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Analysis

Toxicity and profitability of rice cultivation under wastewater irrigation: the case of the East Calcutta Wetlands

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ABSTRACT

The paper reports the results of an empirical study on profitability of rice cultivation in the East Calcutta Wetlands (ECW) region where untreated sewage from the city of Kolkata (earlier Calcutta), India, is used for the purpose of irrigation during the winter/summer crop. The results show that plots using wastewater containing organic nutrients earn lower profits than those using groundwater. We also find that the profitability of plots using wastewater is negatively affected by the presence of heavy metals such as Lead and Mercury that are carried through untreated sewage-water canals and deposited in the soil. Of the two opposing effects of wastewater irrigation, the negative effect of heavy metal toxicity outweighs the positive effects of organic nutrients. The results support regulation of the discharge of the heavy metals like Lead and Mercury into the wastewater from households and industries. This would lead to conservation of the Wetlands generating a number of ecological and environmental benefits to the society.

1. Introduction

Use of wastewater in agriculture undoubtedly helps to recycle useful nutrients through the food chain. But it also poses risks simultaneously for human health and for the profitability of the cultivated crop because of the possible presence of toxic elements in the irrigation water. The East Calcutta Wetlands in India present a somewhat unique case where untreated sewage water from the city of Kolkata (Calcutta) located upstream has been used for decades in downstream agriculture and fisheries. This paper presents the results of an empirical study on the profitability of rice cultivated using such untreated wastewater for irrigation purposes during the dry season.

Since the inception of the plan in 1930 of diverting sewage from the city to the Wetlands through a chain of canals, the sewage water has provided the farmers not only with a cheap irrigation option in the dry season of the year but also an inexpensive substitute for costly fertilizers because the water is full of nutrients. The plan has enabled the East Calcutta Wetlands, spreading over an area of approximately 7500 ha[1] towards the south eastern fringe of the Kolkata metropolis, to provide important eco-system services to the city as well as livelihood support to a large number of people living in the region. Ghosh (2005) reports that this area is home to the largest wastewater-based non-saline fishery in the world. He also points out that the cumulative efficiency in reducing the Biochemical Oxygen Demand (BOD) of the wastewater in this region is above 80% and that of reducing coliform bacteria is 99.99% on average. Not only does the plan save the city the cost of construction of a sewage treatment plant (STP), it also contributes to flood control in the city and serves the cause of carbon sequestration. The area supports a wide variety of flora and fauna and is a storehouse of biodiversity. For these reasons, the East Calcutta Wetlands (ECW) is hailed as a great success story that is both ecologically sound and cost effective when it comes to dealing with urban sewage. Sarkar (2002) measures the value of livelihood support and sewage water treatment services of the Wetlands at Indian Rupees 1656 million per annum (or USD 36.8 million per annum[2]). In 2002, the Wetlands were admitted into the list of Ramsar sites and are now preserved by law against conversion to other usages. Its protected status therefore restricts the expansion of the city towards the south east.

The reliance of the city of Kolkata on the Wetlands for waste disposal is underscored by the fact that despite the manifold expansions in the city over the decades and the corresponding increase in bio-degradable and non-bio-degradable contents in its sewage water, the city has not

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[1] The estimate is given in Chattopadhyay (2002).

[2] Assumed US$1 = Indian Rupees 45.

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constructed a treatment plant for sewage, depending solely on the East Calcutta Wetlands for waste water disposal. However, the appearance, with time, of more industrial plants in and around the city and the use by households of more manufactured chemical products, such as detergents and other household chemicals, have increased the presence of toxic industrial effluents in the sewage water. The question therefore is whether the increase in toxicity of sewage water negatively impacts on the profitability of the fisheries and agricultural practices in the region. An answer in the affirmative points invariably to reduced livelihood support for people in this region and reduced value addition from the existence of the Wetlands. Such a conclusion also, indirectly, supports the growing demand to convert the wetlands to real estate and industry. An answer in the negative on the other hand supports the cause of conservation. Appropriate policy interventions are therefore necessary, including the proper treatment of the sewage water flowing into this region, from those who wish to hold at bay the ever-increasing pressure in favor of conversion and to preserve the wetlands for the valuable ecosystem services it provides for the city.[3]

In this paper, we study whether the presence of heavy metal toxicity in wastewater and soil negatively impacts on the profitability of rice cultivated in the East Calcutta Wetlands region. Although vegetables, jute and oilseeds too are produced in the region, we restrict ourselves to the study of rice cultivation for the following two reasons: (i) rice occupies a majority of the cultivated land in this area during the winter/summer crop when wastewater is used for irrigation; (ii) the crop uses substantial amounts of water at different stages of its production and is therefore the most likely to be vulnerable to toxicity in the water and, through the water, in the soil. The results indicate that in this region rice cultivation through wastewater irrigation is less profitable than rice cultivated using groundwater-based irrigation. This is explained by the presence of Mercury and Lead in the soil. The results of our study are interesting because they help clarify popular perceptions regarding the profitability of wastewater irrigated plots and add new insight to the ongoing policy debate.

The paper is organized as follows. Section 2 discusses the available literature on the subject of our research and lays out the scope of the present study. Sections 3 and 4 describe the methodology and the sampling strategy respectively. Section 5 discusses the data while Section 6 presents the results. The last section concludes with a brief outline of the policy implications and recommendations of our study.

2. Literature survey and scope of the study

How does the toxicity of irrigation water affect plant growth? According to experts, the heavy metals carried through the irrigation water accumulate in the soil over time. Though the presence of heavy metals in small quantities is 'natural' in the water and soil, their elevated concentrations kill micro-organisms that are beneficial to plant growth. As Alloway (1995) points out, Chromium (Cr), Zinc (Zn), Cobalt (Co), Copper (Cu) and Manganese (Mn) in small quantities are good for plant growth but the presence of metals like Lead (Pb), Cadmium (Cd) and Mercury (Hg) is always a cause for concern above a certain level. Of these, Pb and Cd, being heavier metals, work at the root and stem of the plant to destroy them while Hg being lighter gets easily transported to the grains. The metal mobilization and plant uptake would be restricted by the alkaline pH of the soil.

A recent study by Nawaz et al. (2006) investigated the effect of water containing heavy metals on yield, yield components and heavy metal contents in paddy and straw. They looked at three varieties of rice and soil at three different sites in the district of Sheikhupura near the bank of Nallah Daik where the crop is irrigated with water from Nallah Daik in Pakistan. This study showed contamination by the two heavy metals Cu and Cd to be within safe limits in the soil. Moreover, although they observed a minor accumulation of these metals in the plant parts, they found it to remain within the permissible limit. A study by Fazeli et al. (1998), who investigated the degree of accumulation of seven heavy metals (Cu, Zn, Pb, Co, Cd, Cr and Ni (Nickel)) in the soil and in different plant parts of paddy irrigated by paper mill effluents near Nanjangud, Mysore district, Karnataka in India, also found remarkably low concentrations of heavy metals (except Zn) in the seeds of paddy although this was not the case for the roots and leaves. Further, the crop seemed able to tolerate the presence of the heavy metals in the polluted water without suffering much damage.

In another study, Yap et al. (2009) investigated the accumulation of seven heavy metals (Cd, Cr, Cu, Fe (Iron), Mn, Pb and Zn) in the soil and in different parts of the paddy plant at Kota Marudu, in Sabah, Malaysia. Although the results showed Fe to be the most predominant metal ion in the rice grains and roots, the concentrations of heavy metals in the rice grains were still below the maximum levels as stipulated by the Malaysian Food Act (1983) and Food Regulations (1985). Zeng et al. (2007) studied the effect of Pb treatment on soil enzymatic activities, soil microbial biomass, rice physiological indices and rice biomass in a greenhouse pot experiment. Their experiment showed that when the Pb treatment was raised to the level of 500 mg/kg, there was an ecological risk both to soil microorganisms and plants. The results also revealed a consistent increase in chlorophyll contents and rice biomass initially, peaking at a certain level of Pb treatment, and then a gradual decrease with a continued increase in Pb concentration. Studies have shown that Pb is effective in inducing proline accumulation and that its toxicity causes oxidative stress in rice plants. A study by Wang et al. (2003), on the other hand, has estimated the status of trace elements in paddy soil and sediments in the Taihu Lake region in China. It showed Zn, Cu and Pb to be the main pollutants in the experiment sites and the rapid development of village/township industries to be the primary cause of severe environmental pollution in the Taihu Lake region, especially of irrigation river sediments. Markandya and Murthy (2000), in their study of the Kanpur–Varanasi region in India, found that though the mean levels of Cd, Cr, Ni and Pb in the soils were above their respective tolerable limits for agricultural crops, since the pH of the receiving soil was alkaline, their effects were less harmful than expected. They also noted the positive effect on agricultural yield of nutrients present in partially treated wastewater when compared with crops grown using groundwater.

In contrast with the studies discussed above, the primary objective of our study, taking the East Calcutta Wetlands as its study site, is to investigate the effect of wastewater toxicity on the livelihood options of farmers involved in rice cultivation in the region. Therefore, we study whether wastewater cultivation has had a negative impact on the profitability of rice cultivation in this region rather than the impact of heavy metals on yield and the plant body. We consider this important as farmers may adopt a number of measures like using pollutant resistant varieties of seeds, fertilizers and pesticides in order to cope with the negative externality posed by toxicity so that higher yield is achieved at lower profits. But if this indeed happens, the livelihood support provided by the Wetlands will be reduced and the pressure for its conversion into more economically beneficial projects will build up. In the case of the East Calcutta Wetlands, some studies have already noted the presence of heavy metals in the body of fish and vegetables produced in the region. A study by Chatterjee et al. (2004), for instance, has found high Cu concentrations in fish liver. The team of researchers also found Zn, Pb and Ca (Calcium) concentrations to be above the maximum permissible levels in edible muscles. On the other hand, although recent studies by Raychaudhuri et al. (2007, 2008) observed the presence of toxic elements in both the vegetables and fish produced in the region, they also found the elements to be within the safe limit and not substantially higher than in the case of produce coming from the control region. What is important to note is that none of the above-cited studies were carried out in

[3] See Mukherjee (2010) for a discussion.