034) ^b	1.09 (± 0.027) ^a
	40–50	0.887 (± 0.064) ^a	0.17 (± 0.117) ^b	0.599 (± 0.426) ^a
Day 7	0–10	0.65 (± 0.895)	1.15 (± 0.033)	1.37 (± 0.017)
	11–20	0.782 (± 0.017) ^a	2.43 (± 0.004) ^b	0.815 (± 0.034) ^a
	21–30	0.893 (± 0.018) ^a	0.575 (± 0.004) ^b	1.18 (± 0.024) ^c
	31–40	0.514 (± 0.037) ^a	0.731 (± 0.023) ^b	1.16 (± 0.016) ^c
	40–50	1.9 (± 0.251) ^a	0.499 (± 0.014) ^b	0.255 (± 0.254) ^b
Day 14	0–10	0.838 (± 1.11)	0.541 (± 0.695)	1.04 (± 1.52)
	11–20	1.3 (± 0.028) ^a	0.445 (± 0.473) ^b	3.12 (± 0.069) ^c
	21–30	1.27 (± 0.039) ^a	0.482 (± 0.443) ^b	0.447 (± 0.463) ^b
	31–40	0.277 (± 0.130) ^a	0.655 (± 0.325) ^{ab}	0.821 (± 0.259) ^b
	40–50	3.85 (± 6.59)	2.49 (± 3.73)	0.569 (± 1.35)

Note: a, b, c – the mean is row differences significant at p -value < 0.05 (LSD).

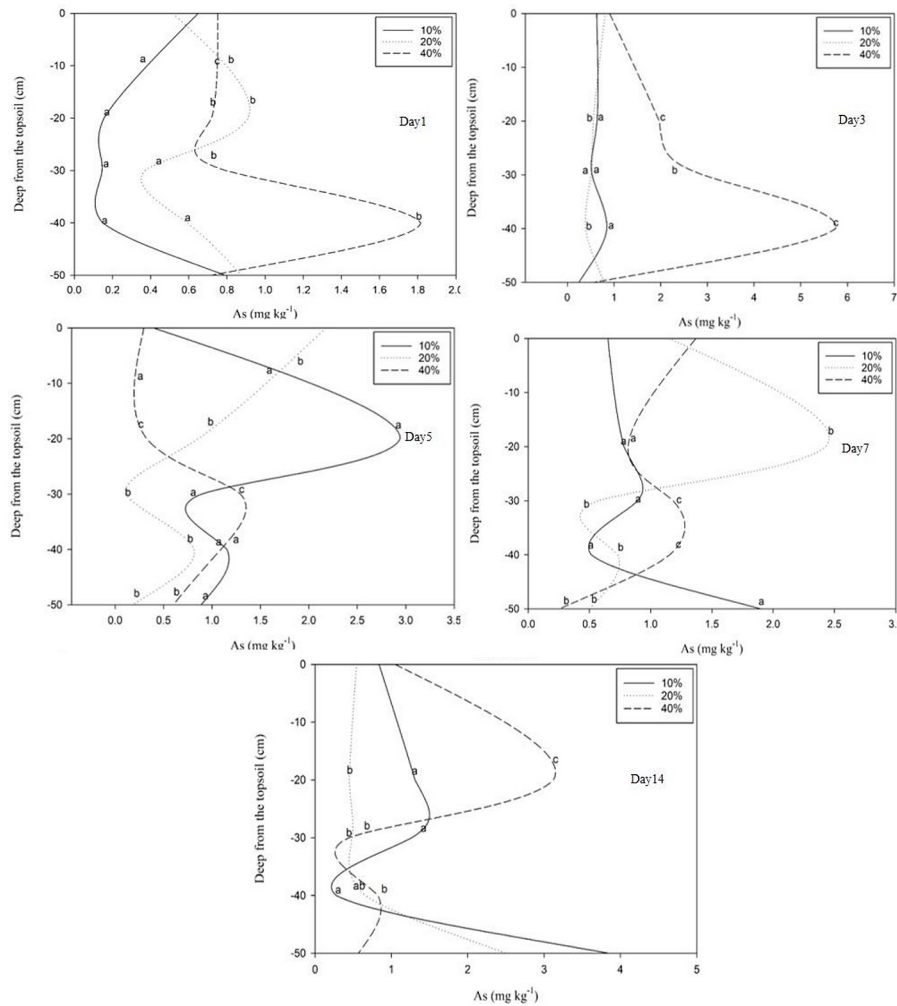


Figure 2. As concentration in soil of vertical distribution of experiment A

water (Zhang et al., 2006). In the plow layer, arsenic accumulates mostly in solution but in the next deeper layer, it will pair with other substances to accumulate in the soil layer (Zhou et al., 2018; Morosini et al., 2023). The following Equation was created assuming that the starting value of accessible arsenic in layer l_0 was C_0 , that a stable equilibrium was reached on day t_m , that the movement rate of As was C_p , and that the downhill direction was negative and the upward direction was positive (Shi et al., 2019).

$$C_i = \frac{\Delta C_i + C_{dis}}{C_0} \quad (4)$$

The ΔC_i movement causes an increase in the l_i layer, due to desorption from bound As in the l_i layer. C_{dis} represents the increment of available As. According to the described equation, the water content in the plow soil layer changes greatly, especially in the 11–20 cm, 21–30 cm, and 31–40 cm layers, with the most common water content being 40% (Figure 3a). However, the amount of

arsenic were highly variable in layers 11–20 cm, 21–30 cm and 31–40 cm every day. Layers 0–10 and 41–50 were more stable after day seven, as shown in Figure 3.

Factors of arsenic available for moving and vertical drive in soil acidic

The correlation analysis revealed that the vertical distribution of arsenic in acidic soil showed a significant correlation with moisture content depths of 21–30 cm (L3) and 31–40 cm (L4) ($r = 0.423$; $r = 0.520$). At L2 (11–20 cm) and L5 (41–50 cm) ($r = 0.329$; $r = 0.311$), there was a correlation between duration and vertical distribution of As, as depicted in Table 2. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test yielded a value of 0.457 (Table 3), indicating sampling adequacy. There was also a significant difference in eigenvalues ($p < 0.001$). Three principal

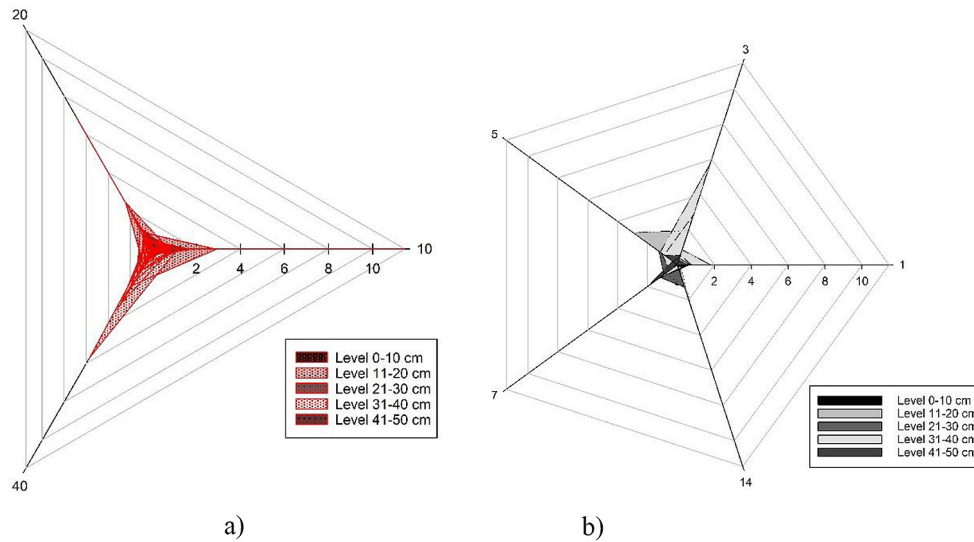


Figure 3. Pattern of arsenic available for moving and vertical drive in soil a) As in the content in level classify from soil moisture 10%, 20% and 40%, and b) As in the content in the level classify from days one, three, five, seven, and 14

Table 2. The correlation between arsenic content in soil acidity difference % moisture and day

Parameter	Day	% Moisture	L1	L2	L3	L4	L5
Day	1			.329*			.311*
% Moisture		1			.423**	.520**	
L1			1				.302*
L2	.329*			1			
L3		.423**			1	.846**	
L4		.520**			.846**	1	
L5	.311*		.302*				1

Note: *Correlation is significant at the 0.05 level (2-tailed), and **Correlation is significant at the 0.01 level (2-tailed); L1 – level 0–10 cm, L2 – level 11–20 cm, L3 – level 21–30, L4 – level 31–40, and L5 – level 41–50 cm.

Table 3. Result of KMO and Bartlett’s test of arsenic available for moving and vertical drive in soil

Kaiser-Meyer-Olkin measure of sampling adequacy	0.457
Bartlett’s test of sphericity	103.82
Degree of freedom	21
Significance	0.000

component (PCs) had eigenvalues of more than 1, which explained 71.4% of total variance in the data set (Table 4). In PC1, the moisture content percentage was most significant for the soil depth layer 21–30 cm (L3), with a factor loading of 0.873, and L4 (31–40) had a factor loading of 0.950. As shown in Table 4 and Figure 4, PC3 revealed relational factors between arsenic concentrations in layer 0–10 cm (L1) and layer 41–50 cm (L5) with factor loadings of 0.756 and 0.832, respectively.

Table 4. The result of the PCA for arsenic available for moving and vertical drive in soil

PCs	Component		
	PC1	PC2	PC2
% of variance	33.3	22.6	15.5
Cumulative %	33.3	55.9	71.4
Eigenvalues	2.32	1.58	1.08
L1	0.10992	-0.03128	0.756149
L2	0.295244	0.77762	-0.06403
L3	0.8739	0.091111	0.134976
L4	0.950998	-0.04454	0.011704
L5	-0.11318	0.172585	0.83244
Moisture	0.705404	0.044578	-0.10743
Date	-0.19138	0.833938	0.20977

Note: PC – principal component; underlined factors loading is weighted when within 10% of the variation of the absolute value of the highest factors loading in each PC; L1 – level 0–10 cm, L2 – level 11–20 cm, L3 – level 21–30, L4 – level 31–40, and L5 – level 41–50 cm.

Behavior of arsenic by evaporation moving from below the plow layer

In the experiment has 0.000104 mm/m²/h in the greenhouse, t, the evaporation rate was measured at 0.000104 mm/m²/h. On day one, the

concentration of arsenic in layer 41–50 cm was significant under soil moisture conditions ranging from 10% to 40% compared to 20% soil moisture ($p < 0.05$). Samples with a moisture content of 40% showed higher concentration than at other percentages. No significant differences were

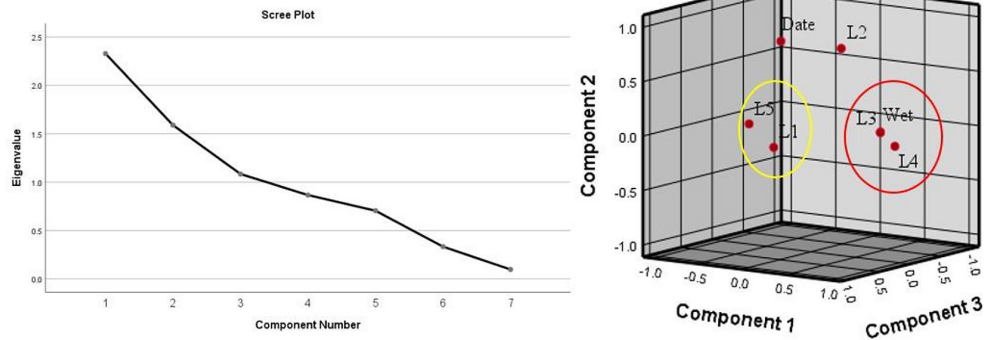


Figure 4. Result of the PCA of arsenic available for moving and vertical drive in soil a) the eigenvalues of component in the principal analysis; and b) the component of PC loading. PC1 is and factors group in the red ring; and PC3 s present in the yellow ring

Table 5. Concentration of arsenic by evaporation from below of plow layer

Date	Layer (cm)	Moisture 10%	Moisture 20%	Moisture 40%
Day1	0–10	0.437(±0.040) ^a	0.835(±0.020) ^b	3.493(±0.250) ^c
	11–20	0.409(±0.043) ^a	0.709(±0.037) ^b	1.66(±0.046) ^c
	21–30	0.282(±0.208)	0.317(±0.068)	2.23(±1.93)
	31–40	0.319(±0.209) ^a	0.158(±0.039) ^a	1.45(±0.584) ^b
	41–50	0.925(±0.381) ^a	0.211(±0.179) ^b	0.833(±0.041) ^a
Day 3	0–10	0.464(±0.374)	0.54(±0.187)	0.8(±0.756)
	11–20	0.606(±0.031) ^a	0.337(±0.259) ^a	2.53(±0.044) ^b
	21–30	0.58(±0.046) ^a	0.195(±0.075) ^b	1.77(±0.069) ^c
	31–40	0.826(±0.066) ^a	2.1(±0.090) ^b	3.02(±0.428) ^c
	41–50	0.623(±0.407) ^a	1.98(±0.023) ^b	1.3(±0.010) ^c
Day 5	0–10	0.774(±0.983)	0.192(±0.156)	0.998(±0.934)
	11–20	1.03(±0.005) ^a	0.177(±0.104) ^b	2.05(±0.024) ^c
	21–30	0.758(±0.042) ^a	0.488(±0.412) ^a	2.44(±0.050) ^b
	31–40	0.700(±0.037) ^a	2.18(±0.060) ^b	0.805(±0.035) ^c
	41–50	0.159(±0.150) ^a	1.91(±0.025) ^b	0.835(±0.046) ^c
Day 7	0–10	0.408(±0.481)	0.709(±0.984)	1.22(±1.62)
	11–20	1.05(±0.045) ^a	1.58(±0.036) ^b	1.21(±0.044) ^c
	21–30	0.747(±0.009) ^a	1.02(±0.021) ^b	1.39(±0.024) ^c
	31–40	0.627(±0.032) ^a	2.8(±0.022) ^b	1.1(±0.018) ^c
	41–50	0.787(±0.181)	0.942(±1.62)	0.579(±0.007)
Day 14	0–10	1.04(±0.206) ^a	0.139(±0.114) ^b	0.596(±0.305) ^a
	11–20	2.83(±0.052) ^a	2.82(±0.041) ^a	0.64(±0.279) ^b
	21–30	1.99(±0.107) ^a	2.72(±0.032) ^b	0.429(±0.422) ^c
	31–40	1.48(±0.144) ^a	2.55(±0.106) ^b	0.472(±0.385) ^c
	41–50	2.92(±0.105) ^a	2.36(±0.078) ^a	0.424(±0.487) ^b

Note: a, b, c – the mean is row differences significant at p -value <0.05 (LSD).

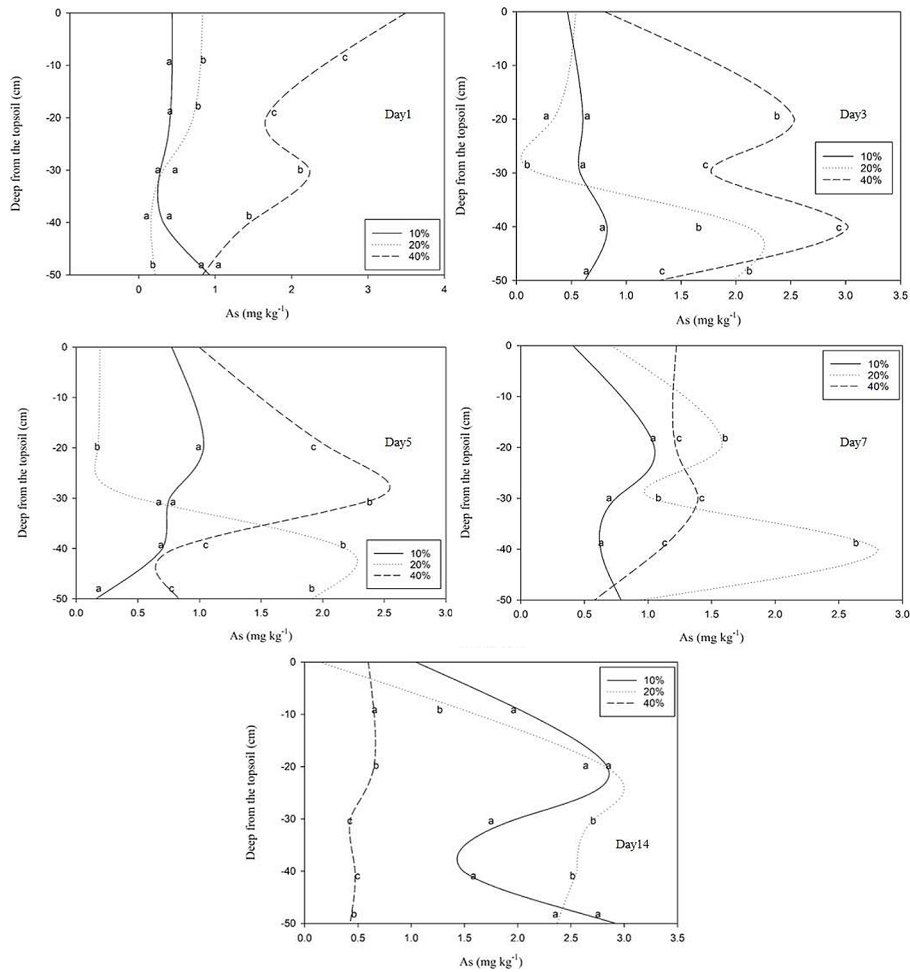


Figure 5. As concentration evaporation moving from below of plow layer experiment B

observed on day three and day five in the 0–10 cm layer regardless of moisture condition but significance was found in other layers ($p < 0.05$). On day seven, layers 0–10 and 41–50 cm showed no significant but layers 11–20, 21–30, and 31–40 did ($p < 0.05$). By day 14, layer 41–50 cm showed lower arsenic concentrations at 40% moisture content, as compared to moisture levels of 10% and 20% ($p < 0.05$). The data on arsenic concentration resulting from evaporation from below the plow layer is presented in Table 5 and Figure 5.

The pattern of arsenic available for moving and evaporation in soil acidity

Arsenic can diffuse horizontally and vertically, including through evaporation from soil (Venteris et al., 2014; Han et al., 2023), and the moisture in the soil is a factor that affects this diffusion (Gao et al., 2007). However, Figure 5 shows that the distribution of arsenic in soil layers exhibits high variability with the most stable

concentrations being observed on the 14th day. Arsenic concentrations were higher under soil moisture levels of 10% and 20% than 40% in layer 41–50 cm, which indicates that lower humidity brings arsenic to the deeper layers. Experiment B showed that the highest arsenic deposition was in layer 41–50 cm (Figure 6a). However, arsenic levels exhibited greater variability in layers 11–20 cm, 21–30 cm, and 31–40 cm regardless of duration, and layers 0–10 and 41–50 were more stable after day 14, as shown in Figure 3b.

Behavior of humidity on arsenic mobility in the plow layer of acidic soils

The movement of minerals is affected by experimental variables such as soil moisture percentage and pH, especially in acidic soil conditions (Shaw, 2006). However, in soil with a slow permeability coefficient is character of silty clay, arsenic migrates to the bottom layers through a combination of gravity and the existence of carrier

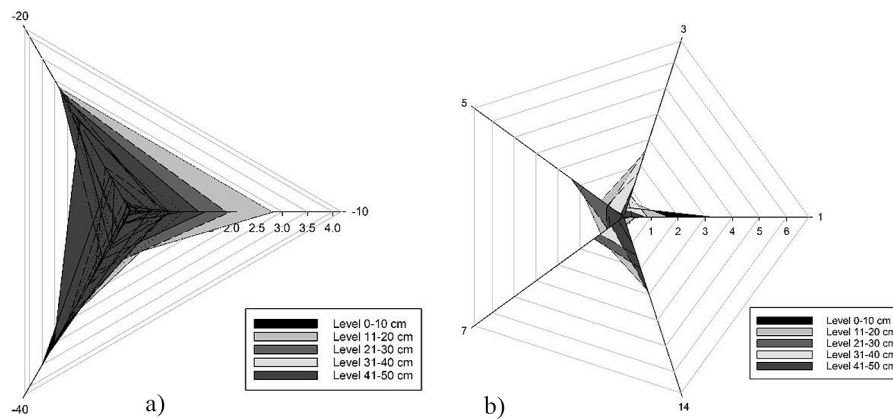


Figure 6. Pattern of arsenic available for moving and evaporation in soil acidity (a) As content in soil humidity levels of 10%, 20% and 40%, and (b) As levels over time in days one, three, five, seven, and 14

element such as iron (Singh and Srivastava, 2020; Tang et al., 2023; Komaei et al., 2023). Therefore, arsenic tends to accumulate in the subsurface layers (Coles and Rohail, 2020). This is in contrast to the movement of arsenic from the lower layers up to the soil surface through evaporation, which consumes a lot of energy (Vásquez-Noga and Hernández-Mendoza, 2022; Tran et al., 2023). Other characteristics of soil parent material include humidity levels, bulk density, and anti-gravity forces in the soil (Chang et al., 1999; Amaibi et al., 2019).

CONCLUSIONS

Arsenic tends to accumulate more effectively within the plow of soil, down as deep as 60 cm. In the central region of Thailand, the soil is the acidic silty clay with an average pH of 3.8 ± 0.17 , an average EC of 107 ± 20 $\mu\text{S}/\text{cm}$, average soil organic carbon of $281 (\pm 130)$ mg C/ha, and average soil organic matter of $6093 (\pm 2355)$ mg/kg. The soil moisture content affects how arsenic moves between the soil layers. However, the lowest layer and the top layer of soil see the greatest movement of arsenic on the 7th and 14th days, with the As variation being highest in layers 11–20 cm, 21–30 cm and 31–40 cm. Experiment B shows that it is difficult for water to bring arsenic to the soil surface, so arsenic is distributed between soil layers 11–20 cm, 21–30 cm, and 31–40 cm. These all have higher variations than layer 41–50 cm. The movement of minerals is affected by experimental variables such as soil moisture, pH, and gravity. While arsenic movement from the lower layers up to the soil surface requires

high energy, arsenic favors deposition in deeper soil layers in acidic soil rather than relying on water release to the soil surface.

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