International Journal of Environmental Science & Technology
Vol. 1, No. 4, pp. 295-300, Winter 2005

Using different amendments to reduce heavy metals movement in soils

[1*] R. Salmasi and [2]A. Tavassoli

[1]Research Center of Agriculture and Natural Resources of East Azarbayjan, Tabriz, Iran

[2]College of the Agriculture, Islamic Azad University, Karaj Branch, Karaj, Iran

Abstract

With long-term use of sewage waste, heavy metals can accumulate to phytotoxic levels and resulted in reduced plant growth and/or enhanced metal concentrations in plants, as a result food chain. If these metals penetrate too rapidly in a particular soil, especially with high water table, they can pollute ground water supplies. The aim of this research is prevention of movement of waste water-borne heavy metals in soils of southern parts of Tehran. These waste waters are used for irrigation of agricultural lands at southern regions since many years ago. For this purpose, 6 soil samples from southern parts of Tehran city and 2 ones from Zanjan city without lime and organic matter were selected. In laboratory, sorption capacities of the soils for Ni, Cd and Pb were compared with those of calcite, Na-bentonite, zeolite, illite and hematite amendments. The method was carried out by equilibration of known quantities of these adsorbents and soils with solutions containing these elements. The results showed that among the 5 amendments, calcite and Na-bentonite had the greatest sorption percentages of the 3 elements and illite had the least one. The retention capacity of calcite and Na-bentonite for Cd was highest in all 8 soils. However, retention capacities of these 2 minerals for Pb and Ni were higher than those of loamy soils without lime and organic matter and also sandy soils. Because of abundance and low price of calcite, this amendment is preferred to Na-bentonite. Therefore, calcite is recommended for adding to soils with low sorption capacity of Ni, Cd and Pb.

Key words: *Heavy metals, movement, sewage waste, amendments, sorption*

*Corresponding Author, E-mail: raminsalmasi@yahoo.com

Introduction

One of the most important problems in cities is disposal or recycling of solid and liquid wastes with industrial or urban sources. Water conservation and reuse, plants nutrients supply, surface water pollution from waste disposal, air pollution from waste combustion and little burial place, have been resulted to study the correct way of using waste disposal. One way that has been recently attended, is using sewage waste (sludge and effluent) in agricultural lands as irrigation water, fertilizer and soil amendments. Not withstanding these, with long-term usage of sewage waste, heavy metals may accumulate to phytotoxic levels in soils and resulted in reduction of plant growth and/or enhanced metal concentrations in plants, when such plants were consumed by animals can enter the food chain (Chaney, 1994). If these metals move too rapidly in a particular soil, they can pollute ground water supplies, especially in areas with high water Tables. While it has generally been assumed that these metals are retained in agricultural soils (McBride, 1995), some factors that reduce their retention and therefore enhance their mobility, can result in more plant uptake or leaching of these metals to ground water. These factors include the properties of the metals, soil texture, pH and competing cations in the soil solution. Dowdy and Volk (1984), in an extensive review of heavy metal movement in sewage sludge-treated soils, concluded that movement most likely occurred where heavy disposal of sewage sludge was made on sandy, acidic and low organic matter soils, receiving high rainfall or irrigation water. Smith (1991) showed evidence of such movement in a sandy soil treated with sewage sludge at intervals over a period of 25 years. Kuo, *et al*. (1985) observed that Cd retention was greater in fine-texture soils with high CEC than in coarse textured soils with lower CEC, while McBride (1995) noted that heavy metal retention was most closely associated with metal-organic complexation and soil pH. Investigations by a number of workers on the movement of heavy metals in soils tend to show that metals added to the soils in wastes particularly in sewage sludge, accumulate on or very near to the surface layers of the soils (McBride, 1995). There is little other evidence to suggest that only a very small percentage of sludge-borne metals leach into the ground water if soil pH is maintained above 6.2 (Sidle and Kardos, 1977 and Candelaria, *et al*., 1995). Anderson and Nielsion (1972) observed that after a 12-year disposal of 84 ton/ha. of sewage sludge to soils, practically all the Mn, Zn, Cu, Pb and Cd remained in the surface 0-20 cm. of the soil. Hinesly, *et al*. (1972) on the other hand noted that metals had moved down some 15 cm. in soil following a 3-year disposal of 166 tons/ha of sewage sludge. Van Erp and Van Lune (1991), in a 14-year study of sludge-amended soil, found that the concentrations of Cd and Zn in the leachate decreased over time, whereas Cu and Pb concentrations increased. In relation to amendments sorption for heavy metals, some of researchers reported that calcareous soils can adsorb heavy metals and reduce their mobilities in soil environment. For example, Artiolla and Fuller (1980) showed limestone spreading on soil surface, cause high sorption and low mobility of Cd and Ni, consequently. According to some of reports, clay minerals adsorb clay minerals considerably. However, some researches showed that clay minerals have low tendencies for adsorbing heavy metals (Gardiner, 1974). Puls, *et al.* (1988), reported that Ni has higher sorption than Cd by Na-bentonite. According to Bittel and Miller (1984), Pb sorption by illite is higher than Cd. With increased disposal of urban and industrial urban waste on agricultural lands, there is a need to understand further the retention of heavy metals in soil, especially those which are of particular concern because of their association with certain health problems.

Sewage wastes from different parts of Tehran city transfer to south areas of this city as 2 small rivers. Water deficiency at these this area is one reason to use wastewaters to irrigate about 6900 ha. of these agricultural lands. Because of sludge-borne metals of these waste waters, there is a question that how can reduce the metals movement in soils to control groundwater pollution owning to 70 years use of these wastes. One way is the application of different amendments. This study was conducted to evaluate use of different amendments to reduce the movement of Cd, Ni and Pb elements in soil profile. Location of this research was in southern parts of Tehran city in 1992.

Materials and Methods

Six soil samples were selected from surface depths (0-15 cm.) from southern parts of Tehran city. The year of research was 1972. Selected areas not receive sewage waste but were in adjacent to cultivated lands. 2 soil samples also selected from Zanjan city that did not have lime and organic matter. pH, EC, $CaCO_3$, gypsum, organic matter, saturated moisture and texture of all soil samples were measured in lab (Klute, 1986 and Page, 1982). To increase sorption capacity and reducing heavy metal movement in soils, lime (calcite), illite, hematite, Na-zeolite and Na-bentonite were used as soil amendments. To measure Ni, Cd and Pb sorption by these amendments and soils, 0.5 g from each amendment and soil poured in 250 ml. flask in 2 replicates and 50 ml. of 0.001 M. of each element was added to it. The concentration of each element in solution was equal to 70 years irrigation, because measured mean concentration of Ni, Cd and Pb in the sewage water samples was 0.034, 0.02 and 0.04 ppm. respectively. After adding the solutions, the samples were rest in reciprocal shaker for 2 hours. Finally flask contains were filtered and concentrations of the elements in filtrate were determined by Perkin Elmer model 560 atomic absorbtion.

Results

Some physico-chemical properties of soil samples are presented in Table 1. As the Table shows, the soil textures differ from sandy to clayey. Figure 1 shows Ni, Cd and Pb sorption percentages by the soils and the amendments. 1, 2, 3, 4, 5 and 6 are numbers of soil samples from south of Tehran city and 7 and 8 those from Zanjan. In Figure 2, 3 and 4 Ni, Cd and Pb sorption percentages are shown, respectively.

Discussion and Conclusion

According to Figure 1, there are apparent differences for the Ni, Cd and Pb sorption among amendments. Among the 5 amendments, calcite and Na-bentonite had the greatest sorption percentages of the 3 elements and illite had the least one. Sorption percentages of the 3 element by each of the amendments are also different. Na-zeolite, hematite and illite, had the most difference and calcite and Na-bentonite had the least one.

Figure 2 shows calcite and Na-bentonite have higher Ni sorption than 5 to 8 soils, but this sorption capacity do not differ with those of 1 to 4 soils. Consequently, calcite and Na-bentonite application to 5 to 8 soils increases their Ni sorption capacities. According to Figure 3, calcite and Na- bentonite

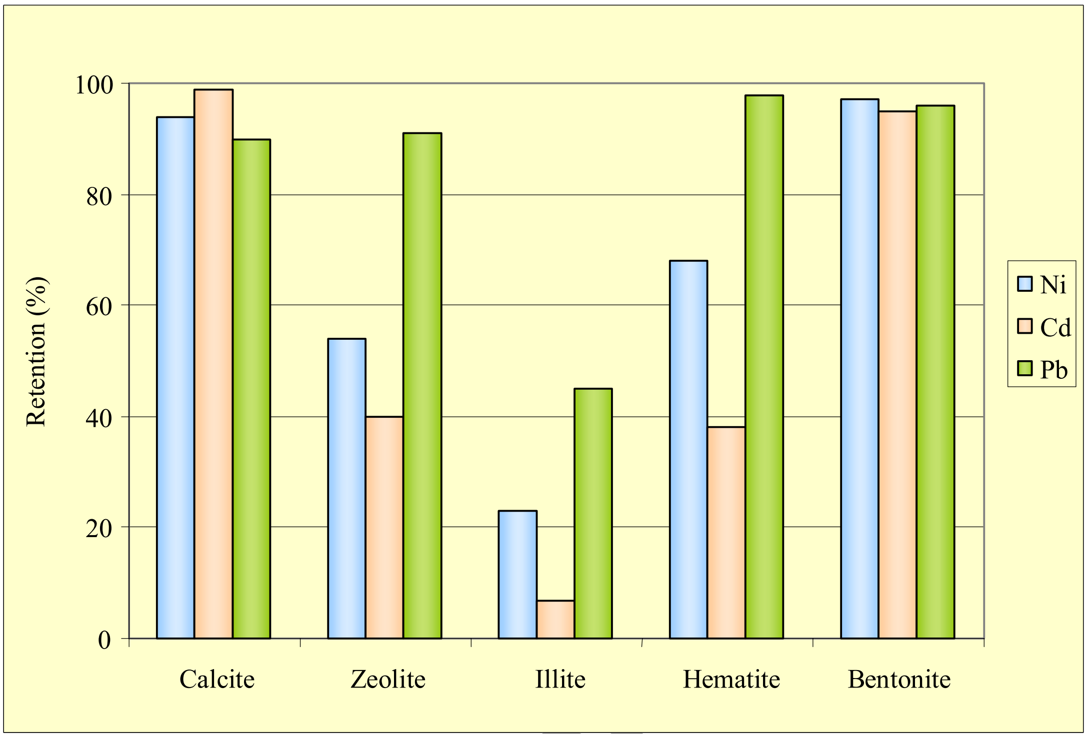

Figure 1: Ni, Cd and Pb sorption percentages by the amendments

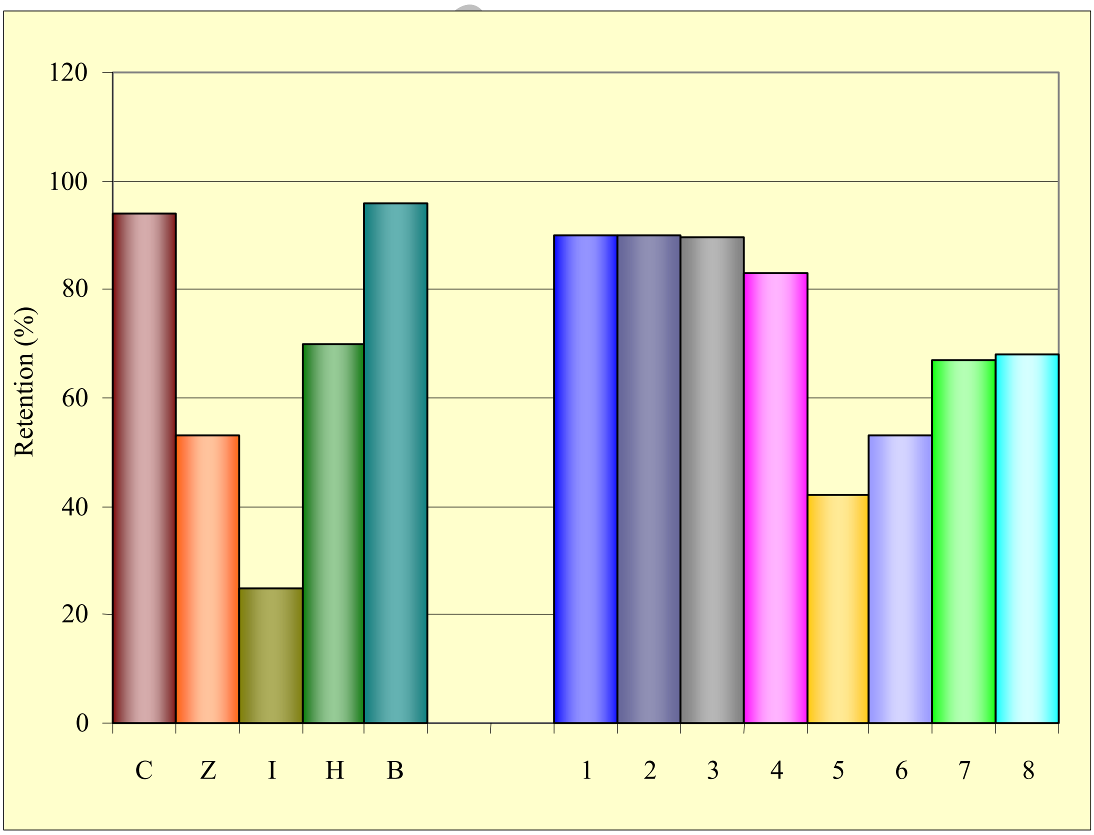

Figure 2: Ni sorption percentages by the soils and amendments (C, Z, I, H, and B represent calcite, zeolite, illite, hematite and bentonite respectively and 1, 2, 3, 4, 5, 6, 7 and 8, soil samples number.)

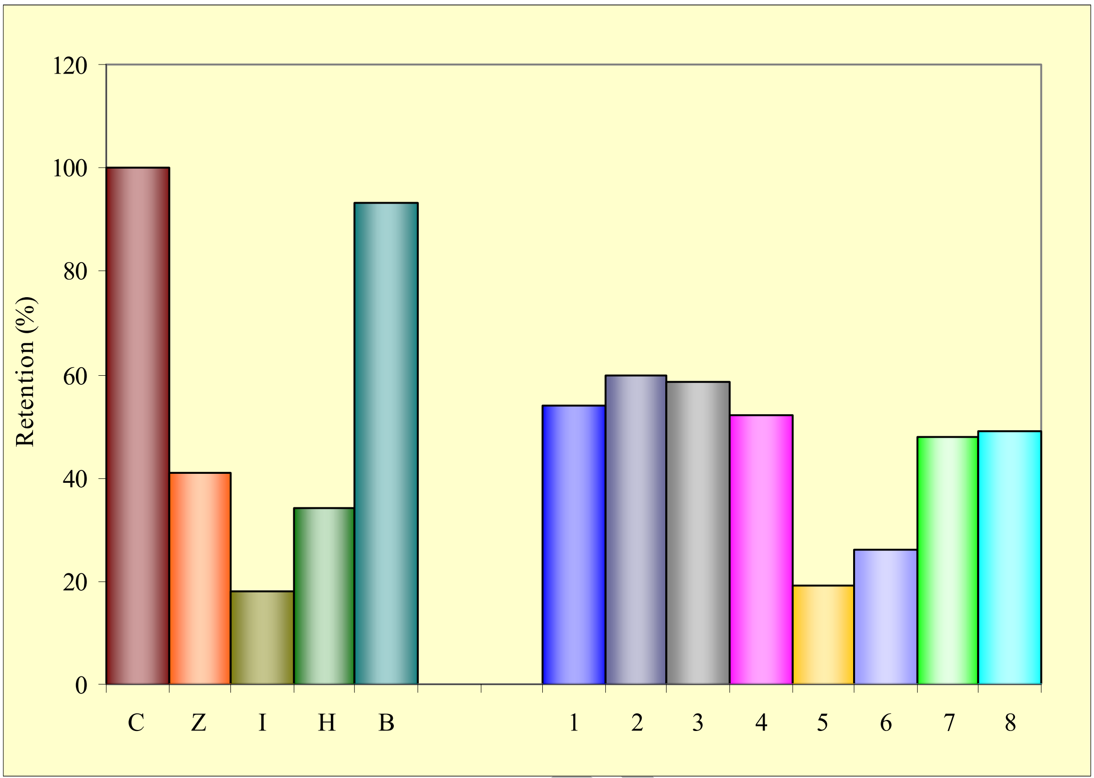

Figure 3: Cd sorption percentage by the soils and amendments (C, Z, I, H, and B represent calcite, zeolite, illite, hematite and bentonite respectively and 1, 2, 3, 4, 5, 6, 7 and 8, soil samples number)

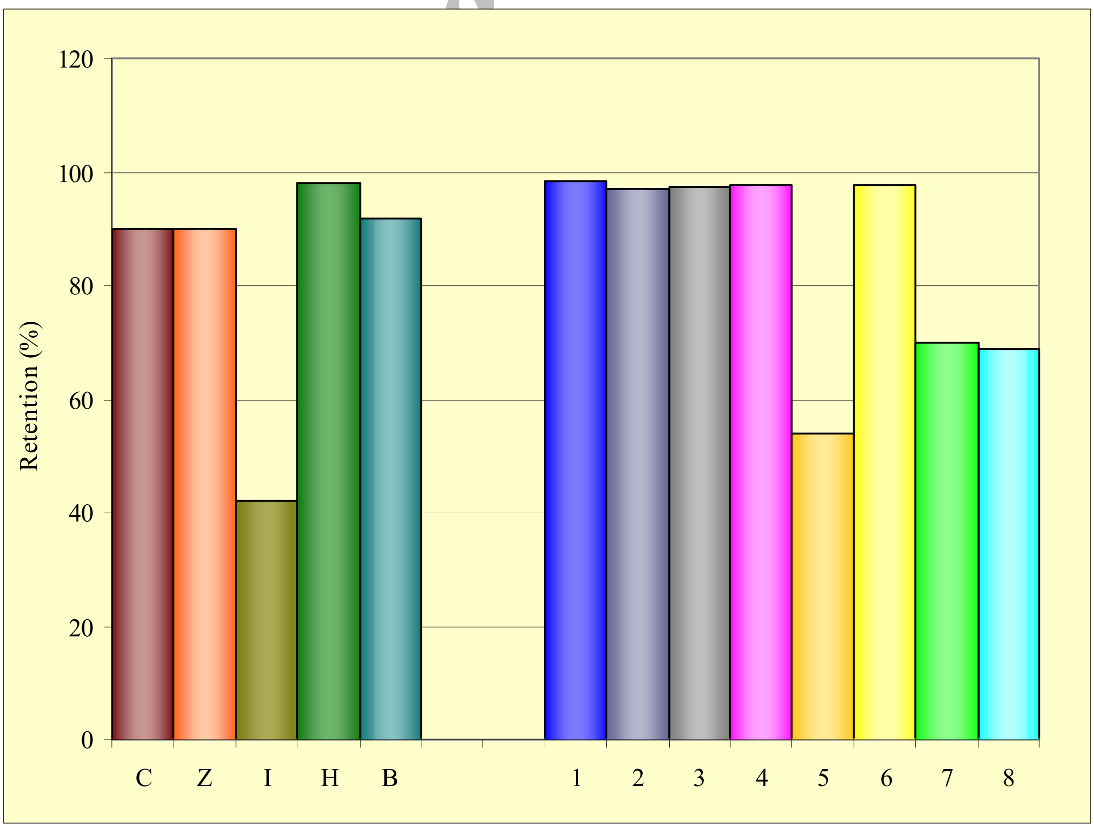

Figure 4: Pb sorption percentages by the soils and amendments (C, Z, I, H, and B represent calcite, zeolite, illite, hematite and bentonite respectively and 1, 2, 3, 4, 5, 6, 7 and 8, soil samples number.)

Table 1: Main physico-chemical properties of the soils

Soil No.	Texture	Saturated Moisture (%)	pH	EC (ds/m)	Organic Matter (%)	Calcium Carbonate (%)	CEC ($Cmol^+/kg$)	Sampling Locations
1	Clayey	73.5	7.8	3.5	0.73	20.0	16.1	South of Tehran
2	Clayey	66.7	7.9	1.3	0.64	15.0	35.8	South of Tehran
3	Loamy	51.7	7.6	3.5	0.83	17.0	18.4	South of Tehran
4	Loamy	51.4	7.9	1.3	0.53	16.0	15.8	South of Tehran
5	Loamy -Sand	34.7	7.6	1.3	0.28	12.0	7.1	South of Tehran
6	Sandy	31.7	8.2	2.8	0.26	14.0	[illegible]	South of Tehran
7	Loamy	49.5	7.5	1.0	0.05	0.0	15.6	Zanjan
8	Loamy	50.3	7.5	.9	0.05	0.0	16.6	Zanjan

have higher sorption capacities than all of the soils for Cd. As a result, these 2 amendments may be used to increase all of the soil sorption capacities for Cd. Figure 4 shows that none of amendments can increase Pb sorption capacities in 1 to 4 and 6 soils. Calcite, Na-zeolite, hematite and Na-bentonite were effective for other soils.

The differences in the 3 element sorption depend on 2 factors: 1. Adsorbent properties such as exchange sites, charge density in surface unit, and spatial distribution of charge and inner sphere complex formations 2. Ion properties in solution phase such as element percentage as soluble complex and kind of the complex and ion radius.

Conclusively, the retention capacities of calcite and Na-bentonite for Cd were higher than all 8 soils; therefore with applying these 2 amendments to all the soils, sorption capacities of these soils were increased. However retention capacities for Pb and Ni of these 2 minerals were higher than those of loamy soils without lime and organic matter and also sandy soils. Because calcite and Na-bentonite had the greatest sorption percentages of the 3 elements and because of abundance and low price of calcite in most areas, this amendment preferred to Na-bentonite. Therefore, calcite is recommended for adding to soils with low sorption capacities of Ni, Cd and Pb.

References

Anderson, A. and K. O. Nielson, Enrichment of trace elements from sewage fertilizers in soils and plant. Ambio, ***1****: 176-179, 1972*

Artiola, [illegible] and W. H. Fuller, Limestone liner for landfill leachate containing be, Cd, Fe, Ni and Zn. Soil Sci., ***129****: 167-179, 1980*

Bi[illegible] E. J. and R. J. Miller, Pb, Cd and Ca selectivity coefficients on a montmorillonite, illite and kaolinite. J. Env. Qual., ***3****: 250-252, 1984*

Candelaria, L. M., A. C. Chang and C. Amerhein, Measuring Cd ion activities in sludge amended soils. Soil Sci., ***159:*** *162-175, 1995*

Chaney, R. L., Trace metal movement in soil-plant systems and bioavailability of biosolids. In: Clapp, C. E., editor. Sewage sludge land utilization and the environment. Soil Sci. Soc. Amer. Pub. Madison, Wisconsin: 27-31, 1994

Dowdy, R. H. and V. V. Volk, Movement of heavy metals in soils. In: Nelson, D. W. Editor. Chelate, mobility and reactivity in soil systems, SSSA Pub. Madison, Wisconsin: 229-240, 1984

Gardiner, J., The chemistry of Cd in natural water. Water Res. ***8****: 157-164, 1974*

Hinesley, T. D., Effects on corn by application of heated anaerobically digested sludge. Compost Sci., ***13:*** *26-30, 1972*

Klute, A., G. S. Campbell, R. D. Jackson, M. M. Mortland and D. R. Nielson, Methods of soil analysis, 2ed. Ed. Agronomy Monograph 9, ASA, Madison, Wisconsin, 1984

Kuo, S., Effects of soil type, liming and sludge application on Zn and Cd availability to Swisschare. Soil Sci., ***122:*** *350-359, 1985*

McBride, M. B., Toxic metal accumulation from agricultural use of sewage sludge. J. Environ. Qual. ***24:*** *5-18, 1995*

Page, A. L., R. H. Miller, D. R. Keeny, D. E. Baker and J. D. Rhoades, Methods of soil analysis, 2nd. Ed., Agronomy Monograph 9, ASA, Madison, Wisconsin, 1982

Puls, R. W. and H. L. Bohn, Sorption of Cd, Ni and Zn by kaolinite and montmorillonite suspentions. SSSAJ, ***25:*** *1282-1292, 1988*

Sidle, R. C. and L. T. Kardos, Transport of heavy metals in sludge-treated forested area. J. Environ. Qual., ***6****: 431-437, 1977*

Smith, S. R., Effects of sewage sludge application on soil microbial processes and soil fertility. Adv. Soil Sci., ***16:*** *191-212, 1991*

Tessier, A., Trace elements in oxiclake sediments: Possible adsorption on iron oxyhydroxides. Cuochim. Cosmochim. Acta, ***49:*** *183-194, 1985*

Van Erp., Long term heavy metal leaching from soils, sewage sludge and soil/sewage mixtures. Environ. Sci. Technol., ***25:*** *706-711, 1991*