Potential impacts of certain remediative amendments in enhancing phytoremediation in various contaminated soil ecosystems

M. Saber[1], Wafaa Haggag M.[2], E. Hoballah[1], Soad El-Ashry[3], A. M. Zaghloul[3*]

(1. *Agric. Microbiology Department, National Research Centre. Dokki, Cairo, Egypt*;

2. *Plant pathology Department, National Research Centre. Dokki, Cairo, Egypt*;

3. *Soils and Water Use Department, National Research Centre. Dokki, Cairo, Egypt*)

Abstract: After building of Grand Ethiopian Renaissance Dam (GERD), significant drastic shortage in Nile water resources in Egypt is expected. This water shortage forced Egyptian farmers to use low quality water in irrigation resources impregnated with a variety of contaminants such as potential toxic elements PTEs transferred into the food chain. In a complete randomized plot design greenhouse experiment, three terrestrial soil ecosystems, collected from Abou-Rawash (Konbera), Sinai and Kafr El-Sheikh Governorates irrigated with varied types of low-quality waters for extended periods were trailed for the sake of valuation of new innovative phytoremediation practices using kinetic approach. Calculated Zinc equivalent ZE parameter, indices for soil safety for cultivation, the numerical values ranged between 340 and 630, while the critical level should not exceed 200. Integrated management practices were applied represented in using canola hyper accumulator plant, in association with *Thiobacillus thioxidane*, *Thiobacillus ferroxidanse* and *Glomus* sp. [Arbuscular Mycorrhiza (AM)] after furnishing the soil ecosystem with the chemical stabilizer probentonite. Results indicated that canola was efficient especially in nickel (Ni) uptake compared to copper (Cu) or Zinc (Zn) pollutants. In addition, the application of Thiobacillus bacteria and AM significantly enhanced the uptake of PTE's. The kinetic parameter of modified Freundlich equation (MFE) empirical model confirmed that a mixture of all remediation amendments was the best in minimizing Zn equivalent value to a safe level. The different mechanisms that might take place between the applied remediation amendments and PTE's in the three contaminated soil ecosystems were discussed.

Keywords: Zn equivalent, kinetic models, PTE's, soil ecosystems, sewage effluents, *Thiobacillus*, *Glomus* sp. *(AM)*

Citation: M. Saber., W. Haggag, E. Hoballah, S. El-Ashry, and A. M. Zaghloul. 2018. Potential impacts of certain remediative amendments in enhancing phytoremediation in various contaminated soil ecosystems. Agricultural Engineering International: CIGR Journal, 20(4): 33–42.

1 Introduction

The contamination with potential toxic elements (PTEs) is ubiquitous problem and persistent unlike other contaminants. These contaminants are not degradable and their residence time in the soil approach thousands of years. Recently, a considerable degree of worldwide concern has been developing regarding the effects of PTEs on the soil ecosystems which would become unsuitable for farming due to restrictions for human and animal health and negative impact on soil microorganisms (McGrath et al., 1998).

Received date: 2018-03-02 **Accepted date:** 2018-07-16

***Corresponding author: A. M. Zaghloul**, Soils and Water Use Department, National Research Centre. Email: alaazaghloul2002@ yahoo.com.

Nowadays bioremediation of PTEs gained top priorities in many countries. In USA for instances million dollars are spent annually to combat metals distribution in the environment which is usually relying on engineering-based technologies, such as isolation and contamination, and decontamination them by physical, chemical or biological technologies (Cunningham and Berti, 1997). Over the past decade phytoextraction of PTEs in contaminated soil ecosystems integrated with other techniques represented great challenge for the modern environmental technologies especially if those contaminants have an eco-toxicological adverse impact.

Today and in many cases, the soils are not actually cleaned, but simply removed from the contaminated site and deposited somewhere else. This is an expensive method and would never be sustainable in the long run (Abou-Seeda et al., 2005). The development of economically and environmentally sustainable methods is therefore of utmost importance.

One of the most recent techniques which have been developed during the last couple of decades is phytoextraction technique, where plants are used to remove the contaminants from the soil ecosystem. The identification of hyper-accumulator plant species demonstrates that they possess a genetic potential to remove PTEs from contaminated soil ecosystem. Understanding the plant-based remedial mechanisms is important for several reasons. For example, the elucidation of these mechanisms might provide clues for optimizing the effectiveness of phytoremediation with appropriate agronomic practices.

The dynamic of PTEs and their transport in the soil profile play a significant role in their bioavailability in soil ecosystem. Understanding contaminants release through the kinetic studies and bioavailability could be a good indicator for PTEs absorption by both regular plants and hyper accumulator (Abouziena et al., 2012).

Although different remediation technologies involving phytoremediation have been used to minimize the risks associated with PTEs in contaminated soil ecosystems (Jang et al., 2005; Usman and Mohamed, 2009; Ok and Lim et al., 2011; Ok and Kim et al., 2011; Ok and Lee et al., 2011), yet a little effort evaluated the impacts of the trailed remediative amendments on enhancing the applied bioremediation technologies. The aim of this work is to evaluate the effects of different remediative amendments used in enhancing phytoremediation technology applied in different soil ecosystems.

2 Materials and methods

2.1 Soils

Three different surface soil samples (0-30 cm) were collected, the 1st alluvial clay from Kafr El-Sheikh governorate S1 (about 134 km north of Cairo, in the Nile Delta of Lower Egypt, The Latitude and Longitude of Kafr el-Sheikh Governorate is 31.3085444 and 30.8039474 respectively), the 2nd clay loam from Abou Rawash-Konbera, Giza governorate S2 (The Latitude and Longitude of Giza governorate is 28.7666216 and 29.2320784 respectively) and the 3rd clay loam from El-Tina plain, Sinai governorate S3 (The Latitude and Longitude of North Sinai Governorate is 30.6084723 and 33.617577 respectively). The selection of these soil ecosystems was based on variation in their land use, biological properties and types and period of LQW used. Some physicochemical properties of used soils are presented in Table 1.

Table 1 Chemical characteristics of soil samples collected from Sinai * (Oven dry basis)

Soil No.	Land use period years	Land use	pH	EC (dS·m^{-1})	OM (%)	TDS (mg kg^{-1})	Sand (%)	Silt (%)	Clay (%)	Soil Text.
Kafr El-Shekh	>70	Common Bean	7.9	2.6	1.8	1152	13.7	32.0	54.2	clay
Konbera	>50	Tomato	7.5	0.6	3.6	390	41.5	23.5	35.0	clay
Sinai	>35	Sugar Beet	7.8	2.2	0.23	1408	47.4	31.3	21.3	Loam

2.2 Remediation strategy

The Remediation management of these soils consisted of three sets of treatments applied in three replicates in columns filled with 15 kg of each soil. The management of treatments applied is as follow:

I. Phytoremediation technique

The main phytoremediation plant used in this experiment is canola (*Brassica napus*), this hyper accumulator plant has significant value in minimizing the hazards of PTE's in soil.

II. Chemo-biological remediative amendments used in this work.

III. Rock phosphate applied at 0.525 ton/hectare enriched with phosphate dissolving bacteria (4 liters of appropriate liquid medium containing about 10^{6} CFU g^{-1} dried soil) and mixed with Probentonite (Abouziena et al., 2012, 2013).

2.3 Soil treatments

T1). Sulfur 0.525 ton hectare^{-1} ton/feddan fortified with *Thiobacillus thiooxidans* (4 liters of appropriate liquid medium containing about 10^{6} CFU g^{-1} dried soil), *Thiobacillus ferrooxidans* (4 liters of appropriate liquid medium containing about 10^{6} CFU g^{-1} dried soil) and *Glomus* sp. (AM) (Abouziena et al., 2012, 2013).

T2). Sulfur + probentonite, (probentonite NRC patent under investigation at the Patents office ASRT (363/2013)

T3). Probentonite incorporated with PR and fortified with phosphate dissolving bacteria (PDB) (2 liters of appropriate liquid medium containing about 10^6 CFU g^{-1} dried soil) (Abouziena et al., 2012, 2013).

T4). Mixture of all materials 0.525 ton $hectare^{-1}$ ton/ feddan

And control treatments represented by:

CU): Control uncultivated soil and

CC. Control cultivated.

Irrigation water used for growing plants was collected from the main irrigation canals of different sites even for control treatment.

Soil quality criteria: Zn equivalent model was numerically expressed for the levels of PTEs toxicity in different soil ecosystems according to Saber et al. (2012) using the following equation:

Zn concentration x1 + Cu concentration x2 + Ni concentration x8 (1)

Zn: Zinc; Cu: Copper; Zinc: Zn.

2.4 Instrumentation and analysis of PTEs

Flame atomic absorption spectrometry (FAAS) is a simple and well available technique frequently used in determining PTEs in natural aquatic samples. A Perkin–Elmer FAAS and HACH DR890 colorimeter was used in this study. Atomic absorption measurements were carried out using air: acetylene flame while HACH colorimeter measurement with the provided test kits. The operating parameters for working elements were set of as recommended by the manufacturer.

2.5 Kinetic studies

The kinetic results were matched in five models representing both empirical and theoretical patterns as follows:

First order equation:

$$\text{Log}\,(q_\varphi - q_t) = \text{Log}b - at \quad (2)$$

Elovich équation:

$$q = (1/a)\ln(ab) + (1/a)\ln t \quad (3)$$

Modified Freundlich equation

The kinetic data was fitted to the Modified Freudlich kinetic model MFE which showed in different in studies the priority of using this empirical model in describing the rate of PTEs release from different soil ecosystems (Saber et al., 2012)

$$q = b\,t^a \quad (4)$$

Parabolic Diffusion equation:

$$q = \text{b} + a\,t^{1/2} \quad (5)$$

HOERL model

$$q_t = a \times X^b \times E^{(a\times t)} \quad (6)$$

where, q = the amount of ion(s) desorbed at time t; a = desorption rate coefficient in mg kg^{-1} soil min^{-1}; b = constant in mg kg^{-1} soil; q_φ = maximum amount of contaminants release; q_0 = initial amount of contaminants at the time of starting; q_t = amount of contaminants release at time t; t = time in minute; k_1 = rate constant of reaction n in sec^{-1}; a & b = Constants represent intensity and capacity factors mathematically calculated by statistical software.

The mathematical equations were tested by least square regression analysis for PTEs release in soil ecosystems. The conformity of release from studied soil ecosystems to a given equation was based on higher coefficient of determination R^2 and lower standard Error SE values (Helal and Zaghloul, 2008).

2.6 Statistical Analysis

All data were processed by Microsoft Excel. Regression of linear and other statistical analyses were conducted using the programs of costate version 6.400, a statistical analysis software package published by CoHort Software (CoHort, 2008).

3 Results

3.1 PTEs uptake by canola plants as affected by remediative amendments at both vegetative and mature stages

Figures 2 showed that in Konbera soil, the application sulfur fortified by *Thiobacillus thiooxidans*, *Thiobacillus ferrooxidans* increased Zn uptake by about 16% over control, the corresponding value in Kafr El-Shekh and Sinai soils were about 10% and 20% respectively. Application of fortified sulfur increased the uptake of Cu by canola plant in the all soil ecosystems studied. The uptake of Cu increased by about 18% over control in Sinai soil, this value decreased to 13% in Konbera while the corresponding value of Kafr El-Sheikh was 20% compared to control. The application of sulfur also increased the concentration in plant by about 15% and 16% in Sinai and Konbera and 14% in Kafr El-Sheikh soils.

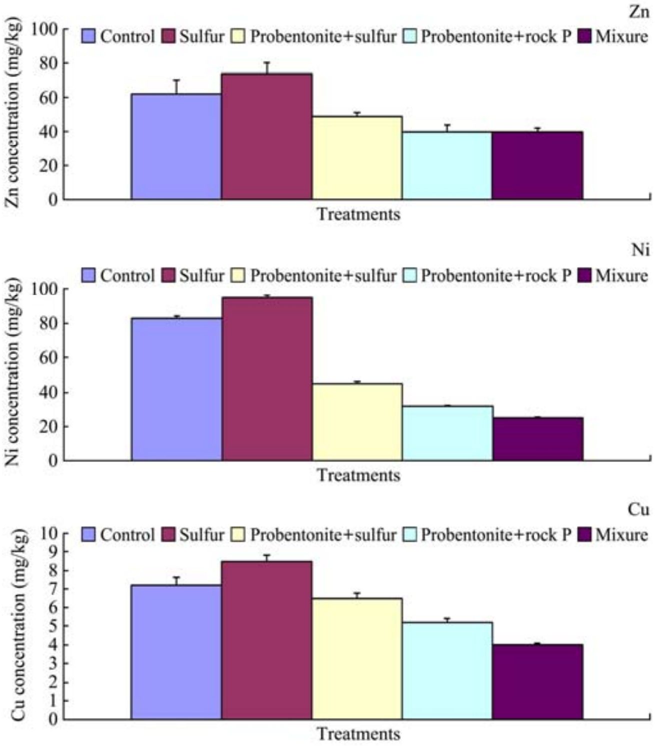

Figure 1 PTEs uptake by canola hyper accumulator at maturity stage as affected by remediative amendments applied in Sinai soil

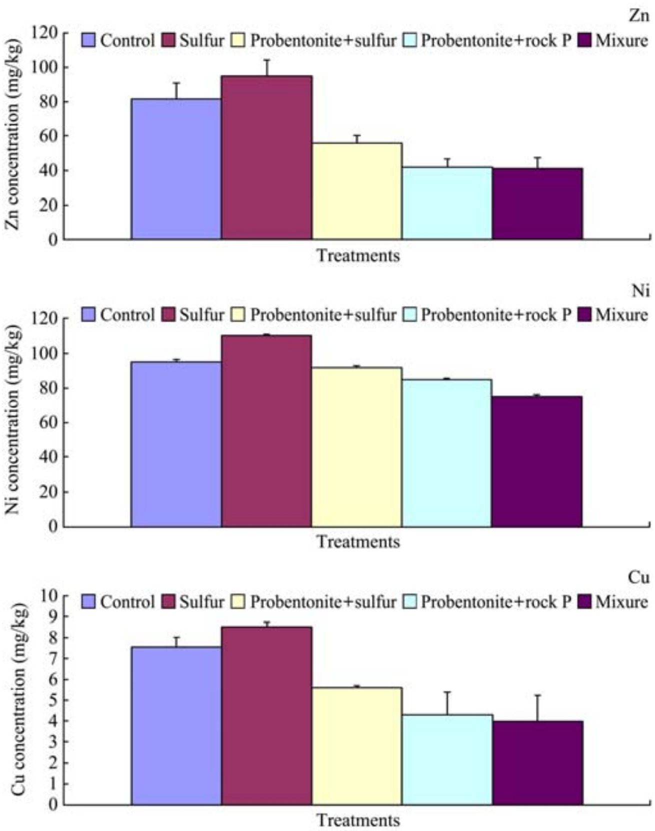

Figure 2 PTEs uptake by canola hyper accumulator at maturity stage as affected by remediative amendments applied in Konbera soil

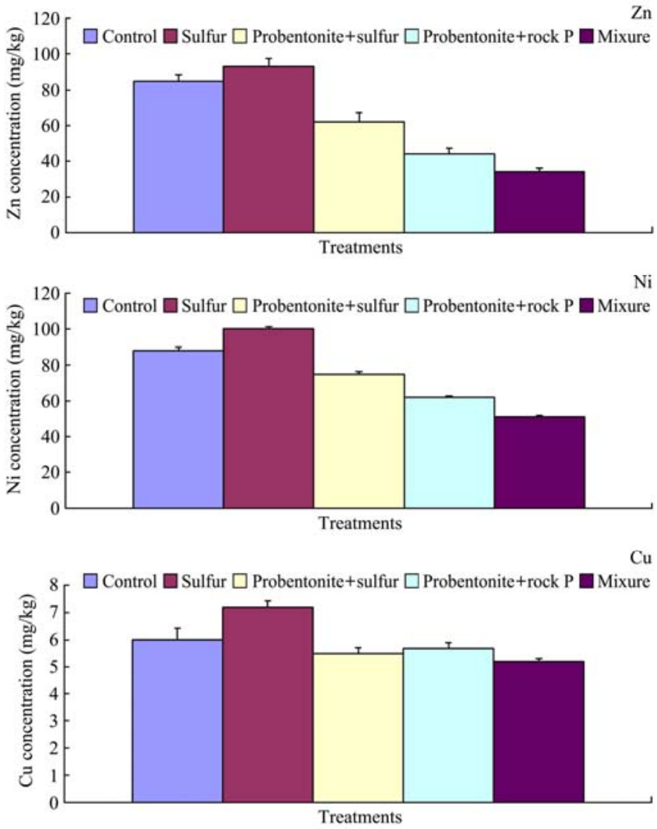

Figure 3 PTEs uptake by canola hyper accumulator at maturity stage as affected by remediative amendments applied in in Kafr El-Sheikh Soil

In the same figures, data imply that incorporation of probentonite in soil reduce the action of sulfur in canola uptake of PTEs. In Sinai soil, incorporation of sulfur with probentonite decreased the uptake of Zn by about 21% compared to control, the same action took place with other PTEs by about 10% and 46% for Cu and Ni respectively.

Figure 2 PTEs uptake by canola hyper accumulator at maturity stage as affected by remediative amendments applied in Sinai soil.

Although the same trend was found in other trailed soil ecosystems in our study, variation in uptake values reached to 32%, 26%, 4% in Konbera; 27%, 9% and 15% in Kafr El-Shekh for Zn, Cu and Ni respectively.

Incorporation of PR fortified with PDB associated with Probentonite in the different trailed soil ecosystems significantly decreased the action of canola in uptake of PTEs. Results showed that in light texture of Sinai soil with conditions, application of Probentonite mixed with PR decreased the uptake of Zn by about 60% less than control; the corresponding values were about 61% and 30% for Cu and Ni respectively. The application of the same treatments in Konbera soil exhibited the same trend with varied percentages. The uptake of Ni decreased by about 10% less than control, yet this value increased to 45% and 50% in Cu and Zn respectively. The same remediative amendments in Kafr El-Shekh contaminated soil with heavy texture, gave the same percentage of decrease in Zn uptake, but decreased to about 5% and 62% in Cu and Ni respectively. These results might describe the effect of soil texture and contaminants distribution in different soil ecosystems.

Mixture of all remediative amendments applied in different soils ecosystems significantly influenced the uptake of PTEs. The lowest values of PTEs uptake by canola hyper accumulator plant from the different soil ecosystems was documented. In kafr El-sheikh soil, for example, the application of a mixture all remediative amendments only absorbed 34 mg kg^{-1} from contaminated soil with decreasing percentage equal to about 60% compared to control, this value decreased to about 45% for Ni and again decreased to 5% in Cu. Although the same trend was again detected in Konbera soil, it should be mention that the percentages of PTEs uptake by canola decreased to 50%, 47%, and 21% for Zn, Cu and Ni respectively less than control with significance differences in case of Cu uptake. In Sinai, the uptake of Cu was drastically decreased from 83 mg kg^{-1} in control to 25 mg kg^{-1} in soil treated with a mixture of all remediative amendments which represent about 70% less than control treatment. The same trend was also showed in other PTEs by about 35 and 45% for Zn and Cu respectively.

From the abovementioned findings, the comparison between different all remediative amendments in enhancing phytoremediation indicated that in all soils ecosystems, sulfur was only treatment that only significantly enhanced the uptake of PTEs from different contaminated soils, however, the application of Probentonite mixed with PR or even sulfur or a mixture all remediative amendments drastically decreased the uptake of PTEs.

3.2 Available forms of PTE's after remediation in different soil ecosystems as influenced by different trailed remediative amendments applied

The available forms of Ni, Cu and Zn in different soil ecosystems are depicted in the Figures 4-6. Results indicated that cultivation of canola hyper accumulator only decreased the available Ni in Kafr-el-Sheikh soil from 26.5 mg kg^{-1} in control uncultivated to about 18.9 mg kg^{-1} with percentage equal to about 28.7% under control, decreased to 7.5% and 7.77% in Cu and Zn available forms respectively. The effect of hyper accumulator cultivated in Konbera soil significantly decreased the available Ni in soil from 49 mg kg^{-1} to 24 mg kg^{-1}, this decrease equaled to about more than 50% under control uncultivated soil, the corresponding values were 36% and 11% for Cu and Zn respectively.

It should be mention that the same trend was also detect in the available forms of PTEs in Sinai soil ecosystem with percentage values equal to 47.2%, 29% and 32.65% for Ni, Cu and Zn respectively.

Application of sulfur to the soil ecosystem significantly decreased the available forms of PTEs in different soil ecosystems. Results in the same Figures (Figure 6 showed that available Ni in Sinai decreased from 18 to 7.5 mg kg^{-1} by sulfur application fortified with *Thiobacillus thiooxidans*, *Thiobacillus ferrooxidans* and *Glomus* sp. (AM). In other words, about 60% of available Ni decreased due to the application S remediative amendment. In addition, about 53% and 47% decrease was recorded in available Cu and Zn by application of the same treatment.

Results in Figure 5 imply that 66.03% of available Ni in Kafr El-Shekh significantly decreased by application of probentonite incorporated with PR, this value increased to 72% in mixture of all remediative amendments added to the same soil. Application of probentonite incorporated with sulfur in the same soil ecosystem, decreased the available Zn by about 83% compared to control uncultivated soil. Although the same trend was observed in other ecosystem, it should be documented that application of mixture of all remediative amendments decreased the available Cu in Konbera to 92%.

3.3 Remediative amendments techniques on Zn equivalent parameter calculated in different soil ecosystems

Zinc equivalent index was used in this work as a promising tool to follow the fate of PTEs in different soils ecosystems as recommended by Hilal (1987), Soad et al. (2011); Saber et al. (2012). The effect of different remediative amendments on the different soils ecosystems are presented in Figure 7 at maturity stage.

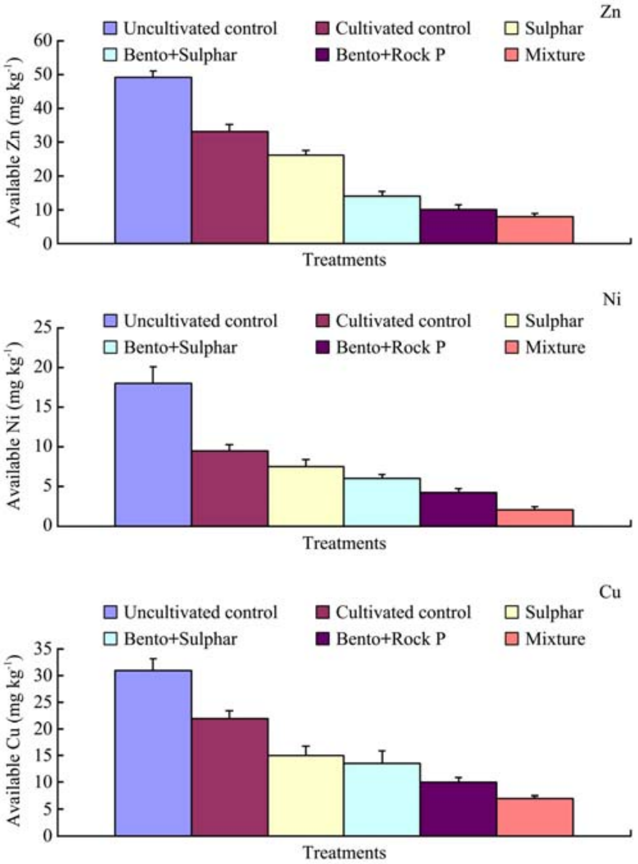

Figure 4 Available forms of PTE's in Konbera soil as influenced by trailed remediative amendments at maturity stage

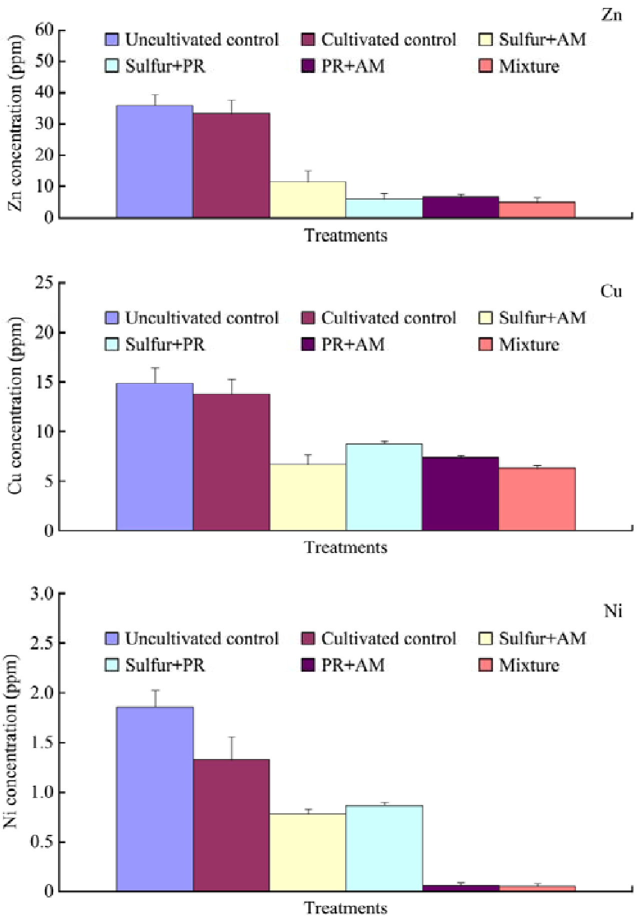

Figure 5 Available forms of PTE's in Kafr-El-Sheikh Sheikh soil as influenced by trailed remediative amendments at maturity stage

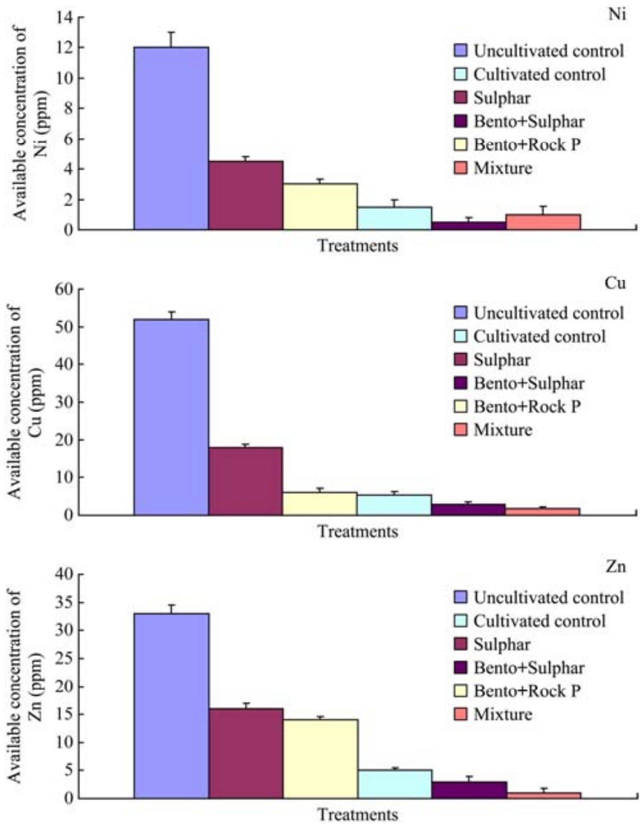

Figure 6 Available forms of PTE's in Sinai soil as influenced by trailed remediative amendments at maturity stage

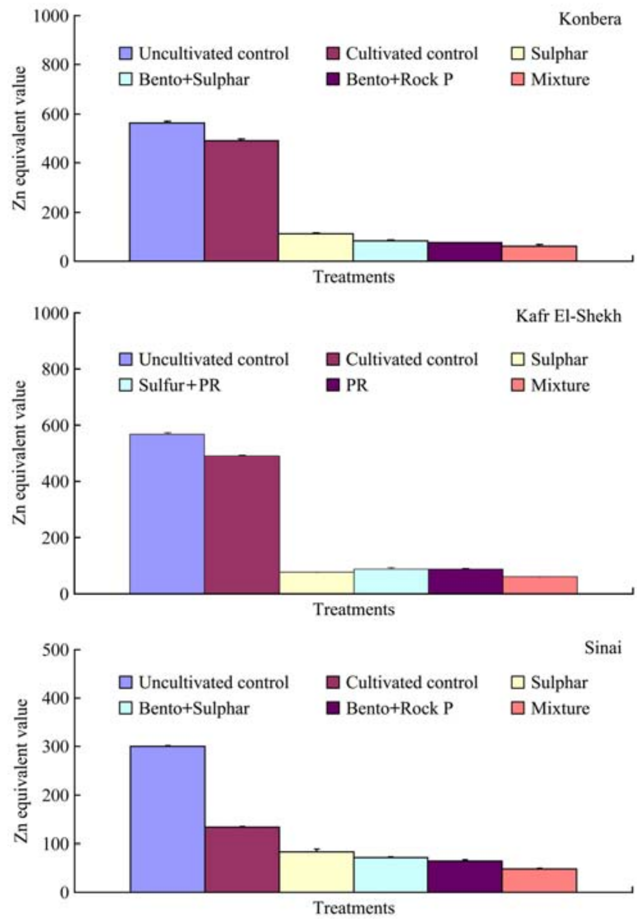

Figure 7 Zinc equivalent (ZE) valued in Konbera, Kafr El-Shekh and Sinai studied soils planted with Canola at maturity stage and different remediation additives

Prior to explain the action of remediative material applied or the effect of cultivated canola, it should be mention that this important parameter significantly influenced by different soil ecosystems studied. The highest values of Zinc equivalent were calculated in both Konbera and Kafr El-Shekh up to 897 and 721 respectively. Results also showed that the same parameter value was only 300 in Sinai which is almost near to critical level with other type of problem like salinity or hardpans in subsurface soil layer. Based on the critical level i.e. 200, cultivation of Canola only in different soils didn't significantly decrease this parameter to the safe level. In Konbera, for example, sulfur application decreased ZE from 766 to 541; this value however, is still over both safe and critical ranges. The respective values of Kafr El-Shaikh were 721 and 463, meanwhile ZE parameter decreased to 165 in Sinai soil.

3.4 Effect of phytoremediation and

Application of sulfur in soils as shown in Figure 7 decreased ZE to about 110 in Sinai, 103 in Kafr El-Shekh and 130 in Konbera soils, all ZE values were significant and less than critical value, but still high to harvest safe food from such soils (Saber et al., 2012). This critical situation urged to use a bio chemically modified form of bentonite, probentonite, fortified with S, PR or mixture of all remediative amendments to retain and decrease ZE parameter to the safe level which economically calculated by 50 or less (Farag et al., 2013).

Results imply that application of probentonite fortified with S Sulfur and association with *Thiobacillus thiooxidans*, *Thiobacillus ferrooxidans* and *Glomus* sp. (AM), reduced the capacity of canola to absorb PTEs from contaminated soils and significantly decreased ZE (Zinc Equivalent) value. Numerically in Figure 7, the application of probentonite fortified with S (Sulfur) in Konbera soil cultivated with canola decreased ZE value to about 70, the corresponding values were 72 and 69 in Sinai and Kafr El-Shekh respectively. Typically, application of probentonite incorporated with PR and fortified with the both phosphate dissolving bacteria and the same abovementioned microorganisms, decreased ZE value to 65 in Sinai and Konbera and to 58 in Kafr El-Shekh.

Breakthrough the results, incorporating mixture of all remediative amendments in contaminated soils decreased ZE values to the lowest level compared to both cultivated and uncultivated control soils regardless the type of soil ecosystem tested. In other wards, application of mixture of all remediative amendments to Konbera and Kafr El-Shekh soils decreased ZE index to 49, the corresponding value of Sinai was 48 recording the lowest values of all remediative amendments applied in different ecosystems. These values represent a safe level to produce healthy foods from such soils.

The application of sulfur to the soil ecosystem significantly decreased the available forms of PTEs in different soil ecosystems. Results in the figures Figure 6 showed that available Ni in Sinai decreased from 18 to 7.5 mg kg^{-1} by the application of sulfur fortified with *Thiobacillus thiooxidans, Thiobacillus ferrooxidans* and *Glomas sp.* (AM), in other words about 60% of available Ni decreased due to the application this remediative amendment. About 53% and 47% decrease in available Cu and Zn was also recorded by application the same treatment. In Konbera soil, all percentages of available forms were increased in different soil ecosystems. For example, about 85% of Cu was absorbed by canola plants cultivated in Konbera soil, while the corresponding values of Ni and Zn were 42% and 73% from control uncultivated soils. Again, the same action of sulfur was observed in Kafr El-Shekh soil.

3.5 Kinetic studies of PTE's desorption from the studied soil ecosystems as influenced by phytoremediation

Table 2 represents the intensity factor of MFE, ranges of R^2 and SE, as high and significant values for coefficient of determination R^2 ranged between 0.85 and 0.99, and decreasing in values of SE ranged between 0.03 and 0.16. These two factors imply that MFE is the best in describing the kinetic data.

PTEs reactivity and kinetics vary from one soil to another according to the soil type, physical, chemical and biological characterization. Quantifying PTEs kinetics is essential for obtaining a precise simulation of its mobility in soils. As shown in the table all remediative amendments except S decreased the rate of PTEs release from the studied soil ecosystems. In Konbera soil the rate of Zn in control untreated soil was 0.31 mg kg^{-1} min^{-1}, which represents highest value compared to the same rates in other soils that reached 0.23 and 0.28 mg kg^{-1} min^{-1} in Kafr El-Shekh and Sinai respectively. Growing of canola in contaminated soils, decreased the rates of PTEs desorption from contaminated soil ecosystems. In Sinai soil ecosystem the rate of Cu desorption from UC was 0.29 and decreased to 0.27 mg kg^{-1} min^{-1} after growing canola. The same trend was also observed for other PTEs and other studied soil ecosystems. Results in the Table 2 showed also that all remediative amendments contained probentonite decreased the rate of PTEs in soils cultivated with canola. In T3, results indicated that incorporating probentonite with PR in Konbera soils, decreased the rate of Ni release from 0.33 mg kg^{-1} min^{-1} in control uncultivated UC to 0.18 mg kg^{-1} min^{-1}. The application of mixture of all remediative amendments resulted in the lowest values in all PTEs release in the different soil ecosystems. For example, application of a mixture of all remediative amendments additives in Kafr El-Shekh soil decreased the rate of Ni from 0.20 in UC soil to 0.12 mg kg^{-1} min^{-1}. This significant decrease in the rate of release was found in Sinai and Konbera soils.

Table 2 Rate constant of MFE (a) represent the intensity factor of pollutants desorbed from the contaminated soil samples influenced by Canola hyper accumulator plant and different remediation additives applied

	Zn (mg kg^{-1} min^{-1})					
	UC	CC	T1	T2	T3	T4
Konbera	0.31	0.27	0.26	0.24	0.22	0.19
Kafr El-Shekh	0.23	0.21	0.20	0.19	0.18	0.17
Sinai	0.28	0.26	0.24	0.23	0.22	0.21
Range R^2	0.89**-0.96**	0.90**- 0.98**	0.89**- 0.97**	0.91**- 0.94**	0.91**- 0.99**	0.85**- 0.95**
Range SE	0.11-0.16	0.14-0.22	0.13-0.20	0.16-0.21	0.16-0.20	0.22-0.26
	Cu					
Konbera	0.47	0.35	0.31	0.28	0.23	0.21
Kafr El-Shekh	0.18	0.15	0.21	0.15	0.15	0.23
Sinai	0.29	0.27	0.21	0.22	0.20	0.19
Range R^2	0.86**-0.95**	0.90**-0.95**	0.89**-0.94**	0.83**-0.96**	0.89**-0.98**	0.87**-0.98**
SE	0.14-0.21	0.15-0.20	0.16-0.18	0.18-0.19	0.15-0.24	0.21-0.25
	Ni					
Konbera	0.33	0.25	0.22	0.20	0.18	0.14
Kafr El-Shekh	0.20	0.19	0.16	0.15	0.13	0.12
Sinai	0.21	0.20	0.15	0.16	0.12	0.11
Range R^2	0.93**-0.99**	0.85**-0.92**	0.91**-0.98**	0.90**-0.92**	0.91**-0.93**	0.91**-0.98**
SE	0.03-0.09	0.06-0.16	0.08-0.14	0.09-0.16	0.11-0.14	0.03-0.16

4 Discussion

All the selected farms were irrigated with low-quality water for extended periods. In Konbera farm, a daily renewable source of sewage effluents input to the farm and daily different kinds of contaminants added to the soil ecosystems in this farm take place. The selected farm cultivated with different kinds of vegetables and other edible crops which represent fetal problem on health. This problem arises from the ease of PTEs released and enteric pathogens availability in such soil ecosystems. In Kafr El-Sheikh soils, the irrigation water used is Nile water mixed with industrial water from the factories of al Mahalla governorate and drainage water. The texture of such soils represents the most important problem in such soils in linking with PTEs in heavy texture and retained significant amounts of pollutants with enteric pathogens besides the presence of hardpans and high salinity which significantly decrease crop production. In Sinai soil, however, the light textures in El-Tina plain retain significantly PTEs. The fatal problems in this area are the salinity hazards and hardpans that minimize root distribution and crop production.

The strategy of remediation technique in such soils through the remediation amendments depend on enhancing the uptake of Ni, Cu and Zn by canola hyper accumulator and the rest of PTEs retain in soil by application of specially modified remediation amendments that are characterized with high capacity in forming complexes with PTEs described by ZE index. Phytoremediation, especially phytoextraction has emerged as a cost-effective, environmental technology for the restoration of PTEs contaminated soils (Salt et al., 1998). Phytoextraction is a green technology that uses plants to remove inorganic contaminants, primarily PTEs from soil and aquatic ecosystems. Phytoextraction could be broadly classified as either natural or chemical assisted. The natural phytoextraction strategy utilizes PTEs hyper-accumulating plant species (Kumar et al., 1995).

Canola (*Brassica napus* L.) is commonly used as a hyperaccumulator for phytoextraction of PTEs from soil and aquatic ecosystems. Like many other PTEs, Ni, Cu and Zn contaminates the environment and thus it is a great problem (Baker et al., 2000). In this work, although canola hyper accumulator absorbs significant amounts of PTEs studied, ZE values indicated that significant concentrations of all PTEs are still found in different soil ecosystems and the contaminated soils needs to other additives to clean up the soil. The effect of sulfur on enhancing PTEs uptake by hyper-accumulators was studied by different authors. Application of elemental sulfur could result in the solubilization of insoluble PTEs, thus increasing them in soil solution by lowering soil pH following microbial driven oxidation of elemental sulfur into sulfate (Kayser et al., 2000). Subsequently, PTEs in the soil solution could be readily absorbed by plant roots and translocated to their shoots.

Although a number of studies have been conducted on the chemically enhanced phytoextraction of PTEs, there is paucity of information regarding behavior of the trailed remediative amendments in different texturally soils. The variation between different soils ecosystems in their texture significantly influenced the rate of PTEs release, the same result was recorded by (Abouziena et al., 2012, 2013). In this study, application of sulfur significantly decreased ZE index less than the critical level. However, the PTEs concentration is still over the safe level to use the soils for a long run especially the same water frequently used and no way to be changed in near future. Remediation of PTEs by clay or modified clay minerals still play a key role in minimizing the hazards of PTEs in Egyptian soils. The research team initiated a patent submitted for registration. Such product enhanced with S or PR and mixed with all remediative amendments that significantly decreased the toxicity of PTEs to a safe level through the ZE index.

Acknowledgement

The authors would like to express their appreciations and gratitude to the authorities of Science and Technology Development Fund (STDF) for financing the present work through the project number 3033 contracted with the National Research Center onn Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water.

References

Abou-Seeda, M., Zaghloul, A.M. and AbdEl-Galil, A. 2005. The role of cement dust in chemical remediation of the sludge treated soil. Assiut Univ. Bull. Environ. Res. 8, 89–107.

Abouziena, H. F., **A.** M. Zaghloul, S. El-Ashry, E. M. Hoballa, and M. Saber. 2013. Some chemical and biological additives with hyperaccumulator plants for amendment the sandy soil contaminated for long term by sewage water. *International Journal of Water Resources and Arid Environments*, 3(1): 15–25.

Abouziena, H. F., M. Saber, E. M. Hoballa, S. El-Ashry, and A. M. Zaghloul. 2012. Phytoremediation of potential toxic elements in contaminated sewaged soils by canola (*Brassica Napus*) or Indian mustard (*Brassica Juncea Czern*.) plants in association with mycorrhiza. *Journal of Applied Sciences Research*, 8(4): 2286–2300.

Baker, A. J. M., S. P. McGrath, R. D. Reeves, and J. A. C. Smith. 2000. Metal hyperaccumulator plants: A review of the ecology and physiology of a biochemical resource for phytoremediation of metal-polluted soils. In *Phytoremediation of Contaminated Soil and Water*, eds. N. Terry, and G. Ba˜nuelos. Lewis Publishers, London, 85–107.

El-ashry, S., M. Saber, and A. Zaghloul. 2011. Chemical characterization of sandy soils irrigated with sewage effluent for extended periods from a kinetic perspective. *Australian Journal of Basic and Applied Sciences*, 5(12): 1–11.

Frag, A., H. F. Abouziena, M. Saber, E. M. Hoballah, F. Abd-El-Zaher, and A.M. Zaghloul. 2014. Economic feasibility study on the use of certain amendments in the bioremediation of sewaged soil. *International Journal of Plant & Soil Science*, 3(10): 1182–1199.

Hilal, M. H. 1987. Non-balanced fertilizers application and cause effect relation of soil pollution. *In 2nd National Congress on Problems and Tech for Invading Desert Soils*, 250. Egypt, December 15-17.

Jang, M., J. S. Hwang, S. I. Choi, and J. K. Park. 2005. Remediation of arsenic contaminated soils and washing effluents. *Chemosphere*, 60(3): 344–354.

Kayser, A., K. Wenger, A. Keller, W. Attinger, R. Felix, S. K. Gupta, and R. Schulin. 2000. Enhancement of phytoextraction of Zn, Cd and Cu from calcareous soil: the use of NTA and sulfur amendments. *Environmental Science and Technology*, 34(9): 1778–1783.

Kumar, P. B. A. N., V. Dushenkov H. Motto, and I. Raskin. 1995. Phytoextraction: the use of plants to remove heavy metals from soils. *Environmental Science and Technology*, 29(5): 1232–1238.

Ok, Y. S., J. E. Lim, and D. H. Moon. 2011. Stabilization of Pb and Cd contaminated soils and soil quality improvements using waste oyster shells. *Environmental Geochemistry and Health*, 33(1): 83–91.

Ok, Y. S., S. C. Kim, D. K. Kim, G. Jeffrey, J. G. Skousen, J. S. Lee, Y. W. Cheong, S. J. Kim, and J. E. Yang. 2011. Ameliorants to immobilize Cd in rice paddy soils contaminated by abandoned metal mines in Korea. *Environmental Geochemistry and Health*, 33(1): 23–30.

Ok, Y. S., S. S. Lee, W. T. Jeon, S. E. Oh, A. R. A. Usman, and D. H. Moon. 2011. Application of eggshell waste for the immobilization of cadmium and lead in a contaminated soil. *Environmental Geochemistry and Health*, 33(1): 31–39.

Saber, M., E. Hobballa, S. El-Ashery, and A. M. Zaghloul. 2012. Decontamination of potential toxic elements in sewaged soils by inorganic amendments. Journal of Agricultural Science and Technology, 2(11)A: 1232–1244.

Salt, D. E., R. D. Smith, and I. Raskin. 1998. Phytoremediation. *Annual Review of Plant Biology*, 49(1): 643–668.

Usman, A. R. A., and H. M. Mohamed. 2009. Effect of microbial inoculation and EDTA on the uptake and translocation of heavy metals by corn and sunflower. *Chemosphere*, 76(7): 893–899.