JOURNAL OF ENVIRONMENTAL SCIENCES 30 (2015) 231–240

Available online at www.sciencedirect.com

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JOURNAL OF ENVIRONMENTAL SCIENCES

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Impact of industrial effluent on growth and yield of rice (*Oryza sativa* L.) in silty clay loam soil

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ARTICLE INFO

Article history:
Received 27 June 2014
Revised 10 September 2014
Accepted 30 October 2014
Available online 3 February 2015

Keywords:
Biomass
Crop yield
Heavy metal
Industrial effluent
Soil pollution

ABSTRACT

Degradation of soil and water from discharge of untreated industrial effluent is alarming in Bangladesh. Therefore, buildup of heavy metals in soil from contaminated effluent, their entry into the food chain and effects on rice yield were quantified in a pot experiment. The treatments were comprised of 0, 25%, 50%, 75% and 100% industrial effluents applied as irrigation water. Effluents, initial soil, different parts of rice plants and post-harvest pot soil were analyzed for various elements, including heavy metals. Application of elevated levels of effluent contributed to increased heavy metals in pot soils and rice roots due to translocation effects, which were transferred to rice straw and grain. The results indicated that heavy metal toxicity may develop in soil because of contaminated effluent application. Heavy metals are not biodegradable, rather they accumulate in soils, and transfer of these metals from effluent to soil and plant cells was found to reduce the growth and development of rice plants and thereby contributed to lower yield. Moreover, a higher concentration of effluent caused heavy metal toxicity as well as reduction of growth and yield of rice, and in the long run a more aggravated situation may threaten human lives, which emphasizes the obligatory adoption of effluent treatment before its release to the environment, and regular monitoring by government agencies needs to be ensured.

Introduction

Industrial influent is a serious threat to human, plant and aquatic lives. In Bangladesh, different industries have emerged in the last decade producing huge amounts of effluents, particularly the textile and composite industries (Saha, 2007). The Gazipur district is one of the major industrially developed areas of Bangladesh, where effluents are directly discharged to the environment without treatment. Although as per government rules every industry has an effluent treatment plant, the plants are not generally operated because of the high cost involved in treating effluents. Release of untreated effluents to the environment is of great concern for the sustainable use of the resources (Eruola et al., 2011). Untreated industrial influent degrades surface water and soil and ultimately it creates negative impacts on crops, insect pests, and animal and human lives (Hossain et al., 2010). The toxicity of industrial effluent varies considerably among different industries (Rautaray et al., 2007). The textile effluent is the most polluting among

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http://dx.doi.org/10.1016/j.jes.2014.10.008

all industrial sectors, considering the volume and composition of effluents, in both developed and developing countries (Vanndevivera et al., 1998; Roy et al., 2010). Water consumption in textile and composite industries is very high (Roy et al., 2010). The effluent is contaminated with different chemicals and toxic components and also harbors a number of harmful pathogens that may cause many diseases for humans and other living beings (Molla et al., 2004). It was reported that the chemical parameters of surface water and soil of industrial effluent-affected areas were above the allowable limits and also tended to accumulate in downstream areas (Fakayode, 2005). The long-term effect of these effluents is to increase the heavy metal toxicity in soil.

The concentrations of different heavy metals such as Pb, Cd, Ni, Zn, Cu, Fe and Mn in agricultural soil of Gazipur, Bangladesh were found to exceed the allowable limits, with the exception of Cr (Islam et al., 2009). Heavy metal concentration was found to vary in soils depending on the types of effluents, and decreased with distance from the discharge area due to the dilution effect of effluent by water (Nuruzzaman et al., 1993). Heavy metals cannot be degraded with time, their concentration can be increased by bioaccumulation, and they have toxic effects even at low concentrations (Aksoy, 2008; Clark, 1992; Davey et al., 1973; Hussain et al., 2008). Heavy metals (Mn, Cu, Zn, Pb, Cr, Cd and Ni) contaminate soils and reduce crop yield, and prominent levels of these elements in agricultural products may provide their access into the food chain. Toxic elements like Cu, Zn, and Ni are phytotoxic and Cd and Pb are zootoxic, and their presence in the food chain can cause harmful effects for humans, animals and other living beings (Alloway, 1995).

Rice fields in industrial areas of Bangladesh are being continuously flooded with industrial effluents. Rice (*Oryza sativa* L.) is the most important cereal crop in Bangladesh, playing a vital role in the national economy and contributing roughly 73% of calories and 66% of the protein intake for the population (Alam et al., 2002). At present, rice production in industrial areas of Bangladesh is a challenge and there are limited reports on the impact of industrial effluents as irrigation water on rice production, though heavy metal buildup in soil from industrial effluents and thereby entry in the food chain have been reported (Zebunnesa et al., 2009). Water quality deterioration resulting from untreated industrial effluents has serious consequences on the aquatic ecosystem and on the health of the downstream user groups. In seriously polluted water bodies aquatic animals, fish, frogs and even snakes cannot survive, water becomes unusable, and dwellers cannot get fresh air for breathing and because of elevated concentrations of toxic gases in the atmosphere, immature fruit drop, malformed and undersized fruits are observed in the industrial areas (Zebunnesa, 2012). Considering the above-mentioned scenarios, a research study was conducted to investigate the effect of discharging untreated industrial effluent in the buildup of heavy metals in soils and thereby entry into rice plants, and subsequent effects on the growth and yield of rice. The research findings might increase public awareness and foster social pressure against environmental pollution, as well as promoting policy ensuring mandatory installation of effluent treatment plants in all industries, to accomplish the aim of the study: a sustainable and congenial production environment both in agriculture and industrial sectors.

1. Materials and methods

1.1. Soil collection and preparation for pot experiment

The pot experiment using industrial effluent was conducted at the Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) (24°02′131″ N and 90°23′810″ E, 8.4 m above mean sea level), Gazipur, Bangladesh. The experimental soil sample was collected from 0 to 15 cm depth from the research field of the BSMRAU campus, which has a sub-tropical humid climate and is characterized by high temperature accompanied by moderately high rainfall from April to September and low temperature from October to March. The soil series is Salna, land type is high land to medium high land, the drainage is poorly drained, and the cropping system is rice–rice, pulse/oilseed/wheat–rice. The samples were air-dried at room temperature. The dried samples were then ground to a small particle size with a mortar and pestle.

The size of individual cylindrical plastic pot was 25 cm in diameter and 30 cm in depth and each of the pot was filled with 12 kg air-dried soil. The soil of each plastic pot was fertilized with 1.8, 1.74, 0.4 and 2.12 g of triple super phosphate, gypsum, muriate of potash and urea, respectively just one day before seedling transplantation. Additionally, at 45 and 80 days after planting, 2.12 g of urea was applied in each pot. The soil of the pots was moistened by mixing 2.5 L of effluent treatment at the time of transplanting. After that, effluent treatments were applied as needed to maintain the water level required for the growth of rice plants.

1.2. Collection and preparation of industrial effluent

Industrial effluents were collected from discharge points of composite industries of textiles and dyeing from three locations (Dhanua, Bangla Bazar and Konabari) of Gazipur district (Fig. 1). The collected samples of effluents from the three locations were mixed together and then used as irrigation water at five different concentrations (0, 25%, 50%, 75% and 100%). Separate samples of effluent were preserved in plastic containers and stored at 4°C for chemical analysis.

1.3. Soil and water analysis

The physic-chemical properties of the soil samples were determined according to standard methods (Bouyoucos, 1926; Jackson, 1962; Nelson and Sommers, 1982; Page et al., 1982; Olsen et al., 1954; Hunter, 1984). As the results the parameters are as follows: soil textural class: silty clay loam, sand: 17.6%, silt: 47.3%, bulk density: 1.40 g/cm^3, particle density: 2.62 g/cm^3, porosity: 46.56%, pH: 6.1, organic carbon (OC): 0.87%, available N: 0.10%, available P: 12.10 μg/g soil, exchangeable K: 0.56 meq/100 g soil, total S: 10.02 μg/g, C/N: 8.70, Mn: 25.19 μg/g, Fe: 43.57 μg/g, Cu: 4.13 μg/g, Zn: 2.88 μg/g, Pb: 8.5 μg/g, Cd: 0.26 μg/g, Ni: 41.5 μg/g, Cr: 12.5 μg/g. Chemical properties of the pot soil were also analyzed after harvesting of rice. Effluent samples collected from