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Agronomic application of food processing industrial sludge to improve soil quality and crop productivity

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ABSTRACT

Sludge, a by-product of wastewater treatment processes, is an alternative to conventional means of disposal and increasingly applied to agricultural lands as a source of fertilizer. In the present work, sludge generated from food processing industry was applied to agricultural soil as a conditioner and its effect on physio-chemical properties of the soil and crop productivity were studied. The industrial sludge was amended in different proportion (10–50 t/ha) with soil and the feasibility of these amendments were studied. The results revealed that application of sludge to soil increased its pH, EC, CEC and other nutrients such as organic matter and phosphorous. A reduction in the soil nutrients (nitrogen and potassium) in post-harvest soil indicates their uptake from soil by the plant and thus, productivity increases. No indication/evidence of harmful effects of heavy metals from sludge on quality of soil and cultivated product was found, when the amendment was controlled within the range of 50 t/ha for both dry and wet sludge applied. However, deterioration in the growth rate was observed beyond 30 t/ha amendment due to the excess organic and nutrient load accumulated in the soil. The effect of bio-fertilizer and chemical fertilizer to support the crop productivity were also studied. Thus, food processing industrial sludge application positively affects crop productivity and significantly improves soil quality. Still, much is to be learnt from this study and the present investigation needs to be continued to determine whether the agricultural objectives are satisfied in longer term.

1. Introduction

Sludge treatment or its disposal is the major problem of wastewater treatment plant if it is not utilized as a fertilizer or for some other economical purpose. Sludge contains essential plant nutrients and organic matter that can help/enhance crop production. Therefore, land application of sludge not only reduces its disposal costs but also produce an alternative to landfill disposal or incineration which is more beneficial and environment friendly. The agricultural use of sludge primed this salvaged material valuable and provides enough profit to defray other treatment costs. The present paper aimed to work in this context and optimized the quantity of sludge to be applied on agricultural land that would not harm soil quality and crop productivity.

Although the agricultural application of sewage sludge has become an alternative to common waste treatment due to practical and economic reasons, a relatively high concentration of heavy metals present in sewage sludge generated from the dense urban and industrial areas pose a threat to environment (Selivanovskaya and Latypova, 2003; Singh et al., 2004; Wong et al., 2007). Sewage sludge application always poses a risk to the environment resulting from nutrient imbalances and toxic element accumulation and leaching. Metal transfer from sewage sludge to soil and subsequently, to groundwater and plants represents potential health and environmental risks (Bhogal et al., 2003; McBride et al., 1997). Evidences for metal percolation have been reported in numerous long-term sludge application experiments (Streck and Richter, 1997). Accumulation of heavy metal in soil can result in a loss of soil functions that may raise concerns about environmental quality protection, maintenance of human health and productivity. Soil pollution may have implications in phytotoxicity at high concentrations and result in the transfer of heavy metals to the human diet from crop uptake or soil ingestion by grazing livestock (Kabata-Pendias and Mukherjee, 2007; Kabata-Pendias and Pendias, 2001; Nicholson et al., 2003). Based on the available evidences regarding various aspects of sewage sludge application on soil fertility and consequent effects on plant productivity, the possibility of its utilization for agronomy and horticulture were reviewed by some researchers (Singh and Agrawal, 2008; Singh et al., 2011). According to them land application of sewage sludge is one of the important alternatives for its disposal. Being rich in organic and inorganic plant nutrients, sewage sludge may be a substitute for fertilizer, but presence of potential toxic metals often restricts its uses.

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Many researches support and establish the positive effects of sewage sludge amendment on crop yield and on physio-chemical properties of soil. For instance, Sigua et al., 2005a, 2005b stated that repeated applications of sewage sludge indicate no harmful effects on soil quality and forage quality. Their results show that repeated land application of sewage sludge would not increase soil sorption for nutrients and trace metals. They suggested that successive land use of sewage sludge for at least three years followed by no sewage sludge use for at least two years may be a good practice because it will boost and/or maintain sustainable forage productivity and at the same time minimize probable accumulation of nutrients, especially trace metals. They advised that possibilities for economically sound application strategies are encouraging, but more research is required to find optimal timing and rates that minimizes negative impacts of sludge on environment, particularly on soil quality. Min et al., 2011 applied Anaerobically Digested Slurry (ADS) to soil to evaluate its effects in mitigating crop damage from parasitic Nematodes. They suggested that application of ADS might be feasible for mitigating Nematode damage, but the rate and timing should be considered correctly to determine the best application method. Müller da Silva et al., 2011 assessed the effects of dry and wet sewage sludge on the growth and nutrient cycling of *Eucalyptus grandis* plantations in Brazil. They recommended that sewage sludge application positively affect leaf litter production and significantly increase nutrient transfer among the components of the ecosystem.

Based on the above mentioned information on land application of sludge as a fertilizer, pot culture experiments were conducted using *Trigonella foenum graecum* (Fenugreek) plant to find the impact of food processing industrial sludge on soil properties and crop productivity. The industrial sludge (both dry and wet sludge) were amended in different proportion (10–50 t/ha) with soil and the feasibility of these amendments was studied. The quantity of sludge required to get better productivity was optimized without much change in the properties of post-harvest soil. To support the crop production, biofertilizer and chemical fertilizer were also applied and their impacts were studied.

2. Materials and methods

2.1. Materials

Sludge samples (dry and wet) were collected from wastewater treatment plant, Haldiram food processing industry, Nagpur, India. It is one of the largest sweets and snacks manufacturing industry in India where a number of food products were processed viz. frozen foods, namkeens, sweets, cookies, papads, chips, packaged dry fruits, bhujia, dal mixtures etc. Wet sludge sample was collected directly from digester after discharge and the dry sludge was collected from the industrial sludge bed after drying. All the chemicals used for preparation of reagents were of analytical grades and purchased from Merck Pvt. limited, India. All the glassware were washed with soap, rinsed with nitric acid and then washed with deionized water before use. Deionized water was used to prepare all required solutions.

2.2. Experimental design

Two sets of experimental treatments were conducted separately for each, dry sludge and wet sludge. Each set of treatment contained eight pot culture experiments including control for the germination of crop (*Trigonella foenum graecum*) under various soil and sludge compositions. Clay pots, having capacity of approx. 15 l and diameter of 9 in. were taken. Each pot was filled with 5 kg of soil–sludge mixture containing differed amount of sludge viz. 10 t/ha, 20 t/ha, 30 t/ha, 40 t/ha, and 50 t/ha. To check any additional requirement of fertilizer, two pots with 5 kg of soil–sludge mixture containing 30 t/ha of sludge in each pot, were supplemented by biofertilizer (Azotobacter) in one and chemical fertilizer (Urea) in other pot. The fertilizers were supplied to soil in the form of blended seeds before sowing them in two different pots. Hence, total sixteen pot culture experiments were conducted.

All the 16 pots were conditioned for 3–4 days before sowing of seeds. Equal numbers of Fenugreek seeds were sown in all the pots at a particular distance apart. Each plant was irrigated with distilled water and maintained under unsaturated conditions (moisture content equivalent to 70%) to avoid the possible lixiviation of metals and salt. The experiment was conducted in a greenhouse to avoid any contamination and infection to the crop during the germination period. The temperature was maintained between 20 °C and 25 °C throughout the growth period. Lighting in the greenhouse was natural. The experiment lasted for 15 days. In this experimental period, the plants developed completely and the effects of sludge were visible.

2.3. Soil characterization

Soil samples were characterized before and after the experiment. At the end of the experiment, soil sample from each pot was taken and air dried, crushed, and passed through a 2 mm sieve. Metals content of soil was extracted after digestion with 3:1 (v/v) concentrated HCl – HNO3 following 3051a method (USEPA, 1997b) and measured by Atomic Absorption spectrophotometer (AAS) Perkin Elmer with graphite furnace. The pH and electrical conductivity (EC) were determined in saturation extract; pH was measured by a Crison micro-pH 2000 (Thomas, 1996) and EC with a Crison 222 conductivity meter (Rhoades, 1996). Organic carbon (OC) content was determined by the Walkley–Black method (Nelson and Sommers, 1996). N content was analyzed by the Kjeldahl method (Bremner, 1996) and phosphorus (P) according to Watanabe and Olsen (1965). Soil Cation Exchange Capacity (CEC) was determined with NH_4OAc/HOAc pH 7.0 (Sumner and Miller, 1996). Soil cations (Ca2+, Mg2+, Na+ and K+) moved with NH_4OAc/HOAc pH 7.0 were measured by Perkin–Elmer 2280 atomic absorption spectrophotometer. Soil texture was determined according to Bouyoucos (1962).

2.4. Sludge characterization

Sludge samples were air-dried and crushed to pass a 2 mm sieve. A fraction of sample was crushed to pass through a 0.074 mm sieve. This fraction was used to determine organic carbon (OC), N and total metal content. EC and pH were determined in saturation extract. Organic carbon (OC) was analyzed by Walkley–Black method (Nelson and Sommers, 1996). N was determined by the Kjeldahl method (Bremner, 1996) and phosphorus (P) according to Watanabe and Olsen (1965). Total metal content of sludge were determined by 3051a method (USEPA, 1997b) and measured by Atomic Absorption spectrophotometer (AAS) Perkin Elmer with graphite furnace. Sludge's Cation Exchange Capacity (CEC) was determined with NH4OAc/HOAc pH 7.0 (Sumner and Miller, 1996). Sludge cations (Ca2+, Mg2+, Na+ and K+) moved with NH4OAc/HOAc pH 7.0 were measured by Perkin–Elmer 2280 Atomic Absorption Spectrophotometer.

2.5. Plants analysis

At the end of the experiment, samples of plants were washed using deionized water, dried at 80 ° C for 48 h, finely ground and stored at 5 °C until metals analysis. Cr, Ni, Cu, Zn, Cd, Co, Fe, Mn and Pb concentrations were assessed by Perkin–Elmer 2280 Atomic Absorption Spectrophotometer after dried tissues were digested in nitric acid and sulphuric acid following the standard procedure described by Gerard et al., 2000.