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COMBINED EFFECTS OF CADMIUM, LEAD AND COPPER ON THE GROWTH AND ON METAL UPTAKE OF BROAD BEANS, CARROTS, RADISHES AND MARROW VEGETABLES*

M.M. AL-SUBU, R. SALIM, A. DOULEH and A. ATALLAH

Chemistry Department, An-Najah National University, Nablus, P.O. Box 7, Palestine, Via Israel

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ABSTRACT

Toxic symptoms of plants treated with a metal ion may not always be due to the increase of the uptake of this metal by plant but might be the result of the effect of the addition of this metal on the uptake of the other metal ions by plant. Thus, the study of the effects of combined treatments with more than one metal is important. In the present study, we have studied using root-treatment and foliar-treatment the combined effect of lead, cadmium and copper on the growth of broad beans, radishes, carrots and marrow vegetables. The effect of presence of each metal ion on the uptake of the other metal ions on the various parts of the plants by both root-treatment and foliar-treatment of plants have also been studied. The results have shown that the combined effect of metal ions differs from one case to another with variation of the metal ions, plant, part of plant or type of treatment.

RESUMEN

Los síntomas de toxicidad en los vegetales relacionados con iones metálicos, no se deben siempre al incremento en la absorción de metal por la planta, sino que están vinculados con los efectos combinados del elemento en cuestión con otros metales, por lo que es importante realizar estudios de estos elementos mezclados. En este trabajo se evaluó la actividad conjunta de plomo, cadmio y cobre sobre el crecimiento de habas, rábanos, zanahorias y calabacines, utilizando tratamientos radiculares y foliares. También se analizó la influencia de cada ión metálico sobre la absorción de los otros elementos en las diversas partes de las plantas, con base en los dos tipos de aplicación. Los resultados en los distintos casos que se presentan al reunir a los iones metálicos dependen de estos iones, tipo y porción involucrada de la planta y clase de ensayo de que se trate.

INTRODUCTION

Toxic metals can be transferred into the plant tissues through soil or rain water deposition. Metal uptake by plant can have damaging effects on the growth of plant and also might cause serious health hazards to man.

Several studies have reported the effects of lead, cadmium or copper on the growth of plant. However, heavy metal contamination does not usually involve single metals but rather combinations of metals. In this study, we aim to present a study involving combinations of cadmium and lead plus copper which is known to be one of the essential elements to plant. Literature has given conflicting results of the effect of combinations of cadmium and lead toxicity or of the effect of addition of these metals on the uptake of the essential elements such as zinc or copper by plant. For example, it has been reported that the addition of cadmium decreased zinc concentrations in radish shoots (Khan and Fran-

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kland 1983) but increased zinc concentrations in lettuce (Mclean 1976). Addition of cadmium was reported to decrease the concentrations of copper in leaves of bush beans (Wallace *et al.* 1977). Toxicity of cadmium and lead was reported to be additive on the growth of radish plants (Khan and Frankland 1983) and on the roots of maize (Hassett *et al.* 1976). Lead uptake was reported to have increased in the roots of maize by the addition of cadmium (Hassett *et al.* 1976). In another study, the presence of lead increased the concentration of cadmium in leaves of oat plants (Bjerre and Schierup 1985). However, this had been completely reversed when the soil type was changed (Bjerre and Schierup 1985).

In the present work, we aim to study the combined effects of cadmium, lead and copper on several types of vegetables grown under exactly similar conditions. We also aim to study this effect by using root-treatment of plant one time and another time by using foliar-treatment of plant.

MATERIAL AND METHODS

Planting

This study was carried out on radish plants (*Raphanus sativus* L.), carrots (*Daucus carota* L., var. sativa DC.), broad beans (*Vicia faba* L.) and marrow plants (*Cucurbita pepol*, var. melopepo). Seeds of plants were planted in plastic pots containing 3 kg of sandy soil (3 seeds in each pot). After the appearance of the first true leaves only the best looking plant was left in each pot and allowed to grow under green-house conditions. The plants were irrigated with 200 mL tap water free from lead, cadmium or copper twice a week. This tap water was replaced by a nutrient solution (1g/L) once every two weeks. The nutrient used was composed of 20% NH_4NO_3, 20% P_2O_5, 20% K_2O, 0.015% Zn, 0.011% Cu, 0.007% Mo, 0.1% Fe and 0.05% Mn.

Treatment with Metal Ions

Two weeks after transplanting the seedlings, their treatment with metal ions was initiated. Three plants were treated with each concentration used for either root-treatment or foliar-treatment. Root-treated plants were irrigated with 200 mL of the required ion concentration every week for the remaining period of growth which lasted 12 weeks. Foliar-treated plants were sprayed with 50 mL of the required metal ion concentration every week for 12 weeks. A plastic sheet was used to prevent the sprayed mist from reaching the soil in the case of foliar-treatment.

Chemical Analysis of Plants

The roots and shoots of the completely grown plants were taken in plastic bags. They were then cleaned thoroughly with distilled water and dried in a oven at 110°C. The dry plants were ground and ashed in a furnace at 550°C for six hours and kept in labelled plastic bags ready for chemical analysis. The allowed relative standard deviation of weight was up to 15%. This included ~ 90% of samples.

A certain weigth of the ash of each sample was treated with 2 mL of conc. HNO_3 and digested under pressure for 10 hours at 170°C. After that, the volume was made up to 15 mL with distilled water and all samples were analysed for cadmium, lead or copper. The analytical method used was the graphite furnace atomic absorption spectrometry using a Perkin-Elmer Spectrometer Model 5100 equipped with HGA-7700 Professional Computer. The heating programs were as follows:

	Cadmium	*Lead*	*Copper*
Step 1	120°C, 30s	130°C, 15s	120°C, 20s
Step 2	700°C, 30s	300°C, 20s	900°C, 15s
Step 3	1800°C, 4s	2100°C, 4s	2300°C, 6s
Step 4	2500°C, 2s	2400°C, 1s	2600°C, 3s

The AAS computer was programmed to do analy ses and calibrations in the sequence: blank, sample, standard S1, standard S2 and standard S3. The standards used were provided ready by the Ecology Department-University of Bielefeld with concentrations of 2, 3 and 6 μg/L in case of cadmium and 60, 80 and 100 μg/L in case of lead and copper. The calibration process was automatically repeated every ten readings and all readings were corrected for the blank. Three batches of each sample were analysed and the average of two or three readings of these (with relative standard deviation < 10%) were reported to appear in the results of this work. A matrix modifier of palladium nitrate was applied for the analysis of samples for cadmium.

TABLE I. DRY WEIGHT OF BROAD BEANS TREATED WITH COMBINATION OF METAL IONS

Concentration of metal ions ppm	*Dry weight (g)*				
	Root	*Stem*	*Leaves*	*Fruits*	*Whole plant*
Root-treatment (200 ml × 12 times)					
Cd + Pb					
0.0 + 0.0	3.036	7.511	5.304	7.640	23.491
0.2 + 6.3	3.008	7.178	5.301	7.353	22.840
0.9 + 3.1	1.836	6.037	4.821	6.456	19.150
0.9 + 6.3	2.457	7.066	5.276	7.456	21.875
Pb + Cu					
3.1 + 1.3	1.293	6.536	3.124	5.894	16.847
3.1 + 6.3	0.368	3.042	2.080	3.776	9.266
Foliar-treatment (50 ml × 12 times)					
Cd + Pb					
0.0 + 0.0	3.036	7.511	5.304	7.640	23.491
0.2 + 6.3	1.955	5.916	4.202	4.952	17.025
0.5 + 6.3	1.190	3.943	3.891	4.056	13.080
0.9 + 3.1	2.360	3.143	2.827	3.302	11.632
0.9 + 6.7	1.880	3.469	2.401	3.189	10.939
Cd + Cu					
0.9 + 1.3	0.518	2.901	1.599	2.398	7.416
0.9 + 2.8	1.600	2.391	1.576	2.129	7.696
Pb + Cu					
3.1 + 1.3	1.150	5.389	3.486	3.215	13.235
3.1 + 6.3	2.302	4.787	3.155	3.032	13.276

RESULTS AND DISCUSSION

Combined Effect of Metals on the Growth of Plants

Effect on the growth of broad beans

The dry weight of the various parts of treated broad bean plants are shown in Table I.

The combined toxicity of cadmium and lead was additive on the growth of foliar-treated broad bean plants (c.f. Table I). This effect was not regular in root-treated plants.

The combined lead and copper toxicities was additive on the various parts of the root-treated plants (c.f. Table I). This effect was additive on all parts of foliar-treated plants other than the roots. The antagonistic effect of copper and lead on the growth of the roots of foliar-treated plants was high enough that the total effect on the whole plant was also antagonistic.

The combined effect of cadmium and copper was on foliar-treated plants exactly similar to that of lead and copper.

Effect on the growth of marrow vegetables

The dry weights of the various parts of treated marrow plants are shown in Table II.

Investigating the results of Table II indicated that the toxicity of cadmium and lead was mostly antagonistic and some times irregular on the parts of root-treated or foliar-treated plants. This same combined effect was also found for the effect of lead and copper on treated plants. On the other hand, the combined toxicity of cadmium and copper was additive on all parts of root-treated and foliar-treated plants.

TABLE II. DRY WEIGHT OF MARROW VEGETABLES TREATED WITH COMBINATIONS OF METAL IONS

Concentration of metal ions ppm	*Dry weight (g)*				
	Root	*Stem*	*Leaves*	*Fruits*	*Whole plant*
Root-treatment (200 ml × 12 times)					
Cd + Pb					
0.0 + 0.0	0.721	2.349	1.884	0.520	5.479
0.2 + 6.3	0.127	0.512	1.229	0.000	1.868
0.5 + 6.3	0.342	1.452	1.263	0.401	3.458
0.9 + 6.3	0.714	1.490	1.689	0.516	4.403
0.9 + 3.1	0.255	1.638	1.742	0.500	4.135
0.9 + 1.5	0.400	1.751	1.836	0.496	4.483
Cd + Cu					
0.9 + 1.3	0.202	2.105	1.800	6.000	4.107
0.9 + 2.5	0.174	0.831	1.512	0.464	2.981
Pb + Cu					
3.1 + 1.3	0.200	1.713	1.278	0.490	3.681
3.1 + 6.3	0.356	1.006	1.668	0.503	3.533
Foliar-treatment (50 ml × 12 times)					
Cd + Pb					
0.0 + 0.0	0.721	0.349	1.889	0.520	5.479
0.2 + 6.3	0.540	0.188	1.419	0.000	2.147
0.5 + 6.3	0.594	0.939	1.183	0.117	2.833
0.9 + 6.3	0.605	1.669	1.721	0.163	4.158
0.9 + 3.1	0.368	2.281	1.775	0.236	4.660
0.9 + 1.5	0.655	2.109	1.800	0.220	4.784
Cd + Cu					
0.9 + 1.3	0.562	0.787	1.047	0.513	2.909
0.9 + 2.3	0.404	0.757	0.964	0.054	2.179
Pb + Cu					
3.1 + 1.3	0.512	1.506	1.008	0.000	3.026
3.1 + 6.3	0.424	1.728	1.369	0.410	3.931

Effect on the growth of radishes

The dry weights of the shoots and roots of treated radish plants are shown in Table III.

The results of Table III showed, in general, an additive toxicity of lead and cadmium on all parts of treated plants by either root-treatment or foliar-treatment. On the other hand, the combined toxicity of cadmium and copper and of lead and copper was found to be antagonistic on both shoots and roots of root-treated plants and on foliar-treated plants, respectively.

Effect on the growth of carrots

The dry weights of the shoots and roots of treated carrot plants are shown in Table IV.

Investigating the results of Table IV indicated an additive toxicity for cadmium or lead with copper on root-treated and on foliar-treated carrots. This was obvious on both the roots and shoots of treated plants.

The combined toxicity of lead and cadmium was

TABLE III. DRY WEIGHT OF RADISH PLANTS TREATED WITH COMBINATIONS OF METAL IONS

Concentration of metal ions ppm	*Dry weight (g)*		
	Root	*Leaves*	*Whole plant*
Root-treatment (200 ml × 12 times)			
Cd + Pb			
0.0 + 0.0	6.898	6.854	13.752
0.2 + 6.3	4.656	2.409	7.065
0.5 + 6.3	1.995	4.028	6.023
0.9 + 6.3	0.994	3.220	5.214
Cd + Cu			
0.9 + 1.3	2.470	1.677	4.147
0.9 + 2.5	4.701	3.521	8.222
Foliar-treatment (50 ml × 12 times)			
Cd + Pb			
0.0 + 0.0	6.898	6.854	13.752
0.2 + 6.3	5.906	5.740	11.640
0.5 + 6.3	4.190	2.485	7.177
0.9 + 6.3	1.529	1.590	3.119
Pb + Cu			
3.1 + 1.3	3.037	3.550	6.587
3.1 + 6.3	4.291	3.984	8.275

distinctly additive on the roots and shoots of both root-treated and foliar-treated plants.

Combined Effect of Metals on the Uptake of these Metals by Treated Plants

Effects on the uptake of metal ions by broad bean plants

The concentration of metal ions in the various parts of broad bean plants treated with combinations of metal ions are shown in Table V.

Investigating the results of Table V revealed that:

1. Increasing cadmium concentration increased the uptake of lead from constant lead solutions on the various parts of root-treated and of foliar-treated plants.

2. Increasing the lead concentration in combination with constant cadmium concentration decreased the uptake of cadmium by the various parts of the root-treated plants and by the stems and the leaves of the foliar-treated plants.

3. Increasing copper concentration in combination with constant cadmium or lead concentration generally increased the uptake of cadmium or lead in the various parts of root-treated and of foliar-treated plants.

Effects on the uptake of metal ions by carrots

The concentration of metal ions in the shoots and roots of carrot plants treated with combinations of lead, cadmium and copper are shown in Table VI.

Investigating the results of Table VI revealed that:

1. Increasing the cadmium concentration in combination with constant lead concentration increased the uptake of lead by roots but reduced this uptake by shoots of the root-treated plants. The increase of uptake by roots was higher than its reduction on the shoots with a resultant increase in the uptake of the whole plant.

2. Increasing the copper concentration in combination with constant cadmium concentrations resulted in increasing the uptake of cadmium by the shoots and the whole plants of root-treated car-

TABLE IV. DRY WEIGHT OF CARROT PLANTS TREATED WITH COMBINATIONS OF METAL IONS

Concentration of metal ions ppm	*Dry weight (g)*		
	Root	*Leaves*	*Whole plant*
Root-treatment (200 ml × 12 times)			
Cd + Pb			
0.0 + 0.0	1.241	0.996	2.237
0.2 + 6.3	0.793	0.964	1.757
0.5 + 6.3	0.213	0.783	0.996
Cd + Cu			
0.9 + 1.3	0.448	0.927	1.375
0.9 + 2.5	0.148	0.710	0.858
Pb + Cu			
6.3 + 1.3	0.787	0.855	1.642
6.3 + 2.5	0.287	0.621	0.908
Foliar-treatment (50 ml × 12 times)			
Cd + Pb			
0.0 + 0.0	1.241	0.996	2.237
0.2 + 6.3	0.344	0.738	1.082
0.5 + 6.3	0.259	0.495	0.754
Cd + Cu			
0.9 + 1.3	0.739	0.693	1.432
0.9 + 2.5	0.602	0.326	0.930
Pb + Cu			
6.3 + 1.3	0.907	0.762	1.669
6.3 + 2.5	0.728	0.320	1.048

rots. The uptake of cadmium by the roots of the root-treated plants was depressed by the increase of copper concentration in combination with cadmium.

3. Increasing copper concentrations in combination with a constant lead concentration resulted in depression in the uptake of lead by the roots and shoots of the root-treated plants.

4. Increasing cadmium concentration increased the lead uptake by the roots and shoots of the foliar-treated plants from solutions having similar concentrations of lead.

5. Increasing copper concentrations in combination with constant lead or cadmium concentrations increased the uptake of lead and of cadmium in the roots and shoots of the foliar-treated plants.

Effects on the uptake of metal ions by radishes

The concentration of metal ions in the roots and shoots of treated radish plants with combinations of lead, cadmium and copper are shown in Table VII.

Investigating the results of Table VII revealed that:

1. Increasing the cadmium concentration in combination with a constant lead concentration resulted in increasing the uptake of lead by the roots and shoots of the root-treated plants. In case of foliar-treatment, the effect on the uptake of lead did not show a regular trend with increasing the companion cadmium concentration.

2. Increasing the lead concentration in combination with a constant cadmium concentration resulted in increasing the uptake of cadmium by the roots and shoots of the root-treated plants.

TABLE V. CONCENTRATION OF METAL IONS (μg/g PLANT) IN TREATED BROAD BEANS

Concentration of metal ions ppm	*Roots*		*Stem*		*Leaves*		*Fruits*		*Whole plant*	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Root-treatment										
Cd + Pb										
0.2 + 6.3	0.130	0.211	0.014	0.435	0.090	0.410	0.279	0.609	0.131	0.062
0.9 + 3.1	0.407	0.055	0.032	0.159	0.116	0.471	0.028	0.451	0.085	0.326
0.9 + 6.3	0.314	0.308	0.012	0.526	0.061	0.628	0.014	0.742	0.059	0.588
Pb + Cu										
3.1 + 1.3	0.588	1.110	0.126	0.464	1.497	1.714	0.048	1.123	0.388	0.975
3.1 + 6.3	2.366	12.006	0.313	3.076	1.752	5.139	0.062	2.170	0.616	3.525
Foliar-treatment										
Cd + Pb										
0.2 + 6.3	0.136	1.733	0.017	0.748	0.070	0.093	0.182	0.098	0.091	0.510
0.5 + 6.3	0.489	1.809	0.029	1.703	0.553	0.266	0.075	0.220	0.237	0.817
0.9 + 3.1	0.770	9.474	0.220	0.288	0.251	1.658	0.283	0.166	0.232	1.281
0.9 + 6.7	0.895	7.659	0.021	0.238	0.313	0.851	0.045	0.157	0.164	0.895
Cd + Cu										
0.9 + 1.3	1.220	1.160	0.026	1.650	0.219	1.210	1.279	1.178	0.550	1.374
0.9 + 2.8	1.373	1.550	0.030	2.183	0.362	1.245	1.015	1.130	0.281	1.569
Pb + Cu										
3.1 + 1.3	0.389	0.826	0.622	1.020	1.992	0.451	1.540	1.045	1.185	0.859
3.1 + 6.3	0.224	1.601	0.806	1.782	1.892	0.362	2.328	1.105	1.311	1.259

3. Increasing copper concentration in combination with constant cadmium concentrations resulted in an increase in the uptake of cadmium by the roots and shoots of the root-treated plants.

4. Increasing the copper concentration in combination with a constant lead concentration in foliar-treatment of radishes resulted in increasing the lead uptake by the roots and shoots of the treated plants.

Effects on the uptake of metal ions by marrow plants

The concentration of metal ions in treated marrow plants are shown in Table VIII for the root-treated and foliar-treated plants with combination of cadmium, lead and copper.

Investigating the results of Table VIII revealed that:

1. Increasing the cadmium concentrations in combination with a constant lead concentration resulted in a general decrease in the uptake of lead by the several parts of the root-treated plants and foliar-treated plants.

2. Increasing lead concentration in combination with a constant cadmium concentration resulted in a general decrease in the uptake of Cd by the parts of the root-treated plants (except an irregular trend in the uptake of roots). No systematic effect for the change in lead concentration was observed on the uptake of cadmium by the parts of the foliar-treated plants.

3. Increasing copper concentration in combination with constant cadmium or lead concentrations resulted in increased uptake of cadmium or lead by the parts of the root-treated plants but decreased uptake of cadmium or lead by the parts of the foliar-treated plants.

TABLE VI. CONCENTRATION OF METAL IONS (μg/g PLANT) IN TREATED CARROTS

Concentration of metal ions ppm	*Roots*		*Leaves*		*Whole plant*	
	M_1	M_2	M_1	M_2	M_1	M_2
Root-treatment						
Cd + Pb						
0.0 + 0.0	0.245	0.398	0.022	0.496	0.146	0.235
0.2 + 6.3	0.198	0.206	0.278	0.310	0.265	1.795
0.5 + 6.3	3.991	1.181	1.660	3.065	2.159	2.661
Cd + Cu						
0.9 + 1.3	2.746	2.011	0.078	0.909	0.219	1.268
0.9 + 2.5	1.229	12.061	0.051	0.187	0.255	2.683
Pb + Cu						
6.3 + 1.3	2.311	8.907	8.591	9.696	5.581	9.318
6.3 + 2.5	1.857	43.554	5.233	16.698	4.163	25.187
Foliar-treatment						
Cd + Pb						
0.0 + 0.0	0.245	0.398	0.022	0.496	0.146	0.235
0.2 + 6.3	0.401	0.294	0.467	6.748	0.446	4.695
0.5 + 6.3	3.429	2.317	4.444	12.359	4.095	8.909
Cd + Cu						
0.9 + 1.3	0.399	0.591	1.329	22.619	0.846	11.251
0.9 + 2.5	0.475	0.857	5.733	58.758	2.319	21.152
Pb + Cu						
6.3 + 1.3	2.545	14.631	10.503	11.969	6.178	13.415
6.3 + 2.5	0.709	22.225	24.719	53.656	7.595	31.823

TABLE VII. CONCENTRATION OF METAL IONS (μg/g PLANT) IN TREATED RADISHES

Concentration of metal ions ppm	*Roots*		*Leaves*		*Whole plant*	
	M_1	M_2	M_1	M_2	M_1	M_2
Root-treatment						
Cd + Pb						
0.2 + 6.3	0.830	1.900	12.380	8.420	0.800	4.130
0.5 + 6.3	3.680	3.800	7.400	24.080	6.170	18.690
0.9 + 6.3	7.570	5.240	8.250	25.900	21.100	21.480
0.9 + 1.5	1.230	2.630	0.842	16.600	1.119	6.620
Cd + Cu						
0.9 + 1.3	0.410	7.840	6.920	5.190	3.040	19.020
0.9 + 2.5	1.270	19.310	7.310	5.760	3.860	13.500
Foliar-treatment						
Cd + Pb						
0.2 + 6.3	0.130	0.260	1.037	6.560	0.577	3.860
0.5 + 6.3	0.396	7.430	6.826	33.850	3.060	18.390
0.9 + 6.3	19.620	1.380	21.865	20.743	20.743	8.620
Pb + Cu						
3.1 + 1.3	0.964	3.280	0.084	8.260	0.488	5.980
3.1 + 6.3	1.244	7.470	6.962	15.670	10.790	10.790

TABLE VIII. CONCENTRATION OF METAL IONS (μg/g PLANT) IN TREATED MARROW PLANT

Concentration of metal ions ppm	*Roots*		*Leaves*		*Fruits*		*Stem*		*Whole plant*	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Root-treatment										
Cd + Pb										
0.2 + 6.3	5.196	5.196	1.053	19.593	—	—	0.654	2.873	1.225	14.031
0.5 + 6.3	2.137	3.866	0.685	15.122	0.416	0.519	0.496	0.768	0.718	6.288
0.9 + 6.3	2.227	2.626	2.003	19.558	0.131	0.296	1.691	0.710	1.717	8.203
0.9 + 3.1	5.470	1.686	2.423	16.479	0.672	0.538	0.657	0.633	1.764	7.362
0.9 + 1.5	4.925	1.045	2.451	7.639	0.609	0.839	2.466	0.459	2.474	3.494
Cd + Cu										
0.9 + 1.3	3.317	8.153	0.900	11.767	—	—	0.490	4.875	10.809	8.057
0.9 + 2.5	3.517	9.770	0.894	17.331	1.252	11.136	1.024	4.223	11.392	12.271
Pb + Cu										
3.1 + 1.3	2.270	10.115	7.271	17.187	0.228	15.376	1.158	4.680	3.217	10.741
3.1 + 6.3	3.430	7.888	7.258	18.391	0.621	24.272	3.292	17.807	5.810	18.004
Foliar-treatment										
Cd + Pb										
0.2 + 6.3	1.063	4.180	3.150	42.871	—	—	2.340	26.622	2.017	21.992
0.5 + 6.3	1.232	0.465	1.554	12.147	0.410	0.701	0.232	2.238	1.000	10.293
0.9 + 6.3	1.441	0.441	11.565	32.820	0.013	0.417	0.410	1.038	5.181	14.081
0.9 + 3.1	1.774	0.886	6.022	32.190	0.318	0.479	0.908	3.405	2.895	12.286
0.9 + 1.5	0.667	1.201	2.478	21.504	0.095	0.164	0.203	1.402	1.118	8.881
Cd + Cu										
0.9 + 1.3	3.245	5.457	17.190	12.647	0.610	20.711	2.094	5.033	7.488	10.620
0.9 + 2.5	0.993	10.720	8.592	68.394	0.092	8.204	0.993	5.605	4.333	34.396
Pb + Cu										
3.1 + 1.3	1.379	5.484	49.792	9.756	—	—	4.540	5.301	19.079	10.147
3.1 + 6.3	1.283	2.156	8.868	9.119	0.035	1.746	3.910	5.941	4.947	6.202

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