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Chemical Remediation of Sludge by Lime and Their Effect on Yield and Chemical Component of Wheat

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Abstract: Two field experiments were carried out at El-Gabal El-Asfar waste water treatment plant during two successive growing seasons to evaluate and assess the chemical remediation of sludge on the yield and chemical composition of wheat. Results observed that application of chemical fertilizer increased both grains and straw of wheat as compared with the control soil .It was noticed that application of sludge at rates of 10 and 20 m^3.fed gradually increased both grains and straw by about 59, 74 and 47, 52% for grains and straw as compared with chemical fertilizer respectively. Data also, noticed that chemical remediation of sludge by burnt lime at a rate of 10 m^3 $fed.^{-1}$ decrease the yield production of wheat for both grains and straw as compared with the untreated sludge. An average of decrease were 13% and 17% respectively. Such phenomenon may relate to the chemical remediation process, since application of burnt lime to sewage sludge may destroy the organic material as will as nitrogen. Results also, revealed that chemical remediation still enhanced the yield production of both grains and straw as compared with chemical fertilizer by about 39, 52, 21 and 33 % for both grains and straw at a rare of 10 and 20 m^3. $fed.^{-1}$, respectively. Application of farmyard manure had slightly effect on the yield production of wheat for both grains and straw as compared with the untreated sludge. An average of increased were about 25%, 7% and 11%, 13%at both rates of 10 and 20 m^3 $fed.^{-1}$, respectively. Data also, observed that both sludge chemical remediation of sludge and farmyard manure increased, crop index, harvest index and grain/straw ratio as compared with chemical fertilizer. Data noticed that the total content of NPK in both grain and straw influenced by adopted treatments reflecting the magnitude variation due to different sources of organic material. It was noticed that chemical remediation of dry sludge had a pronounced effect on the reduction of Pb concentration in both grains and straw by about 73%, 78%and 46% and 61% of both two rates as compared with untreated sludge. Similar trend were observed in case of farmyerd manure.

Key words: Chemical fertilizer, chemical remediation of sludge, farmyard manure, wheat, Yield production, NPK content - heavy metal

INTRODUCTION

High increased food demand in Egypt implies more production of carbohydrate and protein containing crops,(i.e. cereal and leguminous).wheat (*triticum aestivum L*) is one of the main cereal crop cultivated in Egypt. Most of the yield is coming from the fertile clay soil in the Nile Valley and Delta. Recently plans are made to increase the production of wheat through horizontal expansion in desert and reclaimed sandy soils to face the increasing demand for grain production.

Sludge arising during the treatment of municipal waste presents a valuable source of organic matter, nitrogen, phosphorus, potassiumand some trace elements. The fact that waste treatment plant (WTP) are localized in the suburbs of towns and village in close vicinity of intensively used soil offers the possibility of an pratical solution for utilizing surplus sludge in agriculture. However, besides positive aspects, there are also certain risk factors. One of the most significant risk is the presence of toxic heavy metals performs viruses, bacteria and parasites which are of important from the view point of hygiene, epidemiology and epizootiology[1-4]. Bioavailability of metals to plants are typically greater in acidic than alkaline conditions. A range of liming materials are available, which variable in their ability to neutralize the acidity and immobilize metals. These include calcite ($CaCO_3$), burnt lime (CaO), slaked lime ($Ca(OH)_2$). Liming is increasingly being practical as a management tool to immobilize heavy metals in soils, bio-solids and mine tailing, thereby reducing their availability for plant uptake and transport to ground water [5-6-7].

In fact alkalinization of biosolids is commonly done to enhance their immobilization potential for metals [8-9]. Several reasons have been attributed to the lime-induced immobilization of metals: increases in negative charge (CEC), formation of strongly bound hydroxyl metal species; precipitation of metals as hydroxides; and sequestraction due to enhanced microbial activity. The net effect of liming on metal transformation in these soils depends on the relative changes in the pH and the increase in the concentration of Ca^{++} added through liming. For example, the uptake of lead (Pb) is often found to decrease with liming, which attributed to increased adsorption precipitation at high pH[10-11].

Precipitation appears to be predominant process of metal immobilization in alkaline condition of anions such as sulfate, carbonate, hydroxide and phosphate especially when the concentration of metals ions is high[7].

The use of farmyard manures and other forms of organic matter can also change plant available

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micronutrients by changing both the physical and biological characteristics of the soil. Mikhaeel *et al*[12] and Abou Seeda[13] showed that incorporation of organic manures into soil enhanced plant growth as indicated by increases in shoot dry weight, N and P uptake and composted sewage sludge was the superior manure, while town refuse the least influence. Zeidan *et al*[14] indicated that the application of organic fertilizer at the rate of 20 m^3 fed^{-1} significantly increased plant height, leaf area and 1000-grain weight of wheat plants. The highest spikelets/ spike; number of grain /spike grain yield ardab/fed and nutrient uptake kg/fed were recorded when composted sewage sludge was used at the rate of 20 m^3 fed^{-1}. The objective of the investigated research is to evaluate and assess the chemical remediation of sludge by using burnet lime and their effects on the yield production, chemical component and heavy metals content in wheat.

MATERIALS AND METHODS

Two field experiments were carried out during two successive growing seasons of 2003-2004 and 2004-2005 at experimental Station of El-Gabal El-Asfar Kalubia governorate to evaluate and assess the chemical remediation of sludge on the yield and chemical composition of wheat grown in sandy soil. The investigated soil characterized by pH 7.34, Ec 0.37 dSm^{-1}, OM 0.27 %, CEC 4.90 $mol.kg^{-1}$ 100 g soil, total N 259 ppm, available P 1.02 ppm, Sand 96.10 %, Silt 2.90 %, Clay 1.00 % and $CaCO_3$ 0.45 %. Chemical and physical properties of the investigated sludge and farmyard manure were analyzed in Table 1.

The experiments were led in a randomized complete block design with four replicates, area of each plot was 18.0m^2 (six rows 6meter in long and 50cm apart), the plots were separated by borders of 1.5m in width. Wheat (*triticum aestivum L*) cv Giza168 were planted on the second week of November at a rate of 60kg/fed in both seasons. the experiment included the following eight treatments:

1. Control
2. fertilized with NPK (recommended rate)
3. sludge 10 m^3 $fed.^{-1}$
4. sludge 20 m^3 $fed.^{-1}$
5. sludge 10 m^3 $fed.^{-1}$ treated with 2.5 % CaO
6. sludge 20 m^3 $fed.^{-1}$ treated with 2.5 % CaO
7. FYM 10 m^3 $fed.^{-1}$
8. FYM 20 m^3 $fed.^{-1}$

The normal cultural practices for growing wheat were followed as recommended by the extension service in the region. Phosphorus and potassium fertilizers were added to the soil before sowing at a rate of 30 kg P_2O_5 and 24 kg K_2O fed^{-1} as superphosphate and potassium sulfate, respectively. Ammonium nitrate was applied at a rate of 100 kg N $fed.^{-1}$. At harvest, grain and straw yields/ fed and above ground biomass per feddan (biological yield) were determined from the four middle rows of each plot, where, crop index and harvest index were calculated according to the following equations:

Crop index = grain /straw x 100
Harvest index = grain / Biological yield x 100

Total N, P, K and heavy metals were determined in both grains and straw according to the method described by Bremnar and Mulvaney[15] and Cottenie *et al*[16] respectively. The obtained results were subjected to appropriate statistical analysis according to Gomez and Gomez[17]**.** The combined analysis was conducted for the data of two seasons according to Cochran and Cox[18]**.** The least significant difference (LSD) test was used to compare the means at 5% level of probability

RESULTS AND DISCUSSIONS

Yield production: The effect of sludge, farmyard manure and chemical remediation of sludge treated soil on the yield production of wheat is presented in Table 1. Results observed that chemical fertilizers increased the yield production of both grain and straw as compared with control. It was noticed that application of sludge at a rate of 10 m^3 $fed.^{-1}$ increased the grain and straw by about 172 and 131 % relative to the control. Results also showed that application of sludge at 10 and 20 m^3 $fed.^{-1}$ gradually increase the grain and straw yield by about 59, 73, 37 and 52 % as compared with chemical fertilizers, respectively. Cameron *et al*[19] and Abou Seeda[13] stated that organic wastes such as sludge are valuable source of plant nutrients especially N, P and organic substrates, and may therefore, affect the physical, chemical and biological properties of soil They also reported that under lab and field experiments N-mineralization rate and microbial biomass have been shown to increase after a single application of sludge. Similar results were observed by Zaman *et al*[20-21]**.** Also, it was observed that chemical remediation of sludge by burnt lime (CaO) decrease the yield production of wheat for both grain and straw as compared with untreated sludge at same rate. An average of decreased were 12 and 17 % for both grain and straw as compared with untreated sludge. Such phenomena may relate to the chemical remediation process, since application of burnt lime to sewage sludge creates much heat to the contact reaction according the following equation:

$$CaO + H.OH \rightarrow Ca(OH)_2 + heat$$

The reaction will slightly destroy the organic material and also to decrease the total N-borne sludge. Logan and Harrison[22] examined the value of a commercial alkaline biosolids product called N-viro soil, produced by heat treatment of a mixture of burnt lime and municipal sewage sludge. Such alkaline material are effective in reducing the acidity produced during the nitrification of NH_4^+ in biosolids, thereby reducing the bioavailability of both nitrogen and heavy metals. We hypothesize that the plant, directly or indirectly, could heavily influence of certain soil amendments when employed to accelerate natural remediation. Results also revealed that chemical remediation of investigated sludge still enhance the yield production of both grain and straw as compared with chemical fertilizers, an average of increases were 39, 52, 21 and 33% for both grain and straw at a rate of 10 and 20 m^3 $fed.^{-1}$, respectively.

Data in Table 2. noticed that application of farmyard manure had slightly effect on the yield of both grain and straw. Venglovsky *et al*[4] stated that organic fertilizer in

Table 1: Some properties of sewage sludge and Farmyard manure used.

Characteristics	pH	EC dSm^{-1}	Total solids %	OM %	Total (%)			DTPA extractable elements (ppm)			
					N	P	K	Pb	Cd	Ni	Cr
Sewage sludge	6.95	4.01	88.68	56.38	2.3	0.35	0.96	427	34	47	16
Farmyard manure	7.4	2.5	-	60.2	1.50	0.31	0.4	120	11	14	6

Table 2: Effect of sludge, farmyard manure and chemical remediation of sludge by burnt CaO on Grain (ton/fed), Straw (ton/fed), crop index and harvest index (average for two seasons).

Treatments	Rate m^3/fed	Grain ton/fed	Straw ton/fed	Biological yield	crop index	harvest index	Grain/straw
Control	-	0.521	1.558	2.079	33.4	25.0	0.33
NPK	RR	0.889	2.447	3.336	36.3	26.6	0.36
Sludge	10	1.416	3.599	5.015	39.3	28.2	0.39
	20	1.545	3.743	5.288	41.3	29.2	0.41
Sludge+CaO	10	1.238	2.973	4.211	41.6	29.3	0.41
	20	1.354	3.276	4.630	41.1	29.2	0.41
FYM	10	1.557	3.988	5.545	39.0	28.1	0.39
	20	1.652	4.234	5.886	39.0	28.1	0.39
LSD 5%	T	0.313	0.281	0.587	-	-	-
	R	0.256	0.234	0.452	-	-	-
	T x R	0.244	0.216	0.432	-	-	-

FYM: farmyard manure, T: treatment, R: rate, TxR: treatment x rate, RR: recommended rate,

Table 3: Effect of sludge, farmyard manure and chemical remediation of sludge by burnt CaO on NPK content in grains and straw (average for two seasons).

Treatments	Rate m^3/fed	N-content %		P- content %		K- content %	
		grain	straw	grain	straw	grain	straw
Control	-	0.97	0.61	0.69	0.41	1.36	1.22
NPK	RR	2.19	0.64	0.71	0.45	1.47	1.45
Sludge	10	2.33	0.68	0.74	0.48	2.63	1.55
	20	2.47	0.78	0.89	0.51	3.21	1.78
Sludge+CaO	10	2.12	0.70	0.72	0.47	1.51	1.51
	20	2.31	0.73	0.74	0.60	1.52	1.53
FYM	10	2.41	0.66	0.73	0.46	2.49	1.51
	20	2.48	0.69	0.74	0.49	2.65	1.61
LSD 5%	T	0.21	0.05	NS	0.07	0.39	NS
	R	0.18	0.04	NS	NS	0.34	NS
	T x R	NS	NS	NS	NS	NS	NS

FYM: farmyard manure, T: treatment, R: rate, TxR: treatment x rate RR*: recommended rate

all cases improves the cropping with the highest average yield being obtained from plots that receiving farmyard manure. Tawfik and Gomaa[23] indicated that application of organic fertilizer greatly increased all growth parameters, grain yield and protein contents of the grain . the added that the highest yield and yield components recorded by wheat plants fertilized with 20 m^3 $fed.^{-1}$. This results may be attributed to better growth under favourable physical, chemical and biochemical condition and also can be related to the beneficial effect of organic matter which containing a considerable amounts of nutrient elements for plant growth[24].

Data in Table 2 illustrated that harvest index, crop index and grain/straw ratio can be affected by sludge, chemical remediation of sludge and farmyard manure. It was observed that application of sludge and farmyard manure increased crop index, harvest index and grain/straw ratio as compared with control and chemical fertilizer.Results noticed that application chemical fertilizer increase the crop index by about 9%. Application of sludge at different rates gradually increases the crop index by about 17 and 23% as compared with control soil. Chemical remediation of sludge by CaO increases the crop index. Similarly was notice by farmyard manure. Similar trend noticed in the case of harvest index and grain /straw ratio.

Effect of sludge, farmyard manure and chemical remediation of sludge on chemical composition:

Macro-nutrients: Data in Table 3 and 4 presented that the concentration and the uptake of N, P and K by grain and straw of wheat plants. Results noticed that the total content of NPK in both grain and straw were influenced by adopted treatments reflecting the magnitude variation due to different sources of organic material sludge. Farmyard manure and chemical remediation of sludge were varying obvious. It was noticed that chemical fertilizer treatment had significantly effect on the concentration of NPK in grain and straw. Averages of increase of nitrogen 120 % as compared with control one.

Table 4: Effect of sludge, farmyard manure and chemical remediation of sludge by burnt CaO on NPK uptake in grains and straw (average for two seasons).

Treatments	Rate m^3/fed	N-uptake kg/fed		P-uptake kg/fed		K-uptake kg/fed	
		grain	straw	grain	straw	grain	straw
Control		5.05	9.50	3.59	6.38	7.08	19.01
NPK	RR	19.46	15.66	6.31	11.01	13.06	35.48
Sludge	10	32.99	24.47	10.48	17.27	37.24	55.78
	20	38.16	29.19	13.75	19.08	49.59	66.62
Sludge+CaO	10	26.36	20.81	8.91	13.97	18.69	44.89
	20	31.27	23.91	10.02	19.66	20.58	50.12
FYM	10	37.52	26.31	11.37	18.34	38.77	60.22
	20	40.97	29.22	12.22	20.75	43.78	68.17
LSD 5%	T	0.34	0.05	NS	0.07	0.39	NS
	R	0.27	0.04	NS	NS	0.34	NS
	T x R	NS	NS	NS	NS	NS	NS

FYM: farmyard Manure, T: treatment, R: rate, TxR: treatment x rate, RR: recommended rate

Table 5: Effect of farmyard manure, dry sludge and treated with CaO on heavy metals content in both grains and straw of wheat (average for two seasons).

Treatments	Rate m^3/fed	Heavy metal (mg/kg straw)				Heavy metal (mg/kg grain)			
		Pb	Cd	Ni	Cr	Pb	Cd	Ni	Cr
Control		1.90	5.14	3.22	1.94	1.15	1.44	0.90	0.80
NPK*	RR	2.70	5.17	2.57	2.18	1.45	1.78	0.95	0.76
Sludge	10	3.82	7.67	4.09	3.15	3.80	2.20	2.04	1.83
	20	6.05	9.31	5.86	5.29	4.43	3.98	2.15	2.19
Sludge+CaO	10	2.03	5.24	2.63	2.48	0.99	0.93	1.22	1.14
	20	2.33	3.47	2.21	2.05	1.13	0.62	0.91	0.56
FYM	10	4.58	5.13	2.97	1.94	1.27	1.34	0.76	0.82
	20	4.93	5.33	3.12	1.89	0.25	0.40	1.03	0.93
LSD at 5%	T	0.37	0.81	0.50	0.38	0.25	0.13	0.11	0.12
	R	0.32	NS	NS	0.33	0.21	0.11	0.09	0.11
	T x R	0.27	0.59	0.34	0.21	0.11	0.09	0.07	0.08

FYM: farmyard manure, T: treatment, R: rate, TxR: treatment x rate, RR*: recommended rate

This phenomenon may be due to the leachability of investigated elements. It was observed that application of sludge at 10 and 20 m^3 $fed.^{-1}$ generally increase the concentration of nitrogen in grain. Average of increase were 150 and 154 % as compared with control particularly for both two rates, respectively. The predominant effect of sludge due to the beneficial effect of organic material for enhancing the physical and chemical properties of the investigated soil creating a comfortable condition particularly in rhizosphere during the growing season, similar results were observed by[10,13,25].

Results also revealed that chemical remediation of sludge treated soil resulted in a reduction of nitrogen concentration in both grain and straw as compared with untreated sludge at both rates (10 and 20 m^3 $fed.^{-1}$). Adriano *et al*[11] stated that both nutrient NPK and some heavy metals concentration were decreased in finished product by lime stabilization. We hypothesize that after mixing of sludge with CaO slaking of the latter ran tanks to water contained in sludge. Increasing of temperature of the reaction mixture decreasing of the water content and strong increasing of pH (owing to Ca $(OH)_2$ forming) were observed consequently.

Under these conditions most of the available N in the organic matter (sludge) was gradually diminished besides the destruction of the organic nitrogen leaching for increasing the intensity of mineralization and nitrification process. Such process may decrease the available nitrogen content in the chemically treated sludge. It was noticed that application of farmyard manure at both rates stimulates the N-content in grains. This finding is in accordance with Zeidan *et al*[14]. Similar trends were observed in straw.

Results also noticed that application of untreated sludge stimulated the concentration of phosphorus in grain as compared with control. Chemichal fertilizer "superphosphate" had slightly effect on P-concentration in grain. Increasing a rate of dry sludge 20 $m^3.fed^{-1}$ increased the concentration in the grain due to increase its mobility by organic acid forming during the growing stages. It was observed that chemical remediation of sludge by CaO decrease the availability of phosphorus due to forming tri calcium phosphate which rather insoluble even under normal condition[13-24]. Application of farmyard manure had slightly effect on the concentration of phosphorus as compared with dry sludge due to the possibility of losing of phosphorus during collecting process. Similar trends were noticed in straw. Adriano *et al*[11] stated that nutrients particularly phosphorus was decreased its uptake by lime stabilization of sludge. Generally application of

investigated treatments increased the nutrients uptake this means that increasing of nutrients uptake as a result of application of treatments would resulted in a corresponding increase in both grain and straw of wheat.

Heavy metals: Effect of farmyard manure, dry sludge and treated sludge with CaO as a chemical remediation on heavy metals content in both grain and straw are presented in Table 5. from which it was observed that application of chemical fertilizer stimulated the concentration of some heavy metal due to the improvement of the root system, enhancing the absorption phenomenon. An average of increase was 40 % as compared with control soil. Results were observed that application of dry sludge at both rate (10 and 20 $m^3.fed^{-1}$) gradually increase Pb concentration in both grain and straw by about 230%, 285% and 218% at 10 and 20 $m^3.fed^{-1}$ as compared with control soil, respectively, due to heavy metal born in sludge[26].

It was observed that chemical remediation of dry sludge had a pronounced effect on the reduction of Pb concentration in both grain and straw by about 73, 78 % and 46, 61% at both rates (10 and 20 $m^3.fed^{-1}$) as compared with dry sludge. From the chemical point of view bioavailability of metals to the grown plants are typically in acidic than alkaline condition, neutralizing agent such as CaO are usually added to acidic sludge. Although the primary intensive in liming sludge is the suppression of toxic bioavailability heavy metals such as Pb. The net effect of liming on metal transformation in the sludge depends on the relative changes in the pH and the increase in the concentration of Ca^{++} ions added through liming, creating a reduction of Pb uptake which is attributed to increase adsorption/precipitation at high pH and competition between Pb and other cations for uptakes. Results also noticed that the transformation of Pb from shoot to the grain was gradually decreased; similar was observed by Adriano[7] and Adriano *et al*[11].

It was noticed that chemical remediation of sludge stimulate the reduction of heavy metal accumulation in grain. Results were observed that (sludge 10 $m^3.fed^{-1}$ + 2.5% CaO) decrease the translocation of the investigated elements " Pb, Cd, Ni and Cr" from straw to grain by about 59, 81, 11 and 80% for Pb, Cd, Ni and Cr, respectively. Increasing sludge (20 $m^3.fed^{-1}$) + 2.5 % CaO slightly decrease the translocation of heavy metals from straw to grain by about 28, 33, 6 and 21% as mentioned before, respectively. Results revealed that application of farmyard manure gradually decrease the accumulation of heavy metal, as might be expected the organic component has a high affinity for metal cations this of course due to the presence of legends or group that can chelate metals. Abou Seeda[13] Abou Seeda *et al*[24] they stated that increasing pH of the organic materials, the carboxyle, phynolic, alcoholic and carbonyl functionl groups in organic matter dissociate thereby increasing the affinity of ligand ions for metals cations. Similar finding reported by Adriano *et al*[11]

It was noticed that liming of dry sludge at both rates typically enhance the retention of metals increasing retention of Cr^{3+} with lime Binduced increase pH . The pH of lime treated sludge ranged from 7.30 B 9.85 which coincides with effective precipitation range for Cr^{3+} as $Cr(OH)_3$

$$CaO + H.OH \rightarrow Ca^{++} 3\ OH^- \quad (1)$$

$$Cr^{++} + H.OH \rightarrow Cr^{3+} 3\ (OH)^{3-} \quad (2)$$

Thus the retention of Cr^{3+} induced by lime is likely due to the $Cr(OH)_3$ formation. Mc-Bride[6] stated that increasing in pH due to liming could also increase the negative charges of variable charge soil which enhancing Cr^{3+} adsorption. Also Adriano *et al*[11] they stated that application of lime incorporated into contaminated soils speed up and optimize, in the case of metals, their immobilization as mediated by key processes such as (ad) sorption, precipitation and complexation. Hsiau and Lo[8] stated that alkalinization of biosolids "sludge" is commonly done to enhance their immoboloiation potential for metals.

Conclusions: It could be concluded that . Application of sludge at different rates stimulated the yield production of wheat .Chemical remedation sliightly decreased yield, however farmyard manure gradually increased yield.Chemical remedaiation of sludge treated soil decreased the accumilation of heavey metalscontent in grains.

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