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Use of Various Chelates as Soil Extractants

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Abstract
Four chelating agents—DTPA, EDTA, AB-DTPA and six molarities of sodium gluconate (0.005M, 0.01M, 0.015M, 0.02M, 0.025M and 0.03M) were compared as extractants for Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd in 5 diverse soils collected at different locations surrounding Peshawar from 0-30cm depth. Soil samples were also analyzed for soil chemical properties. The data of chemical analysis showed that soil pH was alkaline in nature. Electrical conductivity values of soil samples showed that the samples were non saline. Organic matter was found deficient and medium in 40 and 40 % samples respectively. AB-DTPA was the most effective extractant for Cu, Fe, Mn, Pb, Ni, and Cr whereas EDTA was the most effective extractant for Cd and Zn. An increasing trend in extractability of the nutrient was observed with an increase in the molarities of sodium gluconate.
Keywords: DTPA, EDTA, AB-DTPA, soil pH, Electrical conductivity, mineral nutrients

Introduction

Chelates are chemicals that form soluble, complex molecules with certain metal ions, inactivating the ions so that they cannot normally react with other elements or ions to produce precipitates or scale. A soil extractant is a solution made of solvent and a certain concentration of chemicals to extract nutrients from soil into solution. A soil test requires an extractant to determine the amount of plant nutrients in the soil. Chelates can be used as soil extractants as they extract soil nutrients and hinder them to precipitate.

A comparison of the expected stability of a number of chelates under a variety of soil conditions was made by Sommers and Lindsay (1979). They reported that the common chelating agent EDTA (ethylene-diaminetetraacetic acid), HEDTA (hydroxyethylethylenediamine-triacetic acid), NTA (nitrilotriacetic acid), and EGTA [ethyleneglycol- bis(2-aminoethylether)tetraacetic acid] would have potential as chelating agents to extract microelements and heavy metals under most expected soil conditions. However the choice among the chelating agents is extremely difficult because they have usually been evaluated under widely incomparable conditions. The incentive to adopt a new extractant is the saving in time and cost analysis. Multiple-element extractants may enable determination of other plant nutrients at little additional cost, thereby possibly improving the diagnostic value of soil testing.

The results indicate that chelating agents play an important role in overcoming the rate-limiting steps of solution and adsorbed phase diffusion which are mainly responsible for the movement of ions in alkaline and calcareous soils. Gupta and Mittal (1981) conducted an experiment to evaluate various extractants. They reported that the order of extractability by different extractants was 6 N HCl > 0.1 N HCl > EDTA $(NH_4)_2$ CO_3 > EDTA NH_4 OAc > DTPA+ $CaCl_2$ > 1M $MgCl_2$. They suggested that the use of 0.1N HCl would be much cheaper than DTPA and other extractants.

The average extractability of fertilizer Fe and Zn by NH_4HCO_3-DTPA from soils fertilized with Fe EDDHA or $ZnSO_4$ was 43 ± 6% and 57 ± 8% respectively. The data on extractability of Fe and Zn indicate that the NH_4HCO_3-DTPA soil test effectively measures the residual value of Fe and Zn fertilizers in the soils tested (Havlin and Sutanpour,1984). Fifteen extractants were used for their ability to remove B, F, Mn and Zn from soil, and reported that all extractants removed more Mn, Zn and Fe than the deionized water. The acids were less effective in extracting Mn and Zn than chelating agents. DTPA, EDTA, and mixtures containing them were very effective extractants for Mn, Zn and Fe. The extractants containing EDTA were difficult to analyze because standard solutions prepared for the elemental analysis were unstable (Berghage *et al.*, 1987).

The soils of Peshawar valley are slightly to strongly calcareous with neutral to strongly alkaline reaction having pH from 7.2 to 9.1 (Staff, Soil survey of Pakistan 1973). The fact that largest source of organic matter is crop residue but un-fortunately in Pakistan and many other developed countries, negligible amount of crop residue is left in field after crop harvest especially of wheat and rice. The crop residue is either used to feed animals, to make papers or use as a fuel (Kauser, 1996). The incorporation of plant materials or residues especially legume plant materials which often have high nitrogen content than non legumes to the soil increases both nitrogen content and N mineralization potential (Black, 1968).

Precise and accurate soil test values have been the objective of many researches. Agricultural soils in Pakistan are calcareous and are intensively used for growing not only major crops but also a multitude of fruits and vegetables, correct appraisal of micronutrients is very important. Evaluation of trace element availability to plants is increasingly an important objective in soil testing methods. This need has focused on investigations on

the use of chelating agents, for example the AB-DTPA (Ammonium Bicarbonate Diethylene Triamine Penta Acetic acid) micronutrient soil tests and has led to a comparison of AB-DTPA and other chelating agents as extractants for several trace metals such as Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd. The expression "bound in soil" and "fixed in soil" are concepts depending on the concentration and feature of the extractant used.

Sodium gluconate(Na-G) is the sodium salt of gluconic acid, produced by fermentation of glucose. It is a white to tan, granular to fine, crystalline powder, very soluble in water. The outstanding property of sodium gluconate is its excellent chelating power, especially in alkaline and concentrated alkaline solutions. It forms stable chelates with calcium, iron, copper, aluminium and other heavy metals, and in this respect, it surpasses all other chelating agents, such as EDTA, NTA and related compounds. Its chemical formula is $C_6H_{11}O_7Na$. It is used in the medicine or used as food additives. Little information is available comparing the predictive abilities of this solution with other commonly used soil extractants. The cost of sodium gluconate is Rs.60/kg. It is cheaper than the chelate used so far so this study has been designed to test it in our soil conditions as extractant.

Materials and Methods

Soil Sampling

A total of 5 samples were collected at different sites surrounding the Peshawar city, from 0-30 cm depth. The samples were brought to laboratory of department of Soil and Environmental Sciences, Khyber Pakhtunkhwa Agricultural University Peshawar and were dried, ground and sieved. These samples were analyzed for soil chemical properties i.e. pH, E.C (Richards 1954), and O.M (Nelson and Sommers, 1982). Micronutrient (Cu, Fe, Zn and Mn) in the soil were determined by AB-DTPA (sultan pour 1985), DTPA (Lindsay and Norvell 1978), EDTA (Misra and Pandey 1976) and sodium gluconate as extractants. Heavy metal content (Pb, Ni, Cr and Cd) was also determined using the same extractants.

Chemical Properties of Soil

Electrical conductivity and pH of soil samples in 1:5 soil suspension were determined
(Richards 1954) along with organic matter content (Nelson and Sommer, 1982)

AB-DTPA Extractable Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd

AB-DTPA (ammonium bicarbonate diethylene triamine penta aceticacid) extractable micronutrients and non-essential heavy metals were determined by the method given by (Sultan pour 1985) and by (Havlin and Sultan pour, 1981) respectively using the formula:

$$\frac{\text{(Sample-Blank) *D. F (if any)}}{\text{Wt of soil}}$$

$$\text{D. F} = \frac{\text{Final Volume}}{\text{Initial Volume}}$$

DTPA Extractable Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd

The method of Lindsay and Norvell (1978) was used to determine available
Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd in the soil samples.

EDTA Extractable Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd

The method of Misra and Pandey (1976) was used to determine available Cu,Fe, Zn, Mn, Pb, Ni, Cr and Cd in the soil samples.

Sodium Gluconate Extractable Cu, Fe, Zn, Mn, Pb, Ni, Cr and Cd

Six molarities (0.005M, 0.01M, 0.015M, 0.02M, 0.025M and 0.03M) of sodium gluconate were prepared by dissolving required amount of sodium gluconate in DI water. Ten gram of soil was taken in 125ml conical flask and added 20ml of each of various concentration of sodium gluconate extracting solution. The flask was stoppered and the solution was shaken for 15 minutes and the content was filtered through Whatman No.42 filter paper and stored for reading on atomic absorption spectrophotometer using required standard solutions.

Results and Discussions

The data regarding the chemical properties and the micro nutrients and non-essential heavy metals of soil is presented in table 1-9.

CHEMICAL PROPERTIES

Soil pH:

Soil pH ranged from minimum of 7.50 at Wakel Kala to a maximum of 8.52 at Daud zai, with a mean value of 7.972 in surface soil (Table 1). These results showed that pH of the study area were alkaline in nature. Similar results were obtained by (Shah and Parveen, 2006). The soil of Peshawar valley are slightly to strongly calcareous with neutral to strongly alkaline reaction, having pH from 7.2 to 9.1 (Staff, Soil survey of Pakistan 1973).

Soil Electrical Conductivity:

Electrical conductivity ranged from a minimum of 0.194 ds/m at Wakel Kala to maximum of 0.33 ds/m at Daud zai, with a mean value of 0.227 ds/m in surface soil (Table 1). These results were similar to (Shah and Parveen 2006) who reported that these soils have low content of soluble salts and there is no danger of salinity.

Soil Organic Matter:

Organic matter ranged from 0.98 % at Wakel Kala to 2.01 % at Monacro, with a mean value of 1.44 % in surface soil (Table 1). Organic matter was medium in 40 % samples and deficient in 40 % samples in surface soil. There results were similar to that of (Shah and Parveen, 2006). The crop residue is either used to feed animals, make papers or used as a fuel (Kauser, 1996). In developed countries, crop residues are disposed off by burning in the fields to facilitate straw disposal, seed bed preaparation and weed control (Biederbeck *et al.* 1980), but it is now realized that burning tends to decrease soil O.M and microbial activity (Dick and Christ, 1995).

Table 1. Chemical properties of soil.

Properties	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
pH	-	8.52	8	7.87	7.97	7.50	7.972	0.37	4.75
E.C	ds/m	0.33	0.197	0.196	0.218	0.194	0.227	0.068	29.96
Organic matter	%	1.00	2.01	1.449	1.75	0.98	1.438	0.45	31.3

Comparison of Various Chelates As Exractants

Copper Extraction

AB-DTPA has extracted the highest amount of copper, with mean of 8.521 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of copper, with mean of 3.425 mg/kg (Table 2). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 2. Extraction of Copper by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	2.95	6.9	8.55	13.22	1.505	6.625	4.66	70.4
DTPA	mg/kg	3.61	7.535	9.2	15.845	2.01	7.64	5.42	70.9
AB-DTPA	mg/kg	4.2	8.02	9.824	18.1	2.46	8.521	6.11	71.7
0.005 M Na-G	mg/kg	0.742	3.345	4.685	8.05	0.304	3.425	3.16	92.24
0.01M Na-G	mg/kg	0.909	3.85	5.08	8.65	0.512	3.80	3.33	87.6
0.015 M Na-G	mg/kg	1.3	4.235	5.615	9.415	0.667	4.24	3.54	83.25
0.02 M Na-G	mg/kg	1.63	4.715	6.33	10.24	0.815	4.74	3.80	80.06
0.025 M Na-G	mg/kg	1.81	5.655	7.24	11.78	0.892	5.47	4.4	80.22
0.03 M Na-G	mg/kg	2.13	6.45	7.98	12.23	1.046	5.96	4.54	76.03

Iron Extraction

AB-DTPA has extracted the highest amount of iron, with mean of 8.47 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of iron, with mean of 1.231 mg/kg (Table 3). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 3. Extraction of Iron by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	5.89	9.905	7.41	5.385	1.865	6.091	2.94	48.34
DTPA	mg/kg	6.91	11.745	8.515	6.595	2.275	7.208	3.43	47.6
AB-DTPA	mg/kg	8.21	12.91	10.02	7.92	3.29	8.47	3.51	41.46
0.005 M Na-G	mg/kg	0.943	3.775	1.1	0.114	0.22	1.231	1.48	120
0.01M Na-G	mg/kg	1.23	4.38	1.71	0.254	0.223	1.559	1.70	109
0.015 M Na-G	mg/kg	1.395	5.22	2.525	0.439	0.492	2.014	1.98	98.4
0.02 M Na-G	mg/kg	1.96	6.17	3.73	0.667	0.612	2.628	2.35	89
0.025 M Na-G	mg/kg	2.285	6.765	4.48	1.815	0.777	3.225	2.4	74.32
0.03 M Na-G	mg/kg	2.295	7.715	5.01	2.225	0.932	3.629	2.73	75.1

Zinc Extraction

EDTA has extracted the highest amount of zinc, with mean of 2.193 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of zinc, with mean of 0.551 mg/kg (Table 4). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was EDTA > AB-DTPA > DTPA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate. Same results were obtained by Falatah *et al.* (1998) who reported that zinc extracted by four soil tests was in the order: EDTA> AB-DTPA> DTPA> $MgCl_2$. AB-DTPA soil test extracts slightly higher levels of Zn than the DTPA soil test (Havlin and Sultanpour, 1981).

Table 4. Extraction of Zinc by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	1.03	1.96	2.91	4.32	0.742	2.193	1.48	67.56
DTPA	mg/kg	0.521	1.534	1.99	3.575	0.401	1.604	1.29	80.5
AB-DTPA	mg/kg	0.636	1.712	2.35	3.928	0.486	1.822	1.41	77.2
0.005 M Na-G	mg/kg	0.197	0.433	0.631	1.32	0.176	0.551	0.46	83.8
0.01M Na-G	mg/kg	0.29	0.540	0.742	1.737	0.191	0.7	0.62	88.4
0.015 M Na-G	mg/kg	0.348	0.635	0.812	2.11	0.211	0.823	0.75	91.13
0.02 M Na-G	mg/kg	0.376	0.740	1.255	2.50	0.250	1.024	0.91	89.2
0.025 M Na-G	mg/kg	0.411	1.002	1.705	2.99	0.283	1.278	1.11	86.9
0.03 M Na-G	mg/kg	0.487	1.31	1.91	3.41	0.365	1.496	1.29	83.02

Manganese Extraction

AB-DTPA has extracted the highest amount of mangenese, with mean of 15.592 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of manganese, with mean of 9.652 mg/kg (Table 5). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 5. Extraction of Manganese by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	7.725	19.97	18.07	8.98	14.835	13.916	5.42	38.95
DTPA	mg/kg	9.05	20.695	19.225	9.195	15.33	14.699	5.45	37.08
AB-DTPA	mg/kg	9.92	21.51	20.35	9.95	16.23	5.592	5.52	35.43
0.005 M Na-G	mg/kg	3.99	12.55	14.655	5.855	11.21	9.652	4.54	46.99
0.01M Na-G	mg/kg	4.625	13.1	15.175	6.64	11.63	10.234	4.44	43.4
0.015 M Na-G	mg/kg	5.25	14.025	15.68	7.01	12.09	10.811	4.5	41.6
0.02 M Na-G	mg/kg	5.785	14.91	16.19	7.50	12.655	11.408	4.6	40.07
0.025 M Na-G	mg/kg	6.355	15.475	16.84	8.05	13.42	12.028	4.6	38.32
0.03 M Na-G	mg/kg	7.13	16.235	17.655	8.605	14.02	12.729	4.65	36.5

Lead Extraction

AB-DTPA has extracted the highest amount of lead, with mean of 4.116 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of lead, with mean of 2.226 mg/kg (Table 6). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 6. Extraction of Lead by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	0.09	1.05	4.35	11.09	0.99	3.514	4.53	129.1
DTPA	mg/kg	0.11	1.13	4.89	11.50	1.09	3.744	4.71	125.7
AB-DTPA	mg/kg	0.14	1.28	5.08	12.8	1.28	4.116	5.2	126.34
0.005 M Na-G	mg/kg	0.009	0.11	2.09	8.83	0.09	2.226	3.22	144.72
0.01M Na-G	mg/kg	0.013	0.29	2.73	9.11	0.21	2.471	3.87	156.62
0.015 M Na-G	mg/kg	0.029	0.51	2.85	9.50	0.49	2.676	3.97	148.36
0.02 M Na-G	mg/kg	0.035	0.69	3.09	9.83	0.61	2.851	4.07	142.87
0.025 M Na-G	mg/kg	0.042	0.75	3.57	10.05	0.72	3.03	4.15	137.12
0.03 M Na-G	mg/kg	0.059	0.99	3.93	10.49	0.83	3.26	4.3	131.98

Nickel Extraction

AB-DTPA has extracted the highest amount of nickel, with mean of 0.504 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of nickel, with mean of 0.292 mg/kg (Table 7). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 7. Extraction of Nickel by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	0.215	0.349	0.349	0.93	0.315	0.432	0.28	65.2
DTPA	mg/kg	0.221	0.375	0.361	0.99	0.339	0.457	0.30	66.2
AB-DTPA	mg/kg	0.232	0.408	0.508	1.016	0.358	0.504	0.28	55.9
0.005 M Na-G	mg/kg	0.107	0.207	0.185	0.764	0.197	0.292	0.27	91.4
0.01M Na-G	mg/kg	0.139	0.239	0.213	0.781	0.231	0.321	0.26	81.1
0.015 M Na-G	mg/kg	0.152	0.251	0.253	0.795	0.253	0.341	0.26	75.4
0.02 M Na-G	mg/kg	0.175	0.263	0.285	0.832	0.261	0.363	0.26	73.1
0.025 M Na-G	mg/kg	0.193	0.286	0.307	0.859	0.275	0.384	0.27	70.1
0.03 M Na-G	mg/kg	0.201	0.307	0.331	0.87	0.297	0.401	0.27	66.5

Chromium Extraction

AB-DTPA has extracted the highest amount of chromium, with mean of 0.128 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of chromium, with mean of 0.065 mg/kg (Table 8). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 8. Extraction of Chromium by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	0.015	0.039	0.141	0.321	0.031	0.109	0.13	118
DTPA	mg/kg	0.019	0.047	0.153	0.337	0.037	0.119	0.132	111.7
AB-DTPA	mg/kg	0.02	0.054	0.166	0.356	0.042	0.128	0.14	108.8
0.005 M Na-G	mg/kg	0.003	0.007	0.067	0.241	0.005	0.065	0.103	157.9
0.01M Na-G	mg/kg	0.006	0.011	0.081	0.257	0.009	0.079	0.11	143.8
0.015 M Na-G	mg/kg	0.007	0.014	0.093	0.271	0.013	0.08	0.11	141.6
0.02 M Na-G	mg/kg	0.009	0.019	0.107	0.285	0.019	0.088	0.12	132.6
0.025 M Na-G	mg/kg	0.011	0.025	0.119	0.299	0.023	0.095	0.12	128.4
0.03 M Na-G	mg/kg	0.013	0.031	0.127	0.311	0.027	0.1	0.13	126.7

Cadmium Extraction

EDTA has extracted the highest amount of cadmium, with mean of 0.082 mg/kg and 0.005M sodium gluconate has extracted the lowest amount of cadmium, with mean of 0.026 mg/kg (Table 9). As we increased the molarity of sodium gluconate (Na- G), its extractability was also increased. The order of extractability was EDTA > DTPA > AB-DTPA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

Table 9. Extraction of Cadmium by different chelates.

Extractants	Unit	Locations					Mean	S.D	CV(%)
		Daud zai	Monacro	Shinwar Town	Imran Abad	Wakel Kala			
EDTA	mg/kg	0.057	0.083	0.089	0.168	0.015	0.082	0.06	69.7
DTPA	mg/kg	0.042	0.079	0.084	0.159	0.009	0.075	0.06	73.5
AB-DTPA	mg/kg	0.038	0.07	0.078	0.136	0.006	0.066	0.05	73.7
0.005 M Na-G	mg/kg	0.001	0.031	0.029	0.069	0.001	0.026	0.03	114.8
0.01M Na-G	mg/kg	0.005	0.039	0.035	0.081	0.001	0.032	0.03	95.5
0.015 M Na-G	mg/kg	0.011	0.047	0.043	0.093	0.001	0.039	0.04	94.2
0.02 M Na-G	mg/kg	0.018	0.053	0.051	0.115	0.002	0.048	0.04	90.7
0.025 M Na-G	mg/kg	0.025	0.059	0.063	0.121	0.003	0.054	0.05	84.4
0.03 M Na-G	mg/kg	0.031	0.065	0.071	0.129	0.005	0.06	0.05	78.5

Summary

The study was conducted to compare different chelates as soil extractants and to get a better and cheaper extractant. A total of 5 samples were collected at different sites surrounding the Peshawar city, from 0-30 cm depth and analyzed for soil chemical properties, micronutrients and heavy metal contents of soil.

The data showed that pH ranged from 7.50 to 8.52 with a mean value of 7.972. The data showed that the soil was alkaline in nature. Electrical conductivity ranged from 0.194 ds/m to 0.33 ds/m with a mean value of 0.227 ds/m. The data showed that the soil was non-saline. Organic matter ranged from 0.98 % to 2.01 % with a mean value of 1.44 %. Organic matter was high at Monacro, while the rest of samples ranged from low to medium, being medium in 40% samples.

The data on comparison of various chelates as soil extractants showed that AB-DTPA is the best soil extractant for all micronutrients and heavy metals except zinc and cadmium which were found to be extracted more by EDTA method. The order of extractability for Cu, Fe, Mn, Pb, Ni and Cr was AB-DTPA > DTPA > EDTA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate. The order of extractability for Zn is EDTA > AB-DTPA > DTPA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate. The order of extractability

for Cd is EDTA > DTPA > AB-DTPA > 0.03M sodium gluconate > 0.025M sodium gluconate > 0.02M sodium gluconate > 0.015M sodium gluconate > 0.01M sodium gluconate > 0.005M sodium gluconate.

CONCLUSIONS

The following conclusions were drawn from the present piece of research work.

- The pH of all soil samples was alkaline in nature
- EC of soil samples showed that the soil was non saline.
- Organic matter was found adequate in only 20% samples.
- All the chelates used can effectively extract nutrients but AB-DTPA is the most effective extractant.
- Sodium Gluconate extracted the least but an increase in trend was observed by increasing the molarity.
- EDTA is the most effective extractant for zinc and cadmium.
- AB-DTPA is the best extractant for majority of micronutrients and heavy metals.
- Sodium Gluconate is a cheaper chelate and can extract nutrients effectively, if the molarities double than that in present study is used.

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