TRACE METAL ANALYSIS OF SEWAGE SLUDGE AND SOILS IN BAHRAIN

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Abstract. Trace metals such as Pb, Zn, Cu, Ni, Cd and Fe were determined in sewage sludge produced at a sewage treatment plant in Bahrain (Tubli) and soils. The soils, both untreated and treated with the sludge, are used for agricultural purposes in Bahrain. The Trace-metals level showed the following range (μg g^{-1} dry weight); Pb, 242 to 609; Zn, 704 to 836, Cu, 329 to 512; Ni, 23 to 41; Cd, 1.8 to 3.9 and Fe, 1867 to 4284. The data show the degree to which untreated soils have already been contaminated with trace elements. The level of trace-elements found in sludge showed the following range (μg g^{-1} dry weight); Pb, 140 to 186; Zn, 597 to 836; Cu, 348 to 449; Ni, 47 to 53; Cd 5.7 to 9.2 and Fe, 5950 to 8520. Mean levels were generally close or lower than mean concentration reported in the United Kingdom and the United States for sludge. They were also lower than the suggested concentration limits for application of sludge on agricultural land, which is one of the most cost effective and attractive techniques for sludge disposal. Soils treated with this sludge (after 1 yr) were also analyzed and showed substantial enhancement of the available level of trace elements in the soil. This eventually will lead to an increase in the trace-element level in plants grown for human or animal consumption. This could have phytotoxic effects, and the possibility of toxic effects on live-stocks and human beings.

1. Introduction

Urbanization and the resulting population centers are exerting an ever – increasing demand on technology for procedure to manage municipal wastes in an environmentally safe and acceptable manner (Davis, 1984). The awareness of the need to reuse, when possible, resources contained in wastes has led to an intense interest in the application of municipal sewage sludge to agricultural land. This procedure has been shown to be beneficial to crop growth because of the essential plant nutrients contained in sludges. However, concern regarding the harmful effects of toxic chemicals and/or pathogenic organisms present in municipal wastes, to human consuming food produced on sludge – amended land has led to great anxiety about these procedures (Sommers, 1980; Davis, 1984; Purves, 1985).

The application of municipal sewage sludges on agricultural land is receiving increased emphasis because of environmental and economical constraints associated with alternatives disposal methodologies. The most beneficial use of sewage sludge involves the application to soils at a rate consistent with nutrient utilization by the crops. In addition to essential plant nutrients, sludges contain elements which are non-essential or potentially toxic not only to crops but also to animals and human consuming the plant production. Several studies have been published showing data on the metal concentrations found in sewage sludges (Doty *et al.*, 1977; Page, 1974; Sommers *et al.*, 1976; Silvera and Sommers, 1977; Sommers, 1980; William, 1983; Webber *et al.*, 1984; Purves, 1985; Samhan and Ghobrial, 1987). It is readily

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apparent from the available data that a typical sewage sludge does not exist from the standpoint of metal content.

The chemical species of metals present in sewage sludge applied to soils undoubtedly influences subsequent availability of metals to plants. Unfortunately, the metal species existing in sludges have not been adequately characterized. Several studies indicate that variations in the chemical forms of metals occur in different sludges (Sommers, 1980; William, 1983; Davis, 1984; Webber *et al.*, 1984; Purves, 1985). Additional research is needed to define the metal species, both soluble and insoluble existing in different sewage sludges and their effect on controlling the relative availability of metals to plants following applications to soils. In addition, there is adequate evidence that applications of sewage sludge to agricultural land does lead to substantial enhancement of the available levels in the soil of a number of potentially toxic elements (Sommers, 1980; William, 1983; Webber *et al.*, 1984, Davis, 1984; Purves, 1985; Page, 1974).

The objective of this study is to analyze the trace-metals such as Pb, Zn, Cu, Ni, Cd and Fe in sewage sludge and soils of Bahrain. The sludge analyzed in this work is produced at the main wastewater treatment plant in Bahrain (Tubli). The Tubli sewage treatment plant treats sewage pumped from four main areas: Manama, Isa Town, Sanabis and Hamad Town (detailed information on state of Bahrain is reported elsewhere; see ref. Madany, *et al.*, 1986). The plant has an average daily flow of 70 000 m^3 d^{-1}. The Tubli plant employs a two-stage activated sludge system for sewage treatment. Sludge is digested anaerobically and then subjected to further gravity thickening before it is dewatered on drying beds, producing 2000 to 5000 kg of dried sludge per day.

2. Experimental Section

Samples of sludges were collected in a polyethylene bags from Tubli sewage treatment plant. These samples were 1 d, 1 week, 1 mo, 6 mo, and 1 yr old. Soil samples were collected from various agricultural lands in Bahrain.

Samples were also analyzed where sludge had been applied (for 1 yr). All the samples were ground and dried at 100 °C for at least 3 hr. If the samples were not dried enough, they were left for another 2 or 3 hr. One half g of each sample were taken in a crucible pre-washed with dilute HNO_3 and then rinsed several times with doubly distilled deionized water. One hundred mL of double distilled deionized water and 12 mL of concentrated HNO_3 (research grade) were added to digest the sample. The samples were heated until the volume of the solution was approximately 0.5 mL. Samples were cooled to room temperature, and washed with double deionized water. Samples were filtered until a clear solution was obtained from each one. Each sample was analyzed in triplicate for Pb, Zn, Cu, Ni, Cd, and Fe, using atomic absorption spectrophotometer, SP-9-800 series by PYE-UNICAM. A Computerized Pu 9095 videographic furnace with autosampler, a PM 8251 Chart recorder and a Pu 9090 Data Computer, interfaced with the spectrophotometer, were used for analysis. Continuum source background correction was used wherever needed. For quality assurance, these analysis were also done using atomic absorption spectrophotometer AAS by Baird Atomic Ltd. Model No. Alpha 4 at Tubli plant. After each analytical run, the calibration curve was displayed on the screen and a visual check was made for linearity and replication. Prior to each analysis, the instruments were calibrated according to manufacturer's recommendations. All the standard solutions (1000 ppm) for Pb, Zn, Cu, Ni, Cd and Fe were certified and obtained from Fischer Scientific Company, USA. These solutions were diluted carefully to the required concentrations wth doubly deionized water. A 2% HNO_3 solution was used as a blank and analysed before each analysis to avoid matrix interferences. Both a graphite furnace and a flame were used to check the reproducibility and accuracy of the data.

3. Results and Discussion

The analysis of Pb, Zn, Cu, Ni, Cd and Fe in various types of soil collected from agricultural land from varous sites in Bahrain as reported in Table I. These soils were not treated with sewage sludge. These metals were also analyzed in sewage sludge as reported in Table II. In the as received conditions, all sewage sludge samples were dry except one. The drying time is from 1 d to 1 yr in open air. These sludges were also used as fertilizer on experimental site, named as Al-Buhair. After 1 yr of application of sludge, soil samples were taken from various points of the same site and were analyzed for Pb, Zn, Cu, Ni, Cd and Fe (Table I).

The concentration of Pb, Zn, Cu, Ni, Cd and Fe in various soils, in $\mu g\ g^{-1}$ are in the range, 242 to 609, 704 to 836, 329 to 512, 23 to 41, 1.8 to 3.9 and 1867 to 4284 respectively (Table I). These soils are used as agricultural land, where mostly chemical fertilizer are used. The data shows a significant variation in concentration of these trace-metals, as expected for soil composition, and it may vary as much as thousand fold (Sommers, 1980). A large proportion of the total number of atoms present is bound up in crystal lattice in minerals of the soil, and remains unavailable to plants until released by weathering. A further proportion of the atoms present will be combined in unavailable form in organic molecules in the soil. The concentration of the trace metals (Table I) are expected to be unchanged because of a little rain and hot and humid climate in Bahrain (Madany *et al.*, 1986, 1987).

The concentration of Pb, Zn, Cu, Ni, Cd and Fe in sewage sludge, in $\mu g\ g^{-1}$ are in the ranges of: 140 to 186, 597 to 836, 348 to 729, 47 to 53, 5.7 to 9.2 and 5950 to 8520, respectively (Table II). The concentration of these trace metals in sewage sludge and in soil is quite significant. The data in Table I shows that the degree to which soils have already been contaminated with the trace elements is already so high that one can only speculate about some of the possible consequences of the application of sewage sludge.

The concentrations of Pb, Zn, Cu, Ni, Cd and Fe in soil treated with sewage sludge, as reported in Table I, shows a substantial enhancement of the available

TABLE I

Trace metal concentrations of soils[a] obtained from various agricultural lands in Bahrain.

Sample No.[b]	Location	Metal concentrations, μg g^{-1} dry weight					
		Pb	Zn	Cu	Ni	Cd	Fe
1.	Al-Janabiah	242 ± 10(4.1)	783 ± 26(2.5)	362 ± 17(4.7)	34 ± 4(11.7)	2.4 ± 0.2(8.3)	1938 ± 119(6.1)
2.	Al-Budiya	344 ± 17(4.9)	762 ± 21(2.8)	422 ± 31(7.3)	30 ± 4(13.3)	2.8 ± 0.2(7.1)	2901 ± 140(4.8)
3.	Al-Quraiah	602 ± 21(3.5)	736 ± 21(2.8)	450 ± 32(7.1)	27 ± 3(11.1)	1.9 ± 0.3(15.8)	4284 ± 103(2.4)
4.	Buri	609 ± 23(3.8)	836 ± 31(3.7)	512 ± 27(5.3)	27 ± 4(14.8)	3.9 ± 0.4(10.2)	3695 ± 92(2.5)
5.	Bani Jamra	305 ± 11(3.6)	704 ± 26(3.7)	344 ± 19(5.5)	38 ± 4(10.5)	2.6 ± 0.2(7.7)	2568 ± 106(4.1)
6.	Sitra Village	472 ± 21(4.4)	810 ± 22(2.7)	329 ± 26(7.9)	41 ± 6(14.6)	3.6 ± 0.2(5.6)	2336 ± 107(4.6)
7.	Sar Village	269 ± 13(4.8)	814 ± 16(2.0)	335 ± 21(6.3)	23 ± 4(17.4)	1.8 ± 0.2(11.1)	1867 ± 112(6.2)
8.	Al-Buhair	264 ± 19(7.2)	716 ± 21(2.9)	324 ± 17(5.2)	31 ± 2(6.5)	2.1 ± 0.2(9.5)	4016 ± 170(4.1)
9.	Al-Buhair[c]	470 ± 27(5.7)	902 ± 27(3.0)	347 ± 21(6.0)	33 ± 2(6.0)	2.9 ± 0.2(6.9)	4819 ± 192(4.0)

[a] Without application of Sewage Sludge.
[b] Average of six analysis of each sample with standard deviations and Coefficient of variations in ( ).
[c] Soil treated with Sewage Sludge for one year.

TABLE II

Trace metal concentrations in sewage sludge.

Sludge[a]	% H_2O	Metal concentrations, μg g^{-1} dry weight					
		Pb	Zn	Cu	Ni	Cd	Fe
1 d old	57	140 ± 16(11.4)	823 ± 34(4.1)	348 ± 24(7.0)	48 ± 7(14.6)	7.2 ± 0.8(11.1)	6038 ± 152(2.5)
1 week old	29	142 ± 21(14.8)	836 ± 31(3.7)	350 ± 30(8.6)	47 ± 7(14.9)	7.6 ± 0.9(11.8)	5950 ± 116(2.0)
1 mo old	13	170 ± 14(8.2)	597 ± 40(6.7)	448 ± 37(8.2)	52 ± 8(15.4)	8.2 ± 0.7(8.5)	8520 ± 124(1.5)
6 mo old	12	173 ± 23(13.3)	672 ± 26(3.9)	419 ± 37(8.8)	50 ± 6(12.0)	8.1 ± 0.5(6.2)	6132 ± 173(2.8)
1 yr old	12	186 ± 23(12.4)	729 ± 41(5.6)	380 ± 31(8.1)	53 ± 7(13.2)	9.2 ± 0.9(9.8)	7840 ± 182(2.3)
Wet sludge	96	143 ± 24(16.8)	665 ± 33(5.0)	449 ± 36(8.0)	51 ± 8(15.7)	5.7 ± 0.9(15.8)	8200 ± 216(2.6)

[a] Average of six analysis of each sample with Standard deviation and Coefficient of Variation in ( ).

levels in the soil. The repeated applications of sewage sludge could drastically effect levels of trace-elements in soil in Bahrain, because of the weather conditions (Madany *et al.*, 1986). Table I shows a significant increase in Pb and Cd concentration, which could be dangerous because of its potential to reach an alarming level. However, it is difficult to establish a contaminating effect of sewage sludge when the soils to which it is applied are already contaminated with trace – metals from urban and industrial sources. These sources especially industries, contribute significantly to soil contamination (Madany *et al.*, 1986).

Levels of most metals in local sludge are lower than their levels in sludge from the United States and England (Sterritt and Lester, 1981; Reimers, 1983) but are comparable to levels in sludges from Sweden (Sjoqvist, 1984). These results reflect lower level of industrialization in Bahrain.

The levels of trace metals in local sludges are lower than suggested limits for application on agricultural land (Brantner, 1981; Webber *et al.*, 1984). However, the characteristics of the local soil and prevailing environmental conditions should be taken in to consideration (Samhan and Ghobrial, 1987). For example, levels of trace metals in local soil (Table I) are also lower than the suggested values (Brantner, 1981; Webber *et al.*, 1984). However, application of sewage sludge on these soils will enhance the metal concentration, as is shown in Table I. Furthermore, after several applications of sludge on this soil the trace elements will accumulate especially in hot and humid climate as in Bahrain, and it has to be monitored frequently.

It is clearly evident from the data, the extent to which the enhanced level in the contaminated soils lead to increased trace-element levels in plants grown for human or animal consumption. It is also evident that the increased trace-element uptake can lead to phytotoxic effects and the possibility of toxic effect on livestock and human beings.

4. Conclusions

The trace-metals such as Pb, Zn, Cu, Ni, Cd and Fe were analyzed in soil (untreated with sewage sludge), sewage sludge (both wet and dried at different times), and treated soil with sewage sludge. The data shows a high level of trace-metals in sludge, the fertilizer might inevitably lead to high level contamination of the soil. One cannot therefore, generalize about suitability of sludge as a fertilizer, since each batch produced must be judged on the basis of its trace-elements composition, and this may vary widely even in samples from a single sewage plant.

The possible consequence of contamination of soils, treated and untreated, are extremely difficult to assess. This paper is mainly concerned with pointing to the existence of a particular hazard in Bahrain which requires further attention and study.

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