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THE IMPACT OF SOIL CONTAMINATED WITH HEAVY METALS ON SOIL MICROBIAL DIVERSITY OF INDUSTRIAL AREA NEAR ASSIUT CITY, EGYPT

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The influence of the long-term exposure to heavy metal on the soil microbial diversity was explored in soil from six different sites along a pollution gradient near the superphosphate factory, Assiut, Egypt. The biodiversity of microbial populations by means of numbers of colony forming units in 1 g of dry weight soil (CFU g^{-1}) was determined by plate count on appropriate media: fungi on potato dextrose agar (PDA) and bacteria on nutrient agar (NA). Soil heavy metals content (Fe, Mn, Cu, Zn, Cd, Ni, Cr, Pb) and pH were determined. Results indicated that concentrations of some heavy metals recorded high amount in soil samples exposed to pollution and exceeded the maximum allowable limits. It was possible to isolate thirteen mesophilic and five thermotolerant and thermophilic fungal species from contaminated soil samples under study. A total number of nine morphotypes of Arbuscular Mycorrhizal Fungi (AMF) belonging to the families Acaulosporaceae, Glomeraceae and Gigasporaceae were obtained. The mesophilic and thermophilic bacterial populations were different between the soils. Meanwhile, the thermophilic bacterial populations were regularly lower than mesophilic bacterial populations. Combining the information from heavy metal concentrations and microbial diversity data provided an understanding of the impacts of factory pollution on microbial communities.

Key words: Heavy metals, microbial diversity, pollution, superphosphate factory

INTRODUCTION

Several human activities have resulted in elevated concentration of heavy metals (HM) in many terrestrial environments. Chronic and acute metal pollution arises from a number of anthropogenic sources including petroleum industry activities, fossil fuel combustion, industrial fissions, agricultural pesticides and domestic and industrial effluent discharges [1]. Heavy metals once released into the environment (the air, water, and soil) do not disappear, but accumulate in soils, sediments, and biota [2]. So, soil pollution with metal ions near pollution sources or smelters is a constant process having a toxic effect on plants and on soil microorganisms, because they cannot be degraded by natural processes and persists in soil and sediment and directly or indirectly modify their environment. It has been shown that HM at certain concentrations can have long-term toxic effects within ecosystems [3] and have a clear negative influence on biologically mediated soil processes [4]. Most studies of HM toxicity to soil microorganisms have concentrated on effects where loss of microbial function can be observed and yet such studies may mask underlying effects on biodiversity within microbial populations and communities.

It is generally accepted that accumulated HM reduce the amount of soil microbial biomass [5,6] and various enzyme activities, leading to a decrease in the functional diversity in the soil ecosystem [7] and changes in the microbial community structure [8,9]. However, metal exposure may also lead to the development of metal tolerant microbial populations [10]. Microorganisms possess a variety of mechanisms to deal with high concentrations of heavy metals and often are specific to one or a few metals [11, 12, 13, 14, 15]. Therefore, specific heavy metal resistant determinants can be used as parameters for environmental forensic as biosensors [16, 17, 18]. Microorganisms have been used as biological agents to degrade toxic wastes from the environment [19]. Microorganisms such as *Aspergillus* spp., *Bacillus* spp., *Staphylococcus* spp., *Pseudomonas* spp. [20], *Trichoderma* spp. [21] and *Streptomyces* spp. [22] have been reported to be able to tolerate high concentration of various heavy metals [23]. In naturally polluted environments the microbe’s response to heavy metals toxicity depends on the concentration and the availability of metals and on the action of factors such as the type of metal, the nature of medium and microbial species [24].

Industrial factories such as superphosphate factory and cement factory are located North and North West of Assiut city respectively. These factories cause some pollution problems in Assiut area due to airborne dusts and smokes. Some problems are related to soil contamination with heavy metals, plant damage from industrial dusts and air fumes that may also contain some heavy metals [25]. So, the main objective of this study was to investigate the impact of industrial pollution on the abundance of soil fungi and bacteria in soil samples from agricultural fields near the superphosphate factory, Assiut, Egypt. Also, to find out possible correlation between meals concentration and soil microbial populations. For future bioremediation research, we also evaluated heavy metal resistant soil microbes.

MATERIAlS AND METHODS

Study area and samples collection:

Soil samples were collected from six sites of agricultural areas near the superphosphate factory under study (Fig. 1). This factory is located 9 km north of Assiut city (27º N and 31ºE). It lies between the Nile river (East) and Ibraheemia Canal (West). The area around the factory was cultivated with some main crops [25]. Three replicates were collected from each site. Soil samples under study were silt loam and the dominant crop was maize (*Zea mays* L.). The soil sample was taken for each site at 0-15 cm depth. The soil samples were divided into two parts. The first part was transported to the laboratory, stored at 4°C for microbiological analysis and the second part air-dried at room temperature for chemical analysis.

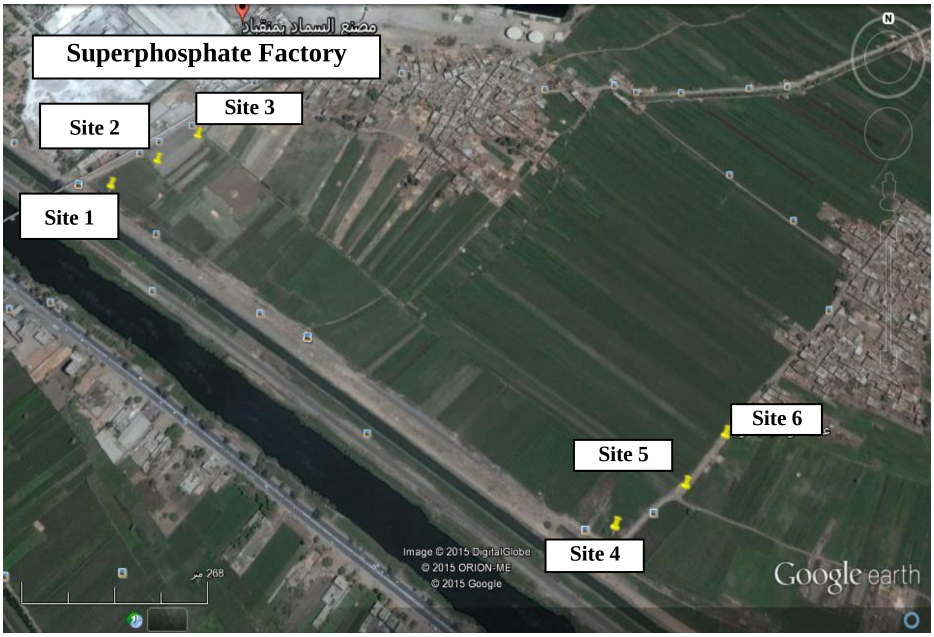

Fig. 1: Map showing the sites of soil samples along the superphosphate factory, Assiut, Egypt.

Chemical analyses of soil samples:

Values of pH were determined in (1:2) [soil: distilled water] suspension using glass electrode pH meter as described by [26]. Total content of heavy metals in soil samples which were digested by aqua regia (hydrochloric acid and nitric acid) according to [27] and determined by Inductively Coupled Plasma Spectrometry (Ultima 2 JY Plasma).

Microbial diversity:

The fungal and bacterial isolates were isolated from the soil by serial dilution and plating technique as described by [28]. Total counts of mesophilic and thermophilic bacteria were determined by using nutrient agar medium as described by [29]. Isolation of mesophilic and thermotolerant and thermophilic fungi were determined by using potato dextrose agar (PDA) medium as described by [30]. Serial dilutions up to 10^{-3} were made and inoculation was done with 0.1 ml. Single colonies were picked and checked for purity by repeated culturing. Fungi were identified on the basis of macroscopic and microscopic features [31,32,33]. Arbuscular mycorrhiza spores were isolated from the soil by wet sieve method [34]. One hundred grams of soil were dispersed in 1Lwater and decanted through a series of 350 – to 38-µm sieves, from which sand and organic matter are removed, while spores remain on the sieve. The shape and frequency of spores was observed using dissection microscope and were preliminarily identified on the INVAM website (http://www.invam.caf.wvu.edu).To determine the percentage of mycorrhizal colonization in plant roots, the roots were cleared in 10% KOH and 1% HCl, and stained with 0.05% tryphan blue in lacto glycerol by [35].

Statistical analysis:

Statistical analysis of the results was performed using Statistic software; Person correlation (r) was applied to test the relationships between the total microbial count and total concentrations of various heavy metals in contaminated soil and soil pH at the level of significance equal to 0.05.

RESULTS AND DISCUSSION

Heavy metal concentrations of the soil samples:

In the present study, different types of microorganisms were isolated from soil samples collected from cultivated area near the superphosphate factory where heavy metals and other pollutants have been emitted in industrial wastes for several years. The resultant data were recorded as a mean value of three replicates in each site. The soils of the six sites were slightly alkaline with pH 7 to 8.5 Table (1). The highest concentration of heavy metals (1155.55 mg/Kg soil) was determined in the soil of the site 3 behind the wall of the factory directly followed by site 4 and site 5 (1153.06 and 1153.69 mg/Kg soil respectively) (Table 1).

Table 1: Heavy metal concentrations and pH values of soil samples collected from 6 sites at different distances from the superphosphate factory.

samples	%Fe	Concentration (mg / Kg soil)							pH (1:2)
		Mn	Cu	Zn	Cd	Ni	Cr	Pb	
Site 1	2.948	644.17	22.40	60.10	1.945	34.50	33.90	1.167	7.0
Site 2	3.508	675.79	22.90	63.45	2.265	41.05	40.33	1.389	7.4
Site 3	3.914	925.60	36.90	98.05	2.650	45.80	45.00	1.550	7.8
Site 4	3.842	933.97	25.40	95.80	1.365	47.60	43.78	5.142	8.0
Site 5	3.346	930.89	41.30	94.75	2.695	41.45	38.13	4.477	8.3
Site 6	3.624	729.60	36.15	69.15	2.300	44.90	41.30	4.850	8.5

Iron. A slight difference between Fe concentrations in all the tested soil samples. The highest Fe value was at site 3 (3.9%) whereas the lowest was at site 1 (2.9%). Iron is very insoluble under oxidizing condition in soil, the organic matter in the soil may form chelate complex by keep considerable amount of Fe (III) in a mobile form [36].

Manganese. Manganese is present in soil as a result of mineral weathering and atmospheric deposition, originating from both natural and anthropogenic sources. According to international agricultural soil standards [37], the concentrations of Mn of all samples (644.17 to 933.97 mg/ kg soil) were found to be above the permissible limit (500mg/kg).

Copper. The copper content in soil samples ranged from 22 to 41.30 mg/ kg soil (Table 1). Copper is usually present in soil within the range of 0-250 µg g^{-1}[38].

Zinc. The amount of zinc in the soil samples ranged from 60.1 to 98.05 mg/ Kg soil. Zinc is ubiquitously emitted element and among its sources are combustion of fossil fuels and wood, metal production, cement production, fertilizers, abrasion of construction materials, material abrasion in traffic, solid wastes, sewage sludge, etc.[39]. The mobility of the metal depends on the soil pH and also depends on the organic matter and granulometric composition of the soil. Acidic pH makes easier the solubilisation of the Zn compounds [40].

Cadmium. In the present study, the cadmium content of the soil samples ranged from 1.37 to 2.65 mg/ Kg soil (Table 1), of which the maximum cadmium content was recorded at site 5 and the lowest at site 4. [41]reported that the critical soil total contents of Cd according to environmental regulations of several countries are 0.3 ppm in both Denmark and Finland; 0.4 in Czech Republic; 0.5 in Canada; 0.8 in both Netherlands and Switzerland; 0.4 for clay soils and 1.5 for sandy soils in Germany; 0.1 in Ireland; and 0.2 ppm in Eastern Europe. The obtained data indicated that the total Cd contents in all the studied soils were greater than the permissible critical limits (limit of contamination) of all the above mentioned countries.

Nickel. Total Ni concentrations in the surface layers of tested soils ranged from 34.50 to 47.60 mg/ kg soil. [41] reported that the critical soil total contents of Ni according to some environmental regulations all over the world are 10 ppm in Denmark; 15 for clay soils and 70 ppm for sandy soils in Germany; 20 ppm in Canada; 30 ppm in Ireland; 35 ppm in Netherlands. The present data indicated that the total Ni contents in all the studied soils were greater than the permissible critical limits of all the above mentioned countries. The reason for the high Ni pollution may be due to the factory wastes.

***Chromium*.** It was observed that the overall level of Cr lied between 33.90 and 45 mg/ kg soil (Table1).The Cr level in the site 3 was the highest. According to international agricultural soil standards [37], the concentrations of Cr of all samples were found within the permissible limit (100mg/kg).

Lead. The lead content of the soil samples ranged from 1.167 to 5.142 mg/ kg soil (Table 1). The highest lead content was at site 4 far away from the factory about 500 meter and the lowest at site 1 far away about 10 meter. [41] reported that the critical soil total contents of Pb according to environmental regulations of several countries are 25 ppm in Canada; 32 ppm in Eastern Europe; 38 ppm in Finland; 40 ppm in Denmark; 40 ppm for clay soils and 100 ppm for sandy soils in Germany; 50 ppm in both Switzerland and Ireland; 70 ppm in Czech Republic and 85 ppm in Netherlands. The obtained data indicated that the total Pb contents in all the studied soils are lower than the permissible critical limits of all the above mentioned countries.

Microbial diversity. Thirteen mesophilic and five thermotolerant and thermophilic fungal species were isolated from contaminated soil samples at a different distance from the superphosphate factory. Abundance and activities of microorganisms in soil are controlled by the availability of water, nutrients, pH, concentration of metal ions, hydrodynamic communication with the ground surface [42].Data in Table (2) revealed that 13fungal species belonging to 8 genera were isolated at 28 ±1ºC from soil samples of 6 different sites at different distances from the factory under study. The total counts of mesophilic fungi were 12.74 x 10^4 CFU per g dry soil, markedly lower than a "typical" temperate soil (10^5-10^6 CFU per g dry soil) reported by [43] as a result of pollution. The site 1 was the richest in fungal population giving rise to 25.1% of total counts, whereas site 5was the lowest in fungal population representing 11.5% of the total counts. This may be due to the low pH and heavy metals content in the soil of site 1.Remarkably, *Rhizopus stolonifer* was found in all sites while *Aspergillus sydowii, A. ustus, Fusarium* *culmorum* and *Penicillium funiculosum* were not detected in all sites except sites 3, 2, 1 and 5 in the same respect. Environmental stresses brought about by the contamination could be a reason for the reduction in microbial species but increasing the population of few surviving species [44].

Remarkably, five thermotolerant and thermophilic fungal species in addition to dark and white sterile mycelia were recorded from contaminated soil samples at 45ºC using the dilution plate method (Table 3). The total counts of thermotolerant and thermophilic fungi were 3.6 x 10^3 CFU per g dry soil. The results showed that site 3 was the richest in fungal population giving rise to 35.6% of total counts, whereas site 4was the lowest in fungal population representing4.72% of the total counts. Only *Emericella nidulans* var. *nidulans* isolated as mesophilic and thermotolerant fungus. In the present study, the differences between the soil samples regarding their microbial diversity and types of species appear to be closely linked to the degree of heavy metal pollution. Generally, pollution of soil by heavy metals may lead to a decrease in microbial populations. This is due to the extinction of species sensitive to the stress imposed, and enhanced growth of other resistant species.

Table 2: Gross total counts (CFU per g dry soil) (T.C), percentage counts (calculated per total counts) (%T.C) of mesophilic fungi isolated from 6 soil Samples collected from 6 sites at different distances from the superphosphate factory**.**

Samples / Fungal species	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	T.C	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**
Aspergillus **Mich. ex Fr.**	1.1×10^4	34.4	1.06×10^4	47.2	2×10^3	13.4	3.7×10^3	18.8	9.97×10^3	68.3	4.6×10^3	19.49
A. flavus **Link**	0	0	0	0	3.3×10^2	2.2	6.7×10^2	3.4	6.7×10^2	4.6	0	0
A. niger **van Tieghem**	0	0	0	0	10^3	6.7	2×10^3	10.2	5×10^3	34.2	1.3×10^3	5.5
A. sydowii **Thom & Church**	0	0	0	0	6.7×10^2	4.5	0	0	0	0	0	0
A. terreus **Thom**	1.1×10^4	34.4	5.3×10^3	23.6	0	0	10^3	5.1	4.3×10^3	29.4	3.3×10^3	14
A. ustus **Thom & Church**	0	0	5.3×10^3	23.6	0	0	0	0	0	0	0	0
Cochliobolus spicifer **Drechesler**	0	0	0	0	0	0	10^3	5.1	0	0	3.3×10^3	14
Emericella nidulans var. *nidulans* **(Eidam) Vuillemin**	5×10^3	15.6	4.3×10^3	19.1	8×10^3	53.3	0	0	3.3×10^2	2.3	0	0
Epicoccum nigrum **Link ex Schlecht**.	0	0	1.3×10^3	5.8	6.7×10^2	4.5	0	0	0	0	0	0
Fusarium **Link**	2×10^3	6.3	0	0	0	0	5×10^3	25.4	10^3	6.8	5.7×10^3	24.1
F.culmorum **(Wm.G.Sm.) Sacc**.	2×10^3	6.3	0	0	0	0	0	0	0	0	0	0
F. oxysporum **Schlecht.**	0	0	0	0	0	0	5×10^3	25.4	10^3	6.8	5.7×10^3	24.1
Penicillium funiculosum **Thom**	0	0	0	0	0	0	0	0	2.3×10^3	15.8	0	0
Humicola grisea **Traaen**	6.3×10^3	19.7	3×10^3	13.3	3.3×10^2	2.2	0	0	0	0	0	0
Rhizopus stolonifer **(Ehrenb.) Lind**	6.7×10^3	20.9	3.3×10^3	14.6	4×10^3	26.6	10^4	50.8	3.3×10^2	2.3	10^4	42.4
Dark sterile mycelia	0	0	0	0	0	0	0	0	3.3×10^2	2.3	0	0
White sterile mycelia	10^3	3.1	0	0	0	0	0	0	3.3×10^2	2.3	0	0
Total counts	3.2×10^4	100	2.25×10^4	100	1.5×10^4	100	1.97×10^4	100	1.46×10^4	100	2.36×10^4	100
No. of genera	5		5		5		4		4		4	
No. of species	5		6		7		6		7		5	

Table 3: Gross Total counts (CFU per g dry soil) (T.C), percentage of total counts (calculated per total counts) (%T.C) of thermotolerant and thermophilic fungi isolated from 6 soil samples collected from 6 sites at different distances from the superphosphate factory

Samples / Fungal species	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	T.C	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**	**T.C**	**%TC**
Aspergillus fumigatus **Fresenius**	0	0	0	0	3.3	0.3	3.3	2	0	0	0	0
Emericella nidulans var. *nidulans* **(Eidam) Vuillemin**	$9.1x10^2$	94.5	$5.6x10^2$	82.4	$1.2x10^3$	93.7	$1.03x10^2$	60.6	70	29.5	36.7	16.7
Malbranchea sulfurea **(Miehe) Sigler & Carmichael**	0	0	0	0	3.3	0.3	10	6	0	0	3.3	1.5
Rhizomucor pusillus **(Lindt) Schipper**	0	0	0	0	0	0	3.3	2	26.7	11.3	0	0
Thermomyces lanuginosus **Tsiklinsky**	0	0	0	0	0	0	16.7	9.8	3.3	1.4	3.3	1.5
Dark sterile mycelia	3. 3	0.3	0	0	0	0	0	0	6.7	2.8	36.7	16.7
White sterile mycelia	50	5.2	$1.2x10^2$	17.6	73.3	5.7	33.3	19.6	$1.3x10^2$	55	$1.4x10^2$	63.6
Total counts	$9.63x10^2$	100	$6.8x10^2$	100	$1.28x10^3$	100	$1.7x10^2$	100	$2.36x10^2$	100	$2.2x10^2$	100
No. of genera	1		1		3		5		3		3	
No. of species	1		1		3		5		3		3	

A total number of nine morphotypes of AMF belonging to the families Acaulosporaceae, Glomeraceae and Gigasporaceae (Table 4) were recovered from soil samples within 6 sites around the factory under study. In all sites, the dominant genus was *Glomus*, which comprised 64.7% of total spore density. *Glomus* was the most frequently isolated mycorrhizal genus from the polluted site [45,46].Based on spore density, the five dominant species in tested soils were *Glomus mosseae*, *Glomus geosporum*, *Glomus constrictum*, *Acaulospora laevis* and *Glomus clarum*, representing 34.2%, 13%, 12.3%, 11.6 and 10.6% of total spore density respectively. It appeared that species producing more spores usually have a wide geographic distribution, while species with narrow geographic range usually produce fewer spore. This result agreed with that of [47] who reported that site geography, especially the altitude and large geographical distance, strongly affected AMF communities. All studied plants formed an arbuscular mycorrhizal association. Colonization by AM fungi was widely varied, ranging from 55 to 88 %, in which the highest value was recorded in site 2 and mycorrhizae were represented by all typical structures viz. arbuscules, vesicles and hyphae. The present study revealed positive relationship between mycorrhizal spore density and mycorrhizal colonization. Heavy metals in the polluted soil samples may induce more percentage of root colonization of plants. AM fungi are known to influence metal transfer in plants by increasing plant biomass and reducing metal toxicity to plants even if diverging results were reported [48]. Species of AM fungi, and even various isolates of one species, can differ in their sensitivity to heavy metals. Strains isolated from HM-polluted soils were found to tolerate higher concentrations of HM than reference strains from unpolluted soils [49,50].

Table 4: Mycorrhizal species, spore density (number of spores in 100 g soil) and root colonization (%) in 6 sites of contaminated soils cultivated with *Zea mays* L.

Samples	Mycorrhizal species	Spore density	Root Colonization (%)
Site 1	*Acaulospora laevis* **Gerd. & Trappe**	13	66
	Acaulospora splendida **Sieverd., Chaverri& Rojas**	4	
	Glomus geosporum **Nicolson &Gerd**	9	
	Glomus mosseae **Gerd. & Trappe**	20	
Site 2	*Acaulospora laevis* **Gerd. & Trappe**	11	88
	Acaulospora splendida **Sieverd., Chaverri & Rojas**	5	
	Glomus clarum **Nicolson & Schenck**	15	
	Glomus mosseae **Gerd. & Trappe**	23	
Site 3	*Acaulospora bireticulata* **Rothwell & Trappe**	8	81
	Acaulospora laevis **Gerd. & Trappe**	10	
	Glomus geosporum **Nicolson & Gerd.**	7	
	Glomus mosseae **Gerd. & Trappe**	17	
	Scutellospora armeniaca **Blaszk**	6	
Site 4	*Gigaspora margarita* **Becker & Hall**	10	55
	Glomus constrictum **Trappe**	8	
	Glomus geosporum **Nicolson & Gerd.**	22	
Site 5	*Acaulospora bireticulata* **Rothwell & Trappe**	5	64
	Gigaspora margarita **Becker & Hall**	8	
	Glomus constrictum **Trappe**	16	
	Glomus mosseae **Gerd. & Trappe**	15	
Site 6	*Glomus clarum* **Nicolson & Schenck**	16	69
	Glomus constrictum **Trappe**	12	
	Glomus mosseae **Gerd. & Trappe**	25	
	Scutellospora armeniaca **Blaszk**	7	

Bacterial populations were isolated as thermophilic and mesophilic bacteria (Fig. 2). The total counts of mesophilic and thermophilic bacteria were 10.4 x 10^6 and 38.96 x 10^4 respectively. Site 2 was the richest in mesophilic bacterial population giving rise to 25.29% of total counts, whereas site 4 was the richest in thermophilic bacterial population yielding 40.29 % of total counts. The results showed that there was a reduction in the total bacterial count of contaminated soil compared to a "typical" temperate soil (10^8-10^9 CFU per g dry soil) reported by [43].

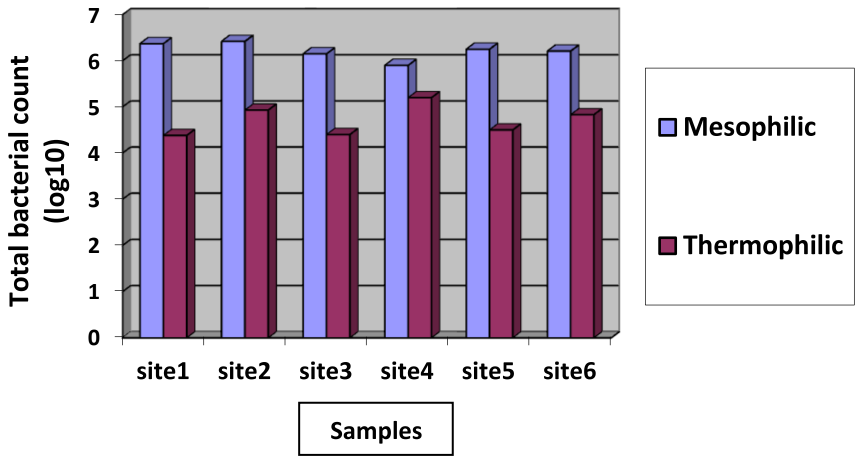

Fig.2. Total count of mesophilic and thermophilic bacteria

Relationship between total microbial count and soil heavy metal concentrations and pH in contaminated soil:

Data in table (5) summarized the relationships between microbial numbers and soil heavy metal concentrations and soil pH using the Pearson correlation (r). Based on statistical analysis a strong negative correlation was observed between total count of mesophilic fungi and various heavy metals under study except cadmium and lead which showed a moderate negative correlation (r = -0.435 and -0.343 respectively) while a weak negative correlation was observed between total count of thermotolerant and thermophilic fungi and most of heavy metals except nickel and cadmium which showed a strong negative correlation (r = - 0.698 and -0.870 respectively). For mesophilic bacteria, we observed a negative strong correlation between total count of mesophilic bacteria and various heavy metals except with cadmium showed a positive correlation (r = 0.299). While a positive correlation was observed between total count of thermophilic bacteria and various heavy metals except cadmium and copper showed a negative correlation (r =-0.781 and -0.423 respectively).These results were in agreement with those of [51] and [52] who reported that a significant decrease in CFU of most microbial groups with the increase of heavy metals concentrations and disagreed with those of [53]. Arbuscular mycorrhizae counts showed a moderate negative correlation with magnesium and zinc while a weak positive correlation was found with other heavy metals. The relationship between total microbial count and soil pH observed a negative correlation between soil pH and the total count of mesophilic and thermotolerant and thermophilic fungi and mesophilic bacteria, while a positive correlation was observed with total count of thermophilic bacteria and Arbuscular mycorrhizae. Our results are consistent with those of [54,55,56] who found that the biomass of the total soil microbial communities is usually negatively correlated with metal stress.

Table 5: Correlation coefficient between total microbial count and heavy metals and pH in contaminated soils (n=3).

(The strong correlation in bold letters)

Microorganisms	pH	Fe	Mn	Cu	Zn	Cd	Ni	Cr	Pb
Mesophilic fungi	**-0.602^{ns}**	**-0.683^{ns}**	**-0.880***	**-0.699***	**-0.88***	-0.435^{ns}	**-0.746***	-0.676*	-0.343^{ns}
Thermotolerant and thermophilic fungi	-0.596^{ns}	-0.010^{ns}	-0.181^{ns}	-0.105^{ns}	-0.100^{ns}	0.360^{ns}	**-0.698***	0.035^{ns}	**-0.870****
Mesophilic bacteria	**-0.624^{ns}**	**-0.670***	**-0.824***	-0.393^{ns}	**-0.811***	0.299^{ns}	**-0.620^{ns}**	**-0.644^{ns}**	**-0.704***
Thermophilic bacteria	0.193^{ns}	0.473^{ns}	0.187^{ns}	-0.423^{ns}	0.152^{ns}	**-0.781***	0.396^{ns}	0.454^{ns}	0.513^{ns}
Arbuscular mycorrhizae	0.191^{ns}	0.031^{ns}	-0.581^{ns}	0.116^{ns}	-0.585^{ns}	0.377^{ns}	-0.004^{ns}	0.037^{ns}	0.105^{ns}

CONCLUSION

The high concentrations and differences in heavy metals level of soil samples collected from the sites beside the superphosphate factory may be due to industrial gas emissions which go to the atmosphere and are finally deposited on soil and or disposing of industrial wastes directly on soil may cause the environmental pollution to a great extent.

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تأثيرالتربة الملوثة بالمعادن الثقيلة على التنوع الميكروبي للتربة بالمنطقة الصناعية بالقرب من مدينة أسيوط، مصر

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تهدف الدراسة الى التعرف على تأثير تعرض التربة لفترات طويلة لبعض العناصر المعدنية الثقيلة وتأثير ذلك على التنوع الميكروبي للتربة،حيث تم تجميع عينات التربة من ستة مواقع مختلفة ومتدرجة من حيث مستويات التلوث و ذلك بالقرب من مصنع سماد السوبر فوسفات – بمحافظة أسيوط – جمهورية مصر العربية. وتم تحديد التنوع البيولوجى لأعداد الميكروبات الموجودة فى جرام واحد من وزن التربة الجافة بأستخدام البيئة المناسبة ، حيث تم تقدير أعداد الفطريات بأستخدام بيئة أجار البطاطس و المولت ، كما تم تقدير أعداد البكتريا بأستخدام بيئة الأجار المغذى و محتوى التربة من بعض العناصر المعدنية الثقيلة مثل (الحديد، المنجنيز ،النحاس ، الزنك، الكادميوم ، النيكل ، الكروم ، الرصاص) و الأس الهيدروجينى . وقد أوضحت النتائج و جود تركيزات عالية من بعض العناصر المعدنية الثقيلة فى عينات التربة بمستويات تتجاوز الحدود الدولية القصوى المسموح بها وقد امكن من خلال عزل ما لا يقل عن ثلاثة عشر سلالة من الفطريات المحبة لدرجة الحرارة المتوسطة بالاضافة الى خمسة سلالات من الفطريات المحبه للحرارة العالية من عينات التربة قيد الدراسة . أضافة الى ذلك أمكن الحصول على تسعة سلالات من فطريات Arbuscular Mycorrhizal و التى تنسب مورفولوجيا لعائلات Acaulosporaceae, و Glomeraceae وGigasporaceae. و قد لوحظ و جود إختلاف بين أعداد البكتريا (الوسطية) و(المحبة للحرارة) ، بين عينات التربة المختلفة ، بينما كانت أعداد البكتريا المحبة للحرارة أقل تنوعا و ذلك مقارنة بأعداد البكتريا الوسطية. و تم ايجاد العلاقة بين تركيزات المعادن الثقيلة وتأثيرة على التنوع الميكروبى – و الذى ادى الى فهم تأثير الملوثات المعدنية من المصنع على التنوع الميكروبى فى التربة .