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Sugar Mill Effluent Irrigation Influences the Soil Microbial Properties: A Field-based Study

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Abstract

This study aimed to investigate the soil microbial properties such as soil respiration rate (SRR) and microbial population (bacterial, fungal and actinomycetes) in soils from sugar industry effluent irrigated belt of the Sri Karanpur, Rajasthan. The soil samples from selected sites (wastewater irrigated belts and freshwater irrigated) were collected and analysed for SRR and microbial population. Results showed the respective population of bacteria, fungi and actinomycetes in the range of 463.33 – 531.67 CFU × 10^{-5} g^{-1} soil, 297.00 – 323.67 CFU × 10^{-5} g^{-1} soil and 208.33 – 218.33 CFU × 10^{-5} g^{-1} soil which were significantly higher than that of control setups i.e. 262.33 – 286.67 CFU × 10^{-5} g^{-1} soil, 203.67 – 212.67 CFU × 10^{-5} g^{-1} soil and 154.67 – 160.00 CFU × 10^{-5} g^{-1} soil. SRR found to be 346.33 – 359.0 mg CO_2/kg soil/48hs in sugar-effluent irrigated soils and 301.33 – 305.67 mg CO_2/kg soil/48hs in the control soils. Results suggested a high The results of this study suggested that wastewater irrigation improves the microbial population in soils mainly due to a high supply of organic matter and soil nutrients during wastewater irrigation which helps in the buildup of microflora in soil and thus improves soil fertility and plant growth.

Keywords:Soil organic matter, Soil fertility, Bacterial population, Sustainable farming system

Introduction

The issue of industrial wastewater treatment is very challenging in developing countries where the majority of industrial operations are under small-scale or medium-scale ventures and such industries contribute about 70 – 80 % of the total industrial manufacturing. The main problem with such industrial sectors is that it's large with the least technological updating and poor implementation of environmental management systems. Industrial water reuse and recycling have been promoted as one of the sustainable approaches to solving manifolds problems like water supply shortage, the economy of water, resource conservation, energy demands, etc.

A review by Klemes (2012) narrated that due to the growing demand for freshwater supply in the industrial sector, the recycling of industrial effluents needs to be addressed effectively to ensure a sustainable supply of water without affecting consumer product quality. He concluded that there is an instant need for improvements in water treatment procedures and wastewater minimization programs in the industrial sector particularly in areas where water availability is limited for various other sectors like public water supply and crop irrigation projects.

Sugarcane is grown worldwide as one of the oldest crops in tropical and subtropical parts of the world. India is considered the origin of sugarcane in the world and India is the second-largest sugar-producing country in the world. Thus sugar-based industries play an important role in economic development and livelihood generation in India. In India, sugarcane is produced on about 5.0 million hectares of land and about 50 million farmers earn a livelihood from this single crop. The Indian sugar industry has been playing an important role in rural livelihood generation and socio-economic development. Sugarcane is the key raw material for the production of sugar and other products like alcohol.

Sugar industry effluent contains a high load of organic matter, soil nutrients and elements which enriches the fertility of the soil but the presence of some toxic substances like heavy metals and other synthetic chemicals also poses an adverse effect on soil and crop quality as well. Literature suggests the pros and cons of the use of reclaimed industrial waste for crop irrigation purposes. For instance, a review by Poustie et al. (2020) reviewed the pros and cons of the use of reclaimed water for irrigation purposes in terms of soil benefits and limitations due to phytotoxicity. They revealed that wastewater poses a high load of nutrients which could be an alternate source of nutrient supply in agroecosystem but phytotoxicity, particularly by xenobiotic present in it pose some limitations on its continued use for such purposes. The magnitude of xenobiotic concentrations which caused plant growth inhibition, while present in higher ranges, need to be addressed before implementing the sustainable reuse of wastewater for crop irrigation purposes.

Ofori et al. (2021) reviewed the potential application of water in crop irrigation practices. They found that in water reuse few issues such as environmental impacts of water reuse, effects of wastewater on soil quality, water resources conservation potential, plant growth or inhibition rate, the overall health of soil biological communities, etc. should be investigated on a priority basis. Another important aspect of wastewater reuse for crop irrigation practices is public health and exposure to chemicals for a longer period leads to contamination transfer to food crops that further deteriorates the food quality and may pose a risk of food chain contamination (Ofori et al., 2021).

Soil microbial population (fungal, actinomycetes and bacterial) is an indicator of soil health and industrial wastewater irrigation's impact on soil health and productivity. and soil respiration activities in crop fields irrigated with industrial effluent. Therefore, the aim of this study was to evaluate the impact of long-term sugar mill effluent irrigation practices on soil microbial properites under different cropping systems. Soil samples were analysed for richness of fungal, actinomycetes and bacterial populations and SRR. The data were compared with soil from freshwater irrigated setups for the same cropping systems.

Materials and methods

Soil sampling and analysis

For microbial analysis the samples of topsoil (20 cm depth) were collected from some selected sites of the sugra effluent irrigated and freshwater irrigated plots. A 100 g soil sample was collected in sterilized polythene zip bags and stored in ice box. The samples were immediately tranfered to analytical labvs for microbial analysis. For each cropping system, a total of three replicate plots (10 × 10 m) were selected and soil samples were collected by following the standard procedure as described by APHA(2005). The population of bacteria, fungi and actinomycetes in soil samples collected from the control and experimental field (wastewater irrigated plots) were estimated using the serial dilutions method. For that, 1 g soil sample (undried) was mixed with 10 mL distilled water in an autoclaved test tube and the aqua extract was prepared. Thereafter, the aqua-extract was then diluted up to 10^{-5} using distilled water. For colony development, 1 mL of aqua extract was placed over the medium in Petri plates containing: Nutrient Agar (bacteria), Rose Bengal Agar (fungi) and Kenknight and Munaier's medium (actinomycetes) and microbial population was conuted for each microbial type and results were expressed per gram soilby following the method described by Negi & Suthar (2018).

Soil respiration rate is also taken as an indicator of microbial activities and their role in the organic matter degradation soil system and CO_2 released during soil incubation is taken as a measurement of soil respiration. Soil respiration rate was measured using NaOH trap method by following the method descrived in earlier study by Gusain & Suthar (2020).

Statistical analysis

The data of chemical analysis were subjected to analysis for descriptive statistics of data sets -including the mean and standard deviation (SD). One-way ANOVAs were used to measure the statistically significant difference among sampling sites for metal load in soils and plants.

Results and discussions

Bacterial population

The bacterial population in soil indicates the soil mineralization rate, organic decomposition process and soil health status. The bacterial population in the soil samples collected from control plots of all three setups of cropping setups ranged between 262.33 – 286.67 CFU × 10^{-5} g^{-1} soil and also varied significantly among the different sampling sites of each experimental plot, evidenced by a large difference between the minimum and maximum value of it. The images of microbial plating are shown in Figure 1.

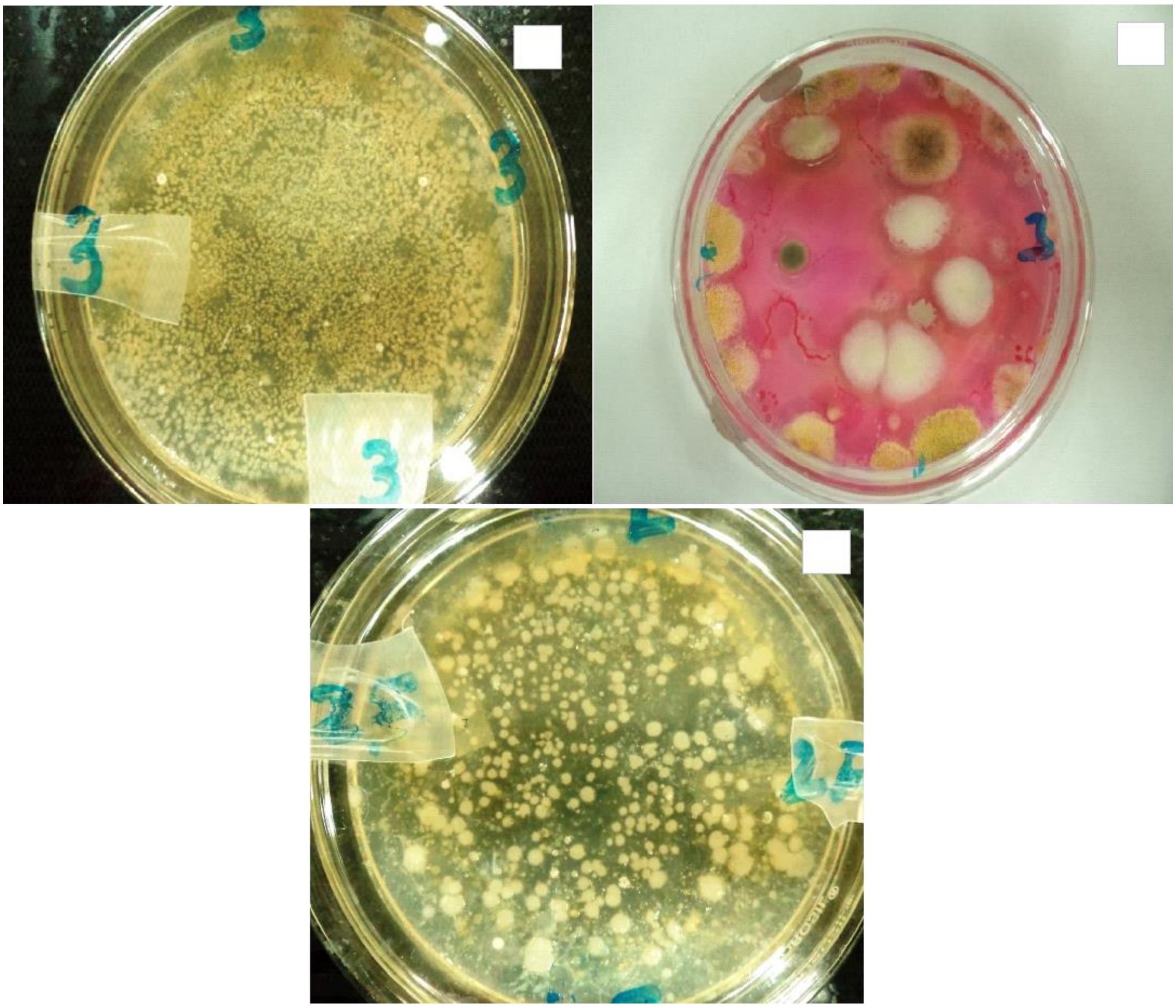

Fig. 1 – Petri plate showing soil plating for bacterial (A), fungal (B) and actinomycetes (C) population estimations.

In experimental plots, the bacterial population in soils ranged between 463.33 – 531.67 CFU × 10^{-5} g^{-1} soil (Figure 2). The maximum bacterial population in the experimental plot was observed in the wheat field (531.67 CFU × 10^{-5} g^{-1} soil) followed by, barley crop soil (529.33 CFU × 10^{-5} g^{-1} soil) and mustard field soil (463.33 CFU × 10^{-5} g^{-1} soil). The difference in bacterial population among different field crops could be related to the plant rhizome structure, leaf litter biomass quality, soil organic matter contents and soil physicochemical properties. The higher bacterial population in field crops with wastewater indicates the scaling impact of industrial effluent on soil microbial population build-up that could be beneficial in terms of soil quality maintenance and soil organic matter mineralization. The difference in bacterial population among different field crops could be related to the plant rhizome structure, leaf litter biomass quality, soil organic matter contents and soil physicochemical properties (Ajmal & Khan, 1983; Zhang et al., 2021; Zhao et al., 2016). The higher bacterial population in field crops with wastewater indicates the scaling impact of industrial effluent on soil microbial population build-up that could be beneficial in terms of soil quality maintenance and soil organic matter mineralization (Hati et al., 2007; Rattan et al., 2005). Fungal population richness in soil suggests the soil health status, pollution load in soil and microbial-mediated leaf mineralization rate and organic matter organic decomposition process.

Fungal population

The fungal population in the soil samples collected from control plots was lower (203.67 – 212.67 CFU × 10^{-5} g^{-1} soil) than that of setups with effluent irrigations (297.00 – 323.67 CFU × 10^{-5} g^{-1} soil)(Figure 2). The maximum bacterial population in the experimental plot was observed in the wheat field (323.67 CFU × 10^{-5} g^{-1} soil) followed by, barley crop soil (322.67 CFU × 10^{-5} g^{-1} soil) and mustard field soil (297.00 CFU × 10^{-5} g^{-1} soil). The difference in fungal population among different field crops could be related to the plant rhizome structure, leaf litter biomass quality, soil organic matter contents and soil physicochemical properties (Zhang et al., 2021). Higher fungal population in field crops with wastewater indicates the scaling impact of industrial effluent on soil microbial population build-up that could be beneficial in terms of soil quality maintenance, microbial-mediated decomposition of organic matter, nutrient mineralization, etc. (He et al., 2018; Irawan et al., 2019). Higher fungal population in field crops with wastewater indicates the scaling impact of industrial effluent on soil microbial population build-up that could be beneficial in terms of soil quality maintenance, microbial-mediated decomposition of organic matter, nutrient mineralization, etc.

Actinomycetes population

Actinomycetes produce several beneficial chemicals adding to the soil nutrient profiles. They are also responsible to produce some antibiotics and antagonistic effect that controls the population of harmful pathogenic microbial species in soil. Actinomycete population in the soil samples collected from control plots of all three setups of cropping setups ranged between 154.67 – 160.00 CFU × 10^{-5} g^{-1} soil and also varied significantly among the different sampling sites of each experimental plot, evidenced by a large difference between the minimum and maximum value of it. In experimental plots, the actinomycete population in soils ranged between 208.33 – 218.33 CFU × 10^{-5} g^{-1} soil. The maximum average actinomycete population in the experimental plot was observed in the wheat field (218.33 CFU × 10^{-5} g^{-1} soil) followed by, barley crop soil (216.33 CFU × 10^{-5} g^{-1} soil) and mustard field soil (208.33 CFU × 10^{-5} g^{-1} soil) (Figure 2)

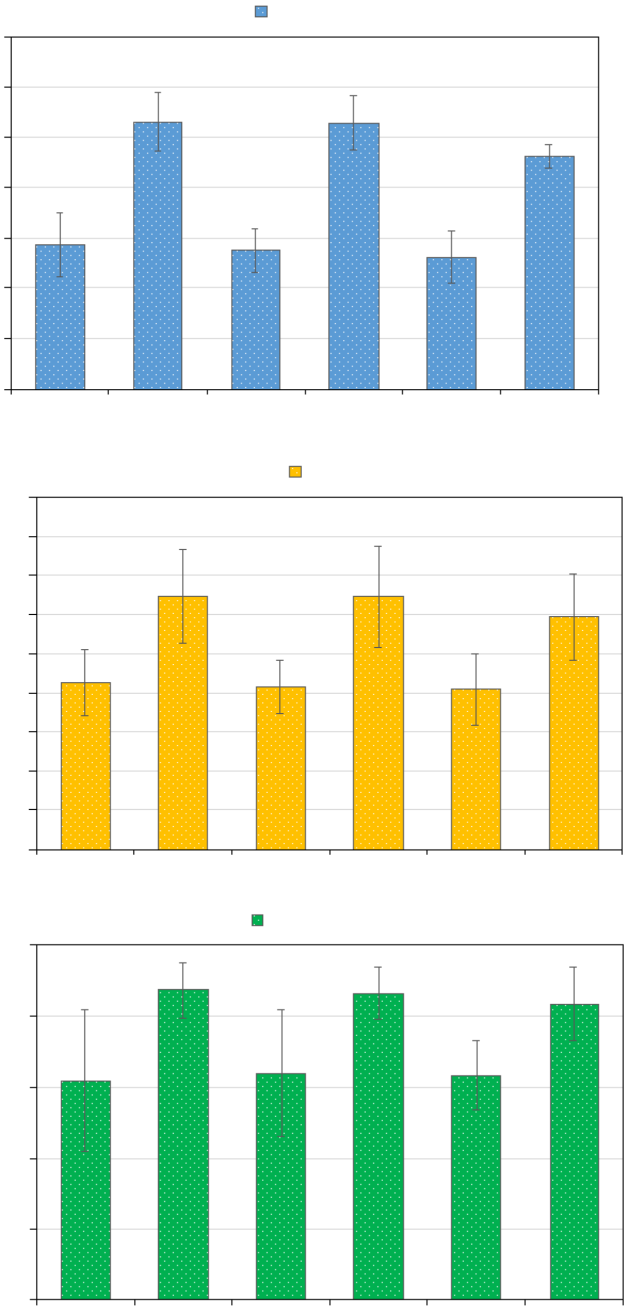

Fig. 2 – Bacteria, fungi and actinomycetes population (mean ± Sd) in soils of studied crops: control (C-I, C-II and C-III) and experimental plots (EP-I, EP-II and EP-III) irrigated with industrial effluent. EP-I (wheat crop), EP-II (barley crop) and EP-III (mustard crop).

A higher actinomycete population in field crops with wastewater indicates the scaling impact of industrial effluent on soil microbial population build-up that could be beneficial in terms of soil quality maintenance, soil anti-pathogenic activities, decomposition of organic matter, nutrient mineralization and process. Results of paired sample t-test suggested a significant difference ($p < 0.05$) between control samples and plant samples from experimental plots for the microbial population in soils in all three crops studied, except for actinomycete population in wheat ($p = 0.07$) and barley crop ($p = 0.06$).

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Soil Respiration

Soil respiration is the indicator of soil microbial activities in soil and this parameter is taken as an indicator of soil health assessment. The result of soil respiration estimation in different cropping systems and control setups is described in Figure 3. The soil respiration rate ranged between 301.33 and 305.67 mg CO_2/kg soil/48hs in control setups while in experimental setups the respiration rate (average) was significantly higher and found to be 359.0, 352.67 and 346.33 mg CO_2/kg soil/48hs in wheat, barley and mustard crop soil, respectively. The maximum soil respiration value was recorded in what cropping systems i.e. 387 mg CO_2/kg soil/48hs and that was slightly higher than barley (327.0 mg CO_2/kg soil/48hs) and mustard crop (376.0 mg CO_2/kg soil/48hs). The statistical analysis results suggested no significant difference between control and experimental setups for soil respiration rates in wheat ($p = 0.140$), barley ($p = 0.213$) and mustered ($p = 0.150$) crops. Soil microbial population (fungal, actinomycetes and bacterial) is an indicator of soil health and microbial activities and their role in soil organic matter decompositions (Gusain & Suthar, 2020b). The soil microbial population assessment in effluent irrigation setups could be used as a parameter to measure the adverse impact of industrial wastewater irrigations on soil health and productivity (Sasmita et al., 2022).

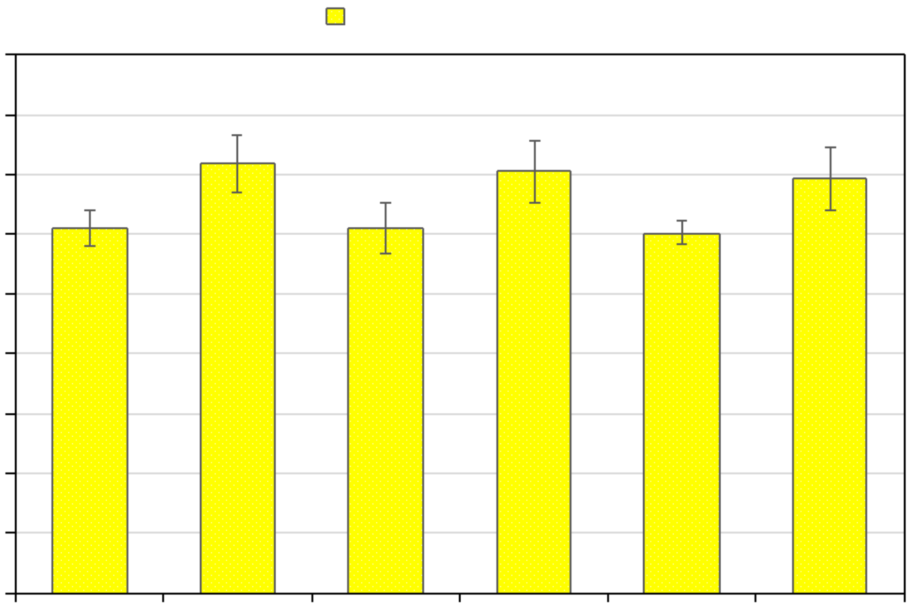

Figure3 – Soil respiration rates (mean ± Sd) in soils of studied crops: control (C-I, C-II and C-III) and experimental plots (EP-I, EP-II and EP-III) irrigated with industrial effluent. EP-I (wheat crop), EP-II (barley crop) and EP-III (mustard crop).

Results suggested that rhizosphere microbial communities altered significantly after long-term wastewater irrigation in soil which also helped in toxic chemical remediation in soil being disposed of through wastewater. Becerra-Castro et al. (2015) reviewed the overall impact of wastewater irrigation on soil microbiological properties and soil fertility management systems. According to their conclusion, wastewater irrigation contributes to the chemical accumulation in soil but simultaneously helps in the building of microbial communities in soil which in return accelerates the soil organic matter degradation and bioremediation of organic pollutants. Soil fertility is also accelerated through wastewater irrigation by a build-up of soil microbial communities which helps in nutrient mineralization and organic matter degradation. The results of this study are also in line with the above-discussed research results that wastewater irrigation improves the microbial population in soils mainly due to a high supply of organic matter and soil nutrients during wastewater irrigation which helps in the buildup of microflora in soil and thus improving the soil fertility and plant growth.

Conclusions

Industrail effluents cause positive as well as negative impact on soil properties in long terms of continuous irrigations of crops. The soil microbial population acts as an indicator of soil helath and well-beings. This study revealed that sugar mill effluent irrigation could be a valuable approach to enrich the soils with microbial (bacteria. Fungi and actinomycetes) communities which plays a vital role in soil fertility enrichments through organic matter mineraliztaion and N fixations. A high soil respiration rate in sugra effluent-irrigated setups than that of control setups also validates these facts.

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