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Role of Drip Irrigation in Controlling Heavy Metal Accumulation

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ABSTRACT: This study was aimed at identifying how drip irrigation could be useful in controlling heavy-metal issues, practically and affordably. Heavy-metal accumulation in soils and uptake by cauliflower curds were observed for two consecutive years. Municipal wastewater and groundwater were used for irrigation, to make it a comparative study. There were various treatments: drip irrigation with groundwater through inline (non-pressure-compensating) surface drip , inline subsurface drip , bioline (pressure-compensating) subsurface drip , bioline surface drip , and the same drip systems using primarily treated municipal wastewater . The results showed that significantly higher concentrations of heavy metals – namely, copper, iron, manganese and zinc – were recorded in cauliflower curds irrigated with wastewater compared with those irrigated with groundwater. Subsurface placement of pressure-compensating drip laterals was found more effective in reducing the heavy-metal concentrations in both cauliflower and soil profile compared with surface-placed non-pressure-compensating drip laterals. This study suggests that drip irrigation systems could be an effective method to reduce heavy-metal concentration in vegetable crops and soils irrigated with treated municipal wastewater.

KEYWORDS: drip irrigation, heavy metal, accumulation, groundwater, wastewater, concentration, soil

I. INTRODUCTION

Wastewater irrigated fields can cause potential contamination with heavy metals to soil and groundwater, thus pose a threat to human beings . The current study was designed to investigate the potential human health risks associated with the consumption of vegetable crop contaminated with toxic heavy metals. The monitored heavy metals included Cd, Cr, Cu, Pb and Zn for their bioaccumulation factors to provide baseline data regarding environmental safety and the suitability of sewage irrigation in the future. The pollution load index (PLI), enrichment factor (EF) and contamination factor (CF) of these metals were calculated. The pollution load index of the studied soils indicated their level of metal contamination. The concentrations of Ni, Pb, Cd and Cr in the edible portions were above the safe limit in 90%, 28%, 83% and 63% of the samples, respectively. The heavy metals in the edible portions were as follows: Cr > Zn > Ni > Cd > Mn > Pb > Cu > Fe. The Health Risk Index (HRI) was >1 indicating a potential health risk. [1,2]

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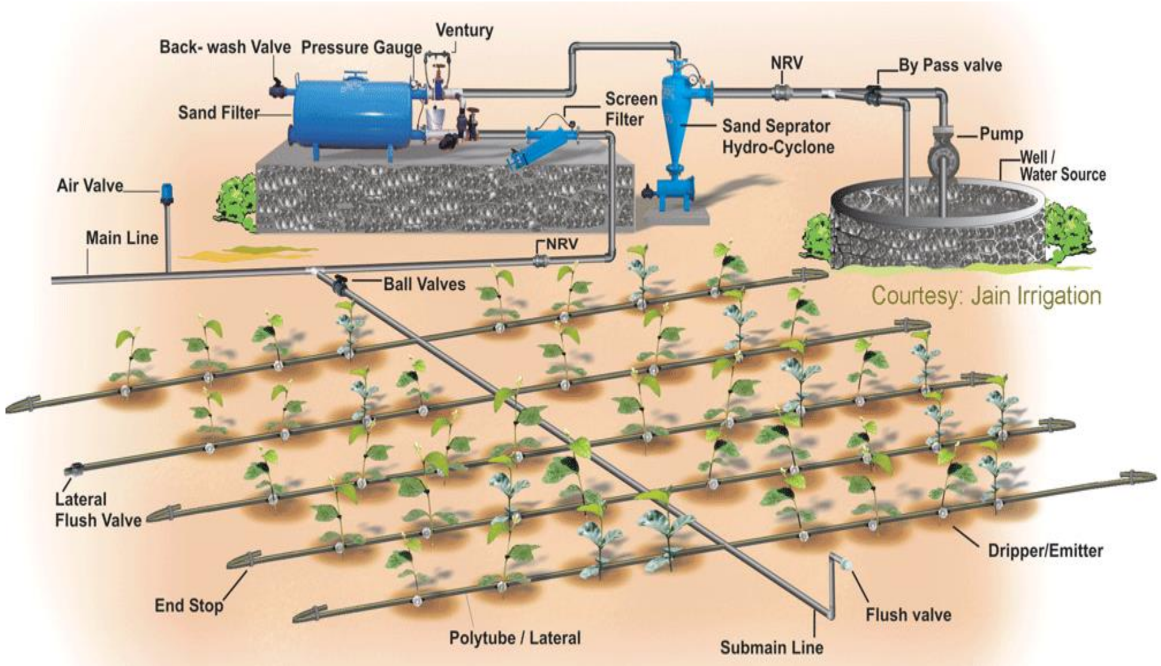

II. DRIP IRRIGATION SYSTEM LAYOUT AND ITS PARTS

The results indicated a potential pathway of human exposure to slow poisoning by heavy metals due to the indirect utilization of vegetables grown on heavy metal-contaminated soil that was irrigated by contaminated water sources. The vegetable tested was not safe for human use, especially for direct consumption by human beings. The irrigation source was identified as the source of the soil pollution in this study.

Treated wastewater (TWW) may contain toxic chemical constituents that pose negative environmental and health impacts. In this study, soil samples under treated wastewater irrigation were studied. For this purpose, six plots were made in an irrigated area in north of Tunisia and treated with two water qualities: fresh water (FW) and treated wastewater (TWW). Five soil depths were used: 0-30, 30-60, 60-90, 90-120 and 120-150 cm. The TWW irrigation increased significantly ($P \leq 0.05$) the soils' EC, Na, K, Ca, Mg, Cl, SAR, Cu, Cd and Ni and had no significant ($P \leq 0.05$) effect on the soils' pH, Zn, Co and Pb contents. EC, Na, Cl, SAR, Zn and Co increased significantly with soil depth. The results for K, Ca, Mg, Cd, Pb and Ni exhibited similar repartition in different layers of soil. It was also shown that the amount of different elements in soil irrigated with fresh water (FW) were less compared with the control soil.[3,4]

Another object of the study was to evaluate treated wastewater as additional water resource under water scarce conditions.

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III. POT IRRIGATION BY ON-LINE DRIPPERS

Large scale field trials were conducted in sandy soil to investigate the effect of legume crops irrigation with secondary treated wastewater from wastewater treatment plant in Cairo in two successive seasons of winter 2017/2018 and 2018/2019 in Berka site located about 20 km north east of Cairo. Faba bean and lupin were grown and irrigated either with surface or drip systems. The results showed some advantages of using treated wastewater where considerable amounts of macronutrients (NPK) were applied to the grown crops during treated wastewater irrigation i.e.; N (61-64%), P (73-76%) and K (99-208%) of the recommended fertilizer rates according to the crop. Heavy metals derived from treated wastewater were very small. Crop yields showed significant differences when treated wastewater was combined with the recommended fertilizer rates for each crop. Irrigation by surface was more efficiently used by the crops, compared with drip irrigation on area basis. However at an individual plant level, drip irrigation produced larger yields than surface irrigation, although this method would not be employed commercially for such crops on economic grounds. It could be concluded from this study that there are some

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advantages of using treated wastewater in field crop irrigation through saving water and fertilizers and decreasing the pressure on Egyptian water budget.[5,6] However some disadvantage appeared under drip irrigation practice through the lower plant density of field crops under this system which affect the final yield as well as the operational problems like clogging and blockage of the network components due to the total suspended solids in the treated.

IV. DISCUSSION

Inspecting water clogging for the drip irrigation network during irrigation practice recorded that about 15-20 % 0f the drippers suffered from clogging and affected the surrounded wetting area for the plants . This was considered to be due to bacterial or algal flocs present in the tank from which the effluent was pumped for the trial and frequent flushing of the irrigation filters was required. [7,8]

Irrigation dripper

This is crucial for drip irrigation to avoid blockage of the emitters. Final wastewater samples collected WWTP over the period of the trials were routinely analysed for nutrients and heavy metals. Since these analyses are based on grab samples, the CVs would be expected to be relatively large and particularly for those parameters (e.g. heavy

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metals) where the concentrations were close to their analytical detection limits. The pH of the wastewaters was within the acceptable range for reuse, normally 6.5 - 8.5. The nutrient contents of the wastewater were broadly as may be expected. Based on these analyses, El Berka treated wastewater had a superior nutrient content and NPK ratio in relation to general crop requirements. The heavy metal concentrations were very small and are well below the limit values for secondary wastewater reuse, usually by at least one order of magnitude. Most of heavy metals occur at comparable concentrations, the zinc content was high, but still well below the limit value for reuse of 2 mg/l. Since zinc deficiency is widespread in Egyptian agriculture, wastewater may provide useful alternative source of this essential trace element. It is worthy to mention that although the analysis of treated wastewater complied with the Egyptian cod of practice, according to the guidelines by WHO all the precautions for preventing exposing of the workers to the irrigation practice were done. Also, since all of the treated wastewaters used for the field trials pass through sand filters prior to irrigation.[9,10]

Drip and sprinkler irrigation system

Drip irrigation is an effective way to reduce the pollution of reclaimed water. Drip irrigation is a modern irrigation method that allows water and fluid fertilizer to drip in small flow, long time, and high frequency to the soil with crops roots, on the basis of water and fertilizer requirement law of the crops . It can save increase production, save water, fertilizer, labor and energy and adopt well to different kinds of landform and soil, which helps to improve utilization efficiency of water and nutrients and reduce agricultural non-point source pollution while ensures high yield and grade . The severe control irrigation time and amount and soil moisture area in drip irrigation allows it to adjust soil moisture and nutrients according to the physical property, crop root system distribution and crop water consumption. Recycling rural domestic sewage by drip irrigation can improve the utilization efficiency of N, P and other nutrients in reclaimed water, save fertilizer and water, improve production and reduce pollutants that might be

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put into environmental ecosystem. This is significant for relieving water shortage crisis, controlling agricultural non-point source pollution and promoting circular economy development. Reusing sewage, applying and promoting reclaimed water is an effective way to increase income and reduce expenditure, important support to construct the economic society, an important measure of harmonious development of realizing economic benefits, society benefits and environment benefits [11,12].By using reclaimed water, we can save regular water source, keep and replenish groundwater, and relieve the conflict between water supply and demand in countries, which brings remarkable economy benefits. This article researches and compares effects of rural domestic sewage reclaimed water and groundwater drip irrigation on the characteristics of crop rhizosphere soil, with other conditions being the same . By measuring related indexes of harvest soil, it shows that recycling rural domestic sewage by drip irrigation can improve the utilization efficiency of N, P and other nutrients in reclaimed water, save fertilizer and water, improve production and reduce pollutants that may be put to environmental ecosystem. It is significant for relieving water shortage crisis, controlling agricultural non-point source pollution and promoting circular economy development. With other conditions same, by comparing the pH value and EC value of rural domestic sewage reclaimed water irrigation , this experiment analyzes the effects of nutrients contents in soil on soil respiration, and researches and compares the effects of rural domestic sewage reclaimed water and groundwater drip irrigation on characteristics of crop rhizosphere soil. It provides evidences for evaluation of reclaimed water irrigation effects on soil environment and making secure control method.[13,14]

V. RESULTS

Rice is a water-intensive crop. It requires water for three primary purposes – preparing land (puddling), continual seepage, percolation, and to grow the actual crop. Further, you have to keep the area spread continually flooded, which results in substantial unproductive water losses (up to 80%) for reasons other than rice cultivation.Traditional rice cultivation demands high investments in water, labor, pre-crop preparation, and fertilizers as well. However, despite these investments, farmers don’t get the expected returns. This is because factors including water inefficiency, lower crop yield, and reduced crop-quality affect their profits, and they keep incurring financial losses every year.Considering the existing and futuristic scarcity of water, the growing food demands, expensive land preparation, wastage of water through flooding, and the inefficiency of conventional techniques reducing land fertility and restricting crop choice in crop rotation, Indian farmers must shift from flood irrigation to drip irrigation.[15]

- Grow More in Less Water: Drip irrigation reduces water use through a precise water supply to the crop. So, for the one kilo of rice that you used to grow in 5000 liters of water conventionally, you now need only 1500-1600 liters. On a large scale, you achieve a higher crop yield in lesser water.
- Shift to High-Income Crops: Drip irrigation allows you to choose any desired close spacing crop after rice in crop rotation. You can also shift from low-income crops to high-income ones after cultivating rice.
- Grow High-Quality Marketable Rice Crop: In paddy farming, rice roots remain submerged. They consume heavy metals and increase the arsenic in the crop, thereby reducing the crop's market value. However, in drip irrigation, it helps reduce the arsenic uptake by around 90%, and further results in the growth of a high-quality and marketable crop.
- Higher Profit-Earnings: With drip irrigation, you reduce labor costs, achieve water efficiency, increase crop yield, improve crop quality. All of these factors reduce investments and increase profits.
- Eco-Friendly Irrigation Solution: Paddy cultivation produces around 10% of methane gas emissions globally. But, even if only 10% of paddy rice cultivators upgrade to drip irrigation, the world will be able to reduce methane emissions equivalent to those of a staggering 40 million cars.[16]

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V. CONCLUSIONS

Just like people, plants like to get their water and nutrients in a balanced way. Nobody wants to eat a month's worth of food in one day, and the same goes for plants. Which is why drip irrigation applies water and nutrients frequently and in small doses, ensuring optimal growing conditions that helps produce the highest yields possible. [14]
Here's why plants are more productive with drip irrigation:

- High availability of water and nutrients
- Doses of water and nutrients tailored to plant's development needs
- No saturation and good soil aeration
- Avoids high salinity caused by excessive fertilizer application
- No wetting of foliage that can result in fungal diseases

By 2050, there'll be 10 billion people living on our planet, and 20% less arable land per person to *grow enough calories*. Include increasing water scarcity, and it's clear why we need a way to increase agricultural productivity *and* resource efficiency. That's where drip irrigation fits in, changing the economics of global agriculture by allowing farmers to produce more calories per hectare and cubic meter of water.[15]

- Reduce impact of drought and climate change on food production
- Avoid contamination of ground water and rivers caused by fertilizer leaching
- Support rural communities, reduce poverty, reduce migration to cities[16]

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