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Status of Heavy Metals in Soils of Paper Mill Effluent Irrigated Fields

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The heavy metals are probably the most harmful and insidious pollutants because of their non-biodegradable nature and hence to assess whether the effluent irrigation has contributed for the heavy metal accumulation in the soil, present study was undertaken at Pallipalayam in Tamil Nadu where paper mill effluent irrigation is in vogue for more than 25 years. Representative soil samples of surface (0-30 cm depth) and subsurface soil (30-60 cm depth) from the fields, which were under different periods of effluent irrigation, viz. more than 25 years, 15 years, 12 years, 9 years and control (no effluent), were collected and analyzed for heavy metals, viz. Cu, Zn, Pb and Cd by atomic absorption spectrophotometer. The study revealed that though there is heavy metal accumulation in the soil, it is below the permissible limit. But continuous effluent irrigation tends to accumulate heavy metals in the soil and hence suitable soil amendment should be applied.

***(Key words** : Paper mill effluent, Heavy metal contamination, Micronutrients)*

Applying wastewater to agricultural lands is a more economical alternative and more ecologically sound than uncontrolled dumping of municipal and industrial effluents into lakes and streams. The utilization of the effluents for irrigation is an appropriate solution as it involves two main principles- use of soil as a treatment system preventing pollution of the surface water and use of wastewater as continuous or supplementary source of irrigation. Recently, effluent irrigation has been adopted with great vigour by most paper mills due to the effective legislation and implementation of pollution control measures by the State Pollution Control Board. Though the concept of effluent irrigation seems promising the real success can be attributed only if there is no adverse impact on the environment. The continuous effluent irrigation can create environmental problems like accumulation of undesirable proportion of toxic elements, viz. heavy metals in soils (Srinivachari *et al.*, 2000). The heavy metals accumulate in the soil which may lead to adsorption by plants. This would act as a direct link for incorporation into the human food chain. Heavy metals are probably the most harmful and insidious pollutants because of their non-biodegradable nature and their potentiality to cause adverse effects in human beings at certain level of exposure. The short term benefit of effluent irrigation should not offset the heath and environmental consideration. Hence to assess whether the effluent irrigation has contributed for the heavy metal accumulation in the soil, the present study was undertaken in an area where effluent irrigation is in vogue for more than 25 years.

METHODS AND MATERIALS

To assess whether the effluent irrigation has contributed for the heavy metal accumulation in the soil, present study was undertaken at Pallipalayam in Tamilnadu where paper mill effluent irrigation is in vogue for more than 25 years. Representative soil samples of surface (0-30 cm depth) and subsurface soil (30-60 cm depth) from the fields put under different periods of effluent irrigation, viz. more than 25 years, 15 years, 12 years, 9 years and field with well water irrigation (control) were collected. These soil samples were dried, powdered, passed through 2mm sieve and analyzed for, Cu, Zn, Pb and Cd by atomic absorption spectrophotometer. The effluent which was let out for irrigation was also directly collected and analyzed for Cu, Zn, Pb and Cd (APHA, 1995). Soil pH and organic carbon of surface and subsurface soil were also estimated as per the standard procedures.

RESULTS AND DISCUSSION

The mean concentration of Cu, Zn, Pb and Cd in the effluents which were let out for irrigation are given in Table 1. The copper content in the effluents ranged from 0.034 to 0.046 mg l^{-1} with an average value of about 0.039 mg l^{-1} and the zinc content varied between 0.002 mg l^{-1} and 0.011mg l^{-1} with a mean value of about 0.007mg l^{-1}. The cadmium and lead content of the effluent ranged from 0.001 to 0.019 mg l^{-1} and 0.103 to 0.267 mg l^{-1}, respectively. The results showed that the effluents let out for irrigation are well within the permissible limit as prescribed by FAO (1992) and USEPA (1992) for the effluents to be utilized for irrigation. Heavy metals in smaller proportion are required for plant growth. The concentration of heavy metals in the treated paper mill effluents was in the order of Pb>Cu>Cd>Zn.

Table 1. *Heavy metals in treated paper mill effluents*

Heavy metals	Mean	Max	Min	Irrigation standards	
				FAO (1985)	USEPA (1981)
Cu (mg/l)	0.039	0.046	0.034	0.2	0.4
Zn (mg/l)	0.007	0.011	0.002	2.0	4
Cd (mg/l)	0.008	0.019	0.001	0.01	0.02
Pd (mg/l)	0.204	0.267	0.103	5	10

Generally soils have the capacity to reduce the toxicity of' heavy metals through absorption onto the soil clay and deactivated by chemical speciation as a result of reaction with other ionic species. Additional protection against build-up of heavy metals in toxic concentration is provided by leaching. Soil texture, pH, amount of calcium carbonate, organic matter, nature and rate of waste application, and interaction with other metals are other factors which influence the heavy metal accumulation in plant uptake (Xiang *et al.*, 1999). The soil texture of the effluent irrigated field was determined and it was sandy loam (sand 68-74.3%, silt 12.2-14.2%, clay 14.8-17.8% at the surface). The soil pH and organic carbon in surface and subsurface soil of the effluent irrigated field is given in Fig 1. Irrigation with effluent altered soil pH. The pH of the surface

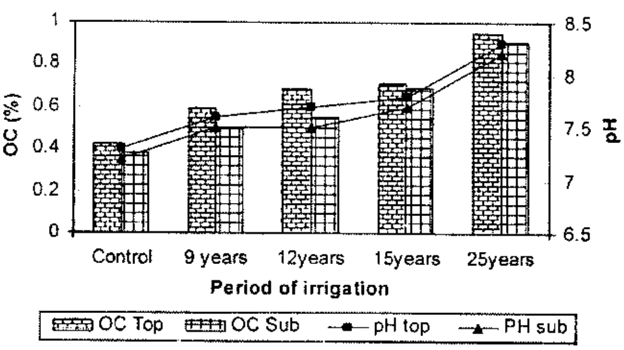

Fig. 1. Soil pH and OC in top and subsoil.

soil in effluent irrigated field ranged from 7.80 - 8.30, whereas it was about 7.30 - 7.40 in control field. The pH decreased with depth and it was observed that the pH of the subsurface soil did not have much variation. The organic carbon content increased with the effluent irrigation. The solubility and plant availability of most heavy metals in soils is known to be inversely related to pH and organic carbon. The organic matter depending upon its nature can either immobilize or mobilize metals. The presence of organic matter or its addition to soils has been shown to fix heavy metals rendering it less available to plants (Srinivachari *et al.*, 2000).

The heavy metals, viz. Cu, Zn, Pb and Cd accumulated in the surface and subsurface soils of the effluent irrigated fields for different periods (Fig 2a and b). Among the heavy metals Cu and Zn are the micronutrients required for the crop production. Heavy metals are present in the soil in different forms with varying degrees of mobility and availability to plants. The magnitude of the bioavailability of the heavy metals and phytotoxicity depends on the interrelationships of a number of factors, such as the rate and frequency of effluent

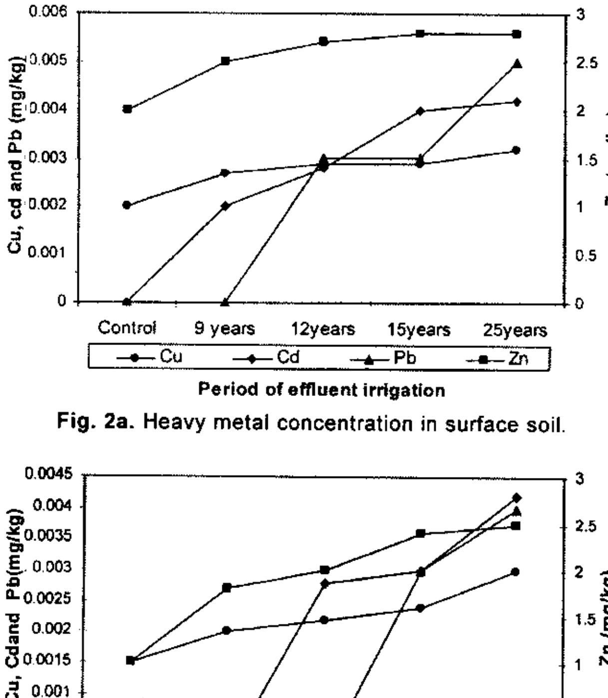

Fig. 2a. Heavy metal concentration in surface soil.

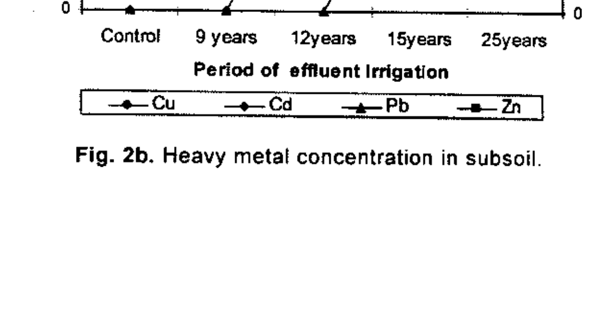

Fig. 2b. Heavy metal concentration in subsoil.

application, soil characteristics and plant species. In general most of the toxic manifestation of metals depend on their synergetic and antagonistic properties (Siebe, 1995).

The results showed that the copper content in the effluent irrigated field increased with the period of effluent irrigation in both surface and subsurface soil (Fig 2a and b). The copper content in the soils were 0.0027, 0.0029, 0.0029 and 0.0032 mg kg^{-1} of soil under 9 years, 12 years and more than 25 years of effluent irrigation, respectively, whereas in well water irrigated field (control) it was about 0.002 mg kg^{-1}. Though the accumulation was not much, the period of irrigation increased the copper accumulation. Moreover, it was also observed that the copper concentration decreased with the depth. The zinc concentration in the soil was about 2.5, 2.7, 2.8 and 2.8 mg kg^{-1} in 9 years, 12 years and more than 25 years effluent irrigation, respectively. Srinivascharti *et al.* (2000) showed that irrigation with undiluted paper mill effluent drastically increased the available micronutrient Zn, Cu, Fe and Mn in soil over control. Moreover, use of paper mill effluent increased these micronutrient concentration in soil, that could cause imbalance in available plant nutrients.

The Pb content under 12, 15 years and more than 25 years effluent irrigation ranged from 0.003 to 0.005 mg kg^{-1}, and it was less in the subsurface soil. Lead was rapidly removed from the effluent when it passed through the soil due to the formation of complexes with the organic matter present in the soil. Due to this mechanism lead concentration in the water is generally low and is quite high in the soil. Moreover, lead is tightly held in soils and there is generally no direct relationship between the amounts in soil and concentrations in crops. Vigerrust and Selmer-Olsen (1986) summarized sludge trials which showed no crop uptake of this element. Most field experiments have failed to demonstrate any significant increase in the Pb content in the food chain. Soil is the principal source of Cd accumulated by plants. Cadmium interferes with crop production as well as it adversely affects the animal health. This is because Cd is readily bio-available for plant uptake in contaminated soils. Cadmium can accumulate in the edible portions of crop plants to levels, which could be injurious to animals if consumed for long periods of time in large quantities, whilst having no apparent detrimental effects on crops themselves. In the effluent irrigated field the cadmium concentration ranged between 0.002 to 0.0042 mg kg^{-1}. Also the study revealed that the Pb, Cd, Cu, and Zn tended to accumulate in the top layers of the soil rather than in subsurface layers. Berti and Jacobs (1996) also reported Pb, Cd, Cu, and Zn to have a tendency of accumulating in the upper layers of the soil. The texture of the soil plays an important role in the mobility of metals. For soils with only slight contamination by heavy metals, lime applications may help. Lime increases the soil pH, and thus reduces the uptake of heavy metals by the crop (Srinivasari *et al.*, 2000).

The plant-soil system has three protective mechanisms that can limit the potentially toxic trace elements in the aerial portions of a plant and so minimize health problems to human or animals. Elements that are insoluble in soil and do not accumulate in plants like Pb are absorbed into the root but being insoluble have limited translocation to shoot. Elements which applied in excess may cause phytotoxicity like Zn and Cu (Aganga *et al.*, 2005).

CONCLUSION

The study thus shows that the heavy metal concentrations in the effluents which were let out for irrigation were very minimum and within the permissible level. But continuous effluent irrigation may lead to heavy metals accumulate in the soil especially in the top layers Though the concentration of the Cu, Cd, Pd and Cd were of very low concentration, continuous monitoring and proper management practices should be taken for minimizing the deleterious effects of the heavy metal accumulation.

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