Sprinkler Irrigation: stops water wastage, lowers arsenic content in rice

The problem

Arsenic poses a serious threat to the health of an estimated 150 million people worldwide. Highly toxic and containing carcinogenic elements even in trace amounts, long-term exposure to arsenic can pose a serious threat to life, including health problems such as: cancers of the skin, bladder, kidney and lungs; peripheral artery disease; diabetes; hypertension; and reproductive disorders.

Many countries have geological environments that produce groundwater with high arsenic content. The arsenic in the groundwater is of natural origin, and is released from the sediment into the groundwater under certain conditions.

The Indus Plains of Pakistan, formed by the River Indus and its tributaries, is one of the regions where alarming levels of arsenic concentrations in groundwater have been observed. Home to approximately 100 million people, agriculture in the highly arid Indus Plains is heavily dependent on irrigation water. Other than the network of irrigation canals, several thousands of private tube wells provide approximately 30% of the total irrigation water to 2.81 million hectares of land in the Indus basin. The high concentrations of arsenic in groundwater combined with the installation of high-volume pumping tube wells, has inadvertently led to one of the most serious environmental health hazards of our time. The pumped water induces the transportation of arsenic ions to the soil which may result in gradual accumulation of arsenic compounds in crops grown on such soil.

Of particular concern is rice, the staple for billions of people, as it is grown in fields flooded with high quantities of irrigation water. When soil is flooded over prolonged periods of time, it creates an anaerobic environment (characterized by the presence of oxygen), which produces a more soluble form of arsenic, which in turn leads to increased arsenic uptake and its accumulation in rice.

In Pakistan, rice is one of the most important summer cereal crops grown in all the four provinces of the country covering an area of 2.5 million hectares (ha) with an annual production of 6,811 million tons. It is an important source of foreign exchange earnings, generating about US $933 annually through exports. Moreover, Pakistan enjoys a near monopoly status in the export of fine aromatic Basmati rice which fetches a price three to four times that of the normal coarse varieties, and has a higher demand in international markets. An assessment conducted to determine levels of arsenic in the rice growing areas of Punjab showed that arsenic concentration

in rice varies from 0.084 mg/kg to 0.356 mg/kg. None of the samples tested were found exceeding the 1.00 mg/kg permissible limit setby the World Health Organization (WHO). While the situation is not cause for alarm yet, the use of arsenic contaminated ground water may turn out to be hazardous in the future. It is therefore important that preemptive measures be considered to deal with the threat posed by arsenic contamination, while implementing irrigation practices.

The study

To better understand how arsenic in soil and groundwater is affecting the rice crop, a two-year study on arsenic content in the paddy soils of Punjab was conducted. Covering over 60 rice fields spread over an area of 63.76 ha, the study aimed at screening irrigation wells and soil for arsenic in order to predict regional distribution in irrigation wells, while identifying factors which cause the uptake of arsenic from the water to soil and from soil to rice grains.

The study also aimed at mitigating the problem by demonstrating how switching from the traditional system of continuous flooding irrigation to a sprinkler irrigation system reduces, to a great extent, the transfer of arsenic ions from soil-to-water-to-rice grains because arsenic occurs in different forms in water and soils, and is more soluble in one form than in the other.

A significant outcome of the research was to determine how switching to sprinkler irrigation system could help conserve water without affecting rice yield and also in the mitigation of the arsenic problem. This is exceptionally important because Pakistan faces a critical water crisis. It is ranked third in the world among countries facing acute water shortage. Reports by the United Nations Development Program (UNDP) and the PCRWR warn that Pakistan could ‘run dry’ by 2025, as its water shortage is reaching an alarming level. In the face of increasing competition for water from industrial, domestic and environmental sectors, concerns are also being raised about the efficient and productive use of water in agriculture.

Findings

In the first phase of the study, irrigation well water and soils were tested in specified areas using field kits. The results clearly showed that the water in the Ravi flood plain is different from the Chenab and Jhelum flood plains and also in the Rachna and Chaj Doabs in terms of arsenic contamination. Water in the Ravi flood plain has higher arsenic concentration with 65% of the wells exceeding 50 micrograms per litre and 10% exceeding 100 micrograms per litre in contrast to the Chenab and Jhelum plains and the Rachna and Chaj Doabs where arsenic contamination does not exceed 50 micrograms per litre in any of the wells.

The same trend of arsenic contamination was observed in the soil in the Ravi flood plain where about 30% of the soil samples exceeded 15 milligrams per kilogram (mg/kg) as compared to the

Chenab and Jhelum flood plain, where only 4% and 1.5 % respectively reach the threshold level of 15 mg/kg. However, in individual fields, the arsenic content in soil varies both laterally and vertically, with higher arsenic concentration found in top soil closer to the well headsas compared to the outer fields; arsenic concentration was also higher in the top 20 cm of soil which is equivalent to the depth of a plough pan.

Based on the results tabulated, one field with high arsenic levels in irrigation wells in Khudpur near Lahore in the Ravi flood plain area, was selected for the next step of the study, and a sprinkler system was installed in the field. The results manifestly demonstrated that despite using the same arsenic-laden water, arsenic concentration in the soil decreased at the end of the rice growing season with the use of sprinkler irrigation as against flood irrigation. More importantly,there was a considerable decrease in the uptake of arsenic in the rice cropwith the use of sprinkler irrigation —31% in the roots, 12 % in the stem, 15 % in the leaves, and about 39% in the rice kernels.

This happens because, as mentioned earlier, when soil is flooded over prolonged periods, the soluble form of arsenic increases due to the anaerobic environment created which in turn leads to an increase in arsenic uptake and its accumulation in rice. Switching from flood irrigation to sprinkler irrigation creates an aerobic environment (one that lacks free oxygen but may contain compounds such as nitrate, nitrite and sulphites) wherein arsenic evolves into a more insoluble form thereby limiting its ability for uptake in rice.

Equally important were the findings regarding the conservation of water by the use of sprinkler irrigation. The average amount of water applied to rice by flood irrigation is about 1435 mm per acre whereas the total amount of water applied by sprinkler irrigation was 1015 mm per acre. This means that 30% water is conserved with the use of sprinkler irrigation without affecting the yield of the rice crop.

Conclusion

The problem of water scarcity in Pakistan is steadily worsening. Given the unreliability in the supply of canal water, farmers are increasingly relying on private tube wells, placing tremendous pressure on groundwater supplies. Overuse of groundwater and poor water management has led to the dropping of water tables in many areas; some studies indicate that the water table has gone down by more than 7 m in parts of the country. Agricultural technologies that conserve water without impairing production are therefore becoming increasingly important.

Rice is an obvious target for water conservation because of the amount of water it needs when cultivated under conventional methods. Failure to adapt to changing economic and environmental conditions can threaten Pakistan’s position as a major rice exporting country. To help rice growers prepare for new challenges posed by changing environmental conditions farmers need to be encouraged to move away from traditional methods of cultivation that are

heavy on the use of water and switch to the sprinkler system. This will help conserve water without compromising on the grain yield or quality. Equally importantly, it will help reduce arsenic levels in rice grown under aerobic environments and thereby significantly reduce concerns about chronic arsenic intoxication in exposed populations. At the same time it will allay any fear in the international market regarding the safety of rice exported from Pakistan.

Recommendations

Create awareness

- While finding safe water sources for irrigation is a long-term goal, there is an urgent need to raise awareness among the vulnerable population, regarding the hazards of arsenic in soil and water. Knowing the locations where arsenic concentrations is higher in their fields, i.e., in the top-soil near well heads, can help farmers make informed decisions about future cropping patterns, perhaps even shifting away from rice, taking into account potential loss of yield in the long run.
- Inform farmers and residents of the risks of using water containing elevated arsenic levels for drinking or cooking and the risk of direct ingestion of arsenic by children playing in contaminated rice fields. This will help residents protect their children from unnecessary exposure to arsenic, particularly in the Ravi flood plain.

Encourage mitigating actions

- Educate farmers/villagers in small-scale mitigation measures to reduce the accumulation of arsenic in the soil.
- The field kits used in this study for soil and water testing offer a quick, easy and cheap method for assessing arsenic levels in the soil and water. Tube well owners can be taught the use of these field kits to test well water and soil without depending on aid from outside agencies.

Switch to sprinkler irrigation

- Encourage farmers to switch to sprinkler irrigation where possible. Over a time period this will significantly reduce the concentration of arsenic in soil while helping conserve water—a pressing need of our time.