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THE ESTIMATION OF THE LIMIT OF PERMISSIBLE CONCENTRATION OF LEAD IN A SOIL BY PHOTOSYNTHESIS ACTIVITY

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ABSTRACT : The present study aims to elucidate the permissible concentration of lead in soils and plants in terms of photosynthetic activity, as well as the effect of soil texture on the absorption of lead by plants. So, soil and plant samples were collected from two locations along the Cairo-Alexandria highways; Kaluob for the rural road and Nubaria for the desert one, at distances on both sides of the two roads. Then, a soil suspension experiment was carried out to study the effect of lead contamination on its content in the dry matter of different plant parts as well as NPK contents in both of the roots and shoots of Pisum sativum (Pea) plants.

The results showed that the total and available lead content decreased with increasing the distance from the road and soil depth. In addition, the application of either 50 or 200 ppm Pb as Pb $(NO_3)_2$ to the soil suspension increased the available lead and decreased the total uptake of N, P and K in the grown plants. Also, photosynthetic activity and transpiration of plants decreased and subsequently dry matter production.

INTRODUCTION

Lead represents a problem since it is dissipated with gas exhaust of different vehicles into the soils and plants on both sides of the roads. Contaminated soils release only a small portion of their total lead content to plant. According to Martea and Hammand (1966), only 2.5ppm Pb existed in the first crop of brome grass grown on a contaminated sandy loam soil containing 680ppm.

In general, lead contamination comes from the automobile industry (Zuber and Bovay, 1969), pesticides (Frank et al. 1976) and/or fertilizers (El-Sherif and Hanna, 1979). El-Sokkary (1978) found that the lead existed in soils at 77-282ppm and in plants at 8-32ppm along the Cairo-Alexandria rural highway. Chow (1969) reported that the Pb content of soils along one highway was 403ppm in the top 5cm layer and 60ppm in the 10-15cm layer. Hansen (1976) indicated that lead concentration was higher in soils with pH < 4.6 than in those with pH >6.4. The highest levels of lead occurred in the heavier soil texture (Harmmssoenn, 1977). Ward et al (1977) stressed the greater overall efficiency of the atmospheric deposition as a source of lead contamination when compared the soil route.

Fiusello and Molinori (1973) stated that the Pb $(NO_3)_2$ had the most inhibitory effect on seedling elongation. The inhibition was greater for the roots than shoots. In addition, Lin (1991) reported that the mean concentrations of lead were 2.11, 3.69 and 2.58 mg/kg dry matter for fruit, leaf and roots, respectively. Zueng-Sang (2000) reported that the Exchangeable (or available) forms of cadmium and lead can be transformed into unavailable forms by applying amendments of manganese oxide, calcium carbonate or zeolite to the soil.

The objective of this work was to study the limit of permissible lead concentration in soils and its effect on plant photosynthetic activity and on uptake of some plant nutrient elements.

MATERIAL AND METHODS

Surface (0-20cm) and subsurface (20-40cm) soil samples were collected at 5, 15, 50, and 110m at both of Kaluob, close to the Cairo-Alexandria main rural road, and El-Nubaria, close to the CairoñAlexandria main desert road.

In addition, plant samples were collected from the same spots. The collected samples were subjected to different physical and chemical analyses according to the standard recommended procedures (Page et al., 1984). The obtained results are depicted in table (1).

A laboratory experiment was conducted during the winter of 2003 to study the limit of permissible lead concentration in soils and its effect on plant photosynthetic activity and uptake of some plant nutrient elements. Forty grams of each soil sample were mixed with 100ml distilled water to establish a soil-water suspension, left to stand still overnight, then cations and anions were determined.

Table (1). General characteristics of the used soil samples.

Distance (m)	Depth (cm)	EC (dS/m)	pH of 1:2.5 extract	$CaCO_3$ %	OM %	C.E.C meq/100g soil	Coarse sand, %	Fine sand, %	Silt, %	Clay, %	Texture
Kaluob											
5	0-20	2.20	8.00	2.07	1.5	37.90	1.71	29.31	30.12	38.86	C.L
	20-40	1.70	7.90	1.29	0.9	32.01	10.92	24.81	35.96	28.31	C.L
15	0-20	0.70	7.60	2.10	1.1	43.50	1.40	33.90	27.80	36.90	C.L
	20-40	0.50	7.20	1.60	0.5	35.40	8.10	32.30	25.50	34.10	C.L
50	0-20	2.65	7.85	2.68	2.1	40.04	4.31	11.69	39.11	44.89	Clay
	20-40	0.50	7.65	2.40	1.3	37.52	12.27	21.45	25.13	41..67	Clay
110	0-20	1.90	7.75	2.70	2.2	52.50	0.42	22.98	24.42	52.13	Clay
	20-40	0.74	7.80	1.74	1.5	48.80	1.74	24.11	25.22	46.93	Clay
El-Nubaria											
5	0-20	0.70	7.30	3.10	0.4	22.40	15.21	37.26	29.92	17.61	S.L
	20-40	0.50	7.10	3.20	0.3	18.70	13.23	36.18	31.22	19.37	S.L
15	0-20	0.60	7.40	2.50	0.5	27.40	13.18	46.54	21.32	19.26	S.L
	20-40	0.50	7.20	2.30	0.3	25.60	11.20	44.50	24.31	19.99	S.L
50	0-20	0.80	7.30	4.20	0.4	20.90	15.33	48.57	21.78	14.32	S.L
	20-40	0.50	7.10	3.50	0.3	18.10	12.21	46.60	233..7	17.49	S.L
110	0-20	0.70	7.50	3.30	0.4	19.50	14.43	32.71	35.10	17.75	S.L
	20-40	0.60	7.20	2.60	0.3	17.60	13.50	13.50	37.53	12.47	S.L

Pea (Pisum sativum) seeds were germinated on moist medical cotton for 10 days in petri dishes. After enough time had elapsed (25 days), the seedlings were dipped into the soil suspension for 30-minute interval for three successive times. Then, photosynthesis attained by the leaves was measured using the portable photosynthesis measuring system model Li-6200.

To another separate set of soil suspensions, 5 or 20 ml of 10ppm Pb $(NO_3)_2$ solution, i.e. 50 or 200 ppm Pb, was added, as well as a non-treated control. Each treatment was replicated three times. The pea seedlings, which were brought up as previously described, were also dipped into the suspensions containing lead nitrate.

Total and available Pb was measured in the soil suspensions. At the same time, plant photosynthesis was measured by the same means prescribed above. In addition, cellular carbon dioxide evolution, stomatal resistance, and transpiration were also measured.

In plant samples collected from each location along each road, plants were rinsed three times with distilled water, then the rinsed and non-rinsed plants were analyzed for lead content. Pea shoots and roots were then dried at 70C, milled and preserved in plastic bags for future analyses.

The obtained data were subjected to statistical analysis according to Gomez and Gomez (1984).

RESULT SAND DISCUSSION

Effect of spatial variability:

Table (2) shows that lead content in the different layers of soil profile decreased with the increase in the distance from the main road at both of Kaluob and El-Nubaria soils. This finding coincides also with the findings of El-Sokkary (1978), who stated that total lead content was negatively related to both of the distance from roadside and depth in soil profile. Also, Chow (1969) reported that the Pb content of soils along the Cairo-Alexandria main desert road was 403ppm in the top 5 cm soil layer and 60ppm in the 10-15 cm layer. It can, generally, be concluded that the greater the distance from the roadside, the less the precipitation of heavy metals.

From another perspective of comparison, Kaluob soils contained higher available and total Pb than those found in El-Nubaria soils at all the studied distances from the roadside (Table 3). These differences can be attributed to differences in soil texture and/or to the traffic intensity. Soils of Kaluob are clay loam in texture, but those of El-Nubaria were loamy sand in texture. This is supported by the findings of Harmmssoenn (1977) who found that the highest levels of lead occurred in the heavy clay soils

Table (2). Effect of distance (m) from road on lead distribution in soil layers.

Distance (m)	Soil depth (cm)	Available Pb (ppm)		Total Pb (ppm)	
		Kaluob	Nubaria	Kaluob	Nubaria
5	0-20	5.32	3.54	25.69	16.66
	20-40	4.92	2.85	15.35	14.37
15	0-20	5.04	2.72	21.37	13.95
	20-40	4.32	1.02	15.15	11.16
50	0-20	4.55	1.81	18.76	10.14
	20-40	3.91	1.32	12.35	8.54
110	0-20	4.02	0.94	15.36	7.53
	20-40	3.33	0.30	10.14	5.53
L.S.D 0.05		0.02	0.04	0.11	0.12

Table (3). Mean values of Pb in the studied soil as affected by distance from roadside.

Distance (m)	Available Pb (ppm)		Total Pb (ppm)	
	Kaluob	El-Nubaria	Kaluob	El-Nubaria
5	5.12	3.20	20.52	15.51
15	4.68	1.87	18.26	12.55
50	4.23	1.57	15.56	9.34
110	3.68	0.62	12.75	6.53
L.S.D 0.05	0.03	0.05	0.44	0.13

as compared with the light-textured ones. We can also conclude that the deeper the soil profile, the less the Pb concentration. It is obvious that lead dissemination far away from the highways should be controlled.

Effect of soil Pb on photosynthesis:

Table (4) shows that soil lead had a depressive effect on the rate and efficiency of the photosynthesis procedure and related parameters in pea leaves. The higher level of Pb application significantly decreased photosynthetic procedure compared with the control treatment.

It is evident that CO_2 evolution as well as stomatal resistance increased as a result of Pb application. These findings were also supported by the inhibition of the intensity of photosynthesis and transpiration from the leaves. It seems that the higher Pb concentration hinders photosynthetic procedure and related phenomena. Lead seems to block carbon dioxide exchange between chloroplasts and the atmosphere in the cell cavity.

This is eventually expected since lead retards, in some ways, the stomatal conductance of the atmospheric gases into the cell cavities. Virtually, this was reflected as low photosynthetic activity and moisture transpiration with the higher lead concentration. It

Table (4). Photosynthesis parameters as influenced by Pb treatments.

Pb (ppm)	CO_2 in cell (ppm)	Stomatal resistance (sec/cm)	Intensity of photosynthesis		Transpiration (mol/m^2.sec)
			(mmol/m^2.sec)	%	
0	378	20	6.62	100	0.62
50	1137	128	2.18	32	0.23
200	825	85	1.10	16.5	0.10
L.S.D 0.05	32	3	0.10	3	0.04

can be concluded that Pb pollution in the cultivated soil is detrimental to photosynthetic procedure and the related parameters in the leaves of the growing plants. From the preceding findings, it is obvious that soil pollution with lead from the highway should be controlled to avoid its damping effects on plant photosynthesis.

Table (5) shows that the addition of Pb to each of the two studied soils resulted in a significant increase in the soil available Pb, which was accompanied by a marked drop in photosynthetic activity in the growing plants. Supportive of this observation was the incurred decrease in transpiration. Generally, these effects were more evident at Kaluob area than at Nubaria, which is attributed to the greater available lead concentration in the former location (Table 5).

Generally, the lead emitted with the exhaust gases from the moving vehicles on the highways is a major source of soil pollution. Also, the greater lead concentration is expected, as shown previously, to be in the vicinity of the highways. So, the greater contamination is expected to take place in the growing plants, which are very close to these highways.

Effect of lead on plant:

Table (6) supports the above mentioned findings regarding the significantly diminishing concentration of lead as we go far from the roadside. It is also obvious that the plants rinsed with distilled water had lower Pb content compared with non-rinsed ones.

This finding stresses the precipitation of lead from the atmosphere as a result of emission from the moving vehicles on the highways. In other words, it emphasizes the role of highways as a source of contamination to the surrounding ecosystems. In addition, this precipitation diminishes with the distance from the road at both of the studied locations with the Nubaria area being greater than Kaluob as a source of pollution. So, the adopted pea plants could successfully exhibit the pollution that takes place at both of the studied areas. From another point of view, the Cairo-Alexandria desert highway is more polluting to the ecosystem than the rural highway owing to the heavier traffic intensity on the former.

Table (5). Effect of lead soil application on its availability, plant photosynthesis and transpiration in the two studied soils.

Pb (ppm)	AV. Pb (mg/L)	Photosynthetic intensity ($mmol/m^2.sec$)	%	Transpiration ($mol/m^2.sec$)
Kaluob				
0	0.25	6.90	99.58	0.57
50	0.62	3.64	52.84	0.16
200	0.86	1.60	23.21	0.13
L.S.D 0.05	0.02	0.12	1.17	0.02
El-Nubaria				
0	0.13	9.17	99.60	0.53
50	0.21	7.13	76.75	0.44
200	0.27	3.54	38.63	0.40
L.S.D 0.05	0.01	0.06	1.51	0.02

The previous results agree with those found by El-Sokkary (1978), who found soil levels of lead as high as 282 ppm and plant levels as high as 32 ppm along the Cairo-Alexandria rural highway. He added the total lead content was positively related to traffic

Table (6). Lead concentration (ppm) in different parts of pea plants before and after rinsing with distilled water.

Distance from road (m)	Before rinsing		After rinsing	
	Kaluob	El-Nubaria	Kaluob	El-Nubaria
	Total Pb (ppm)			
5	8.52	5.32	3.81	2.53
15	8.32	5.12	3.21	2.02
50	7.62	4.62	2.71	1.83
110	7.02	3.53	2.03	1.03
L.S.D 0.05	0.10	0.07	0.05	0.05

density and negatively related to both of the distance from roadside and depth in soil profile.

Table (7) shows a simulation to the ecological system along the highway roads. High Pb concentration in the soil suspension represents what happens in the vicinity of the road, and the lower the farther. The existence of lead in the soil markedly increased its concentration in the dry matter of different plant parts; shoot, root and whole plants. Plants were more susceptible to pollution with lead at Nubaria than at Kaluob, which confirms the previously findings regarding the study locations.

Generally, the higher the Pb concentration in the ecosystem, the higher is its concentration in the dry matter of pea plants. Lead concentration in shoots was markedly higher than that in roots of pea plants. This point reflects a strong effect of pollutant concentration (lead) on its content in plant aerial parts. It also reveals to the diminishing role of root on restricting the absorption of heavy metals as lead. It recommends the establishment of as deep plant fence as possible on both sides of the road to help catch the pollutant heavy metals such as lead. To deepen the plant fence, it can be constructed of more than two rows. Helping also is to have this fence grow as tall as possible to

Table (7). Dry matter production of different parts of pea plants in response to lead in the soil suspension.

Pb (ppm)	Dry Weight (gm)					
	Shoot	Root	whole plant	Shoot	Root	Whole plant
	Kaluob			El-Nubaria		
0	1.31	0.32	1.63	0.91	0.27	1.18
50	1.25	0.30	1.55	0.70	0.19	0.89
200	1.18	0.26	1.44	0.50	0.12	0.62
L.S.D 0.05	0.03	0.02	0.04	0.03	0.03	0.03

prevent the gas exhaust overcome the plant fence far from the side of the road.

These results agree well with Ward et al. (1977), who stated that higher lead content of leaves compared with roots reflected the overall efficiency of the atmospheric deposition of lead compared with the alternative pathway via the soil and root systems. Chow (1969) found that root side grass contained 20-60ppm of Pb in the dry matter. Also Fiusello and Molinori (1975) stated that the Pb (NO3)2 had the most inhibitory effect on seedling elongation. The effect seems to vary with plant spices. The inhibition was greater for the roots than shoots.

Table (8) shows that the addition of Pb to soils decreased N, P and K concentrations in pea plants. The N and P concentrations in shoots were higher than in roots of pea plants, while K concentration showed an opposite trend. It seems that potassium compensates for the decrease in the absorption of both N and P. This held true in both soils at the two different locations. In general, the absorption of the three macro-nutrients decreased with the increase in lead concentration in the soil suspension. This may be explain the bad performance of plants with the exposure to lead pollution in the ecosystem.

The previous results agree with the results of Lagerwerff et al. (1973), who found that an increase in the concentration of lead in the soil by a factor of 1.8 resulted in an increase in the lead content of the plant tissue by a factor of less than 2.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this work stresses the critical role of the vehicles moving on the highways in polluting the ecological systems. This pollution is proportional to the density of the traffic and inversely related to the distance from the highway road and also to the soil structure. The severe effect of pollution with lead was clear on photosynthesis of both of the pea plants. It seems that the investigated heavy metals block the photosynthetic activity.

Table (8). N, P and K concentration (%) in pea plants grown in different locations in response to lead contaminated soils.

Pb (ppm)	Root			Shoot		
	N	P	K	N	P	K
	%					
Kaluob						
0	3.30	0.0227	0.977	3.90	0.0223	0.697
50	2.10	0.0180	0.667	2.40	0.0207	0.513
200	2.15	0.0040	0.413	2.48	0.0050	0.353
L.S.D 0.05	0.06	0.0033	0.028	0.07	0.0027	0.031
El-Nubaria						
0	0.51	0.0013	0.098	0.61	0.0143	0.0017
50	0.31	0.0002	0.077	0.40	0.0014	0.0014
200	0.41	0.0001	0.071	0.51	0.0011	0.0011
L.S.D 0.05	0.03	0.0003	0.004	0.02	0.0008	0.0003

So, this study stresses the establishment of deep (more than two rows) and high enough fence to prevent the dissemination of lead into the soils on both sides of the highways. The suspension experiment could effectively represent the real effects of highway pollution. Plant samples from the studied locations around the Cairo-Alexandria rural and desert highways confirmed that the moving vehicles are behind the pollution.

In general, the inclusion of lead in the gasoline used in the moving vehicles should be stopped or, at least, decreased. Washing pollutants off the plants is not recommended to be as an effective means of getting rid of pollution because it increases their contents in the soil, then in the plant tissues. From another point of view, different soil textures mean variable ability to sequester heavy metals and keep them out of the soil solution.

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تقدير التركيز المسموح به من الرصاص في التربة بدلالة التمثيل الضوئي

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تهدف الدراسة الحالية إلى تحديد التركيزات المسموح بها من الرصاص في الأراضي والنباتات تحت الدراسة هذا بالإضافة إلى تأثير قوام التربة على امتصاص النباتات للرصاص لهذا أخذت عينات من التربة من موقعين؛ الأول عند قليوب على طريق مصر-اسكندرية الزراعي والثاني عند النوبارية على طريق مصر-اسكندرية الصحراوي وعلى أبعاد من جانبي الطريقين هي ٥، ١٥، ٥٠، ١١٠ متراً. ثم أقيمت تجربة معملية حيث أخذت عينات من هذه المواقع المذكورة وعمل منها معلق تربة غمست به بادرات نبات اللوبيا ثلاث مرات مدة كل منها ٣٠ دقيقة بعد إضافة الرصاص لهذا المعلق بتركيز ٥٠، ٢٠٠ جزء في المليون، ثم درس تأثير الرصاص المضاف على البناء الضوئي ومقاومة الثغور للتوصيل والنتح وأيضاً كمية ثاني أكسيد الكربون البين خلوي وأيضاً محتوى النباتات من النتروجين والفوسفور والبوتاسيوم.

وأظهرت النتائج أن إضافة تركيزات مختلفة من نترات الرصاص إلى محلول التربة أدت إلى زيادة الرصاص الميسر في التربة، مما أدى إلى انخفاض امتصاص النتروجين والفوسفور والبوتاسيوم في النباتات، كذلك انخفاض إنتاج المادة الجافة عموما، و يرجع ذلك إلى نقص معدل عملية التمثيل الضوئي، وكذلك انخفاض معدل النتح من النباتات.