Journal Home: www.bioticainternational.com

Popular Article

Article: RT0224

Biotica Research Today

Vol 2:7 2020

611/614

Agricultural Drainage Water as an Alternate Source for Irrigation Water

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How to cite this article?

Parameswari *et al*., 2020. Agricultural Drainage Water as an Alternate Source for Irrigation Water. Research Today 2(7): 611-614.

Abstract

Intensive irrigation practices dramatically enhanced the agricultural productivity. However, these practices have also resulted in enhanced drainage water production and the ground water chemical contamination. It is generally acknowledged that the long term agricultural production in the irrigated areas depends upon the adequate system of drainage outflow and various management strategies are being currently considered for reducing the drainage volume that ultimately requires treatment or disposal. Several ways are found to be effective however; none of these could be used alone for complete disposal of agricultural drainage water. The new concept of SBC (Sequential Biological Concentration) system integrates these concepts into a system that is capable of meeting the objective of drainage water disposal. The system is one of the successive uses of the drainage water for irrigation of progressively higher salt tolerant crops to concentrate the salt and reduce the total volume of water for disposal.

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Keywords

Agricultural drainage water, Irrigation, Salinity, Salt tolerant crops

Article History

Received in 14th July 2020

Received in revised form 20th July 2020

Accepted in final form 21st July 2020

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Introduction

Reuse of the saline drainage water needs careful management for preventing potential problems like secondary salinization. Reuse through the plant-based system that reduce the quantity of waste water requiring further disposal or management. The effective control measures to salinity should be implemented for sustaining the irrigated agriculture and for preventing degradation of the existing water resources. These measures should be considered within the whole irrigation and the geohydrologic system. Some of the practices could be used for controlling salinity within crop root zone, while the others could control the salinity within the larger management units (catchments, irrigation areas). The on-farm practices generally consist of engineering and agronomic techniques applied by farmers at the field scale. The large-scale practices usually consist of the engineering structures for control of water (discharge and delivery) and the systems for collection, treatment, reuse, or disposal of the drainage water. An appropriate combination of the drainage disposal is based upon the economic, climate, hydrogeological and social factors of the region.

On-farm management of the drainage effluent are considered, tested or/and adopted in numerous places around the world. Choices of the reuse option are based on the drainage water (quality, quantity and time availability), salinity tolerance of the crop and availability of the fresh water resources. The sequential reuse of drainage water, referred as sequential reuse or SBC (Sequential Biological Concentration) system. It involves drainage water reuse on the successively more salt tolerant crops reducing the effluent volume while the salinity increases, that ultimately results in a small volume of highly saline effluent for the disposal in a small evaporation basin.

In this system, the higher quality water was used to grow salt-sensitive crop, and drainage from this operation are collected by the subsurface drains and are subsequently used for more salt-tolerant crop. This process is continued on progressively higher salt tolerant species until final residual is collected and sent to the evaporation ponds. As substantial water is used as evapotranspiration at each stage, volume of drainage water available for irrigation is progressively reduced, while salt concentration is correspondingly magnified.

Characteristics of the Agricultural Drainage Water

The drainage quality discharge depends on the nature and amount of salts present in soil profile and salinity of ground water (Sharma, 2007). The range of EC of the drainage water in some drainage projects in India are reported in Table 1.

Table 1: Drainage water quality at different locations in India

Station	EC (dS m^{-1})	Station	EC (dS m^{-1})
Karnal (Haryana)	0.5 – 0.8	Loonkaransar (Rajasthan)	3.5 – 6.5
Hisar (Haryana)	4.0 – 8.0	Segwa (Gujarat)	2.0 – 5.7
Gohana (Haryana)	3.2 – 5.8	Upper Krishna (Karnatka)	0.8 – 1.5
Sampla (Haryana)	8.0 – 27.0	Konanki (Andhara Pradesh)	1.3 – 2.4
Mundlana (Haryana)	4.1 – 6.4	Lakhuwali (Rajasthan)	4.5 – 7.4
Chambal (Rajasthan)	2.0 – 5.0	Pollachi and Udumalpet (TN)	3.0 – 3.5

(Sharma, 2007)

Agricultural drainage water is complicated by the presence of soluble inorganic and organic pollutants in addition to hazardous chemicals. Large scale systems of desalination for the agricultural drainage water needs the development of affordable pretreatment for removing soluble organic matters. The drainage water not only saline, but also contains potentially toxic trace elements like molybdenum and selenium. The ion compositions in the effluents of saline drainage are predominating in the order of Na^{+}, SO_4^{2-}, Cl, Mg^{2+} and Ca^{2+}.

Reuse of the Agricultural Drainage Water for Irrigation

In order to make reuse strategy of drainage water successful and environmentally acceptable, there arises a need for consideration of various management aspects. For instance, extra quantity of water from irrigation or resulting from a predictable rainfall in excess of that needed for evapotranspiration should be applied as a long-term strategy and done in a manner that does not adversely affect the growing crops. This would prevent higher salt accumulation in root zone. Extra quantity of the irrigation water, referred to as the leaching requirement, should be able to pass through root zone. The adequate drainage is important criteria for obtaining desired leaching requirement for maintaining soil salinity at suitable levels for crop growth. It also keeps water table sufficiently deep for permitting adequate development of, prevents net upward flow of salt-laden ground water into the root zone and allow movement and operations of the farm implements in fields (Sebastian *et al*., 2009).

The main aim behind successful use of such waters for the irrigation will be: (i) for obtaining adequate stand and the yield of appropriate salt-resistant crop, (ii) for controlling sodicity, salinity and water logging problems in soil, (iii) for maintaining soil hydraulic properties, (iv) for protecting quality of water for the long-term sustainable agriculture.

The crops vary considerably in their ability for tolerating sodicity/salinity. These intergenic differences could be exploited to select crops that produce some satisfactory yield under a given levels of root zone sodicity and salinity. The saline drainage effluent can be used in several modes without an appreciable yield reduction in the wheat crop. The oil seed crops requiring lesser water could tolerate higher irrigation water salinity levels whereas, most of pulses and the vegetables are salt sensitive. General recommendations for the successful use for saline drainage water includes crops that are semi-tolerant to tolerant (mustard, cotton, wheat) as well as crops with low water requirement must be grown whereas crops such as rice, forages and sugarcane, requires liberal water use, must be avoided.

Numerous tree plantations had been used for reclaiming sodic soils or for reusing drainage waters asirrigation source. These include: *Prosopis juliflora*, *Leucaena leucocephala*, *Terminalia arjuna*, *Dalbergia sissoo, Acacia nilotica* and *Prosopis cineraria*. The subsurface drainage provision permits the use of the saline drainage water through the surface applications. Reductions in yields were much meager in the fields having a sub-surface drainage system than in the fields with deep-water table and differences were higher at applied water salinities of more than 10 dS m^{-1}. The sub-surface drainage helped to maintain more favorable moisture regime in root zone that lead to enhanced productivity (Parameswari, 2009).

Serial or Sequential Biological Concentration System

Serial or SBC system is relatively new option for managing saline drainage water, combining both the irrigation reuse and the disposal to evaporation basin. SBC concept was initially proposed for minimizing the evaporation basins size required for the drainage water disposal with high Se contents in the San Joaquin valley, California. The SBC involves the process of irrigating crops in series of enhancing crop salt tolerance (Fig.1). The drainage water collected from beneath one crop are used for irrigating, next more salt tolerant crop in the series, with the final highly saline drainage pumped into small evaporation basin. This concentration process aims to reduce significantly the drainage water volume and therefore the size of evaporation basin required for the final disposal. Number of stages used in SBC system design will differ according to soil and irrigation water salinity, salt tolerance of plants used in the system.

Sequential reuse experiments had involved use of shrubs, grasses and trees. The tree–shrub combination by growing *Eucalyptus camaldulensis* with the subsurface drain water collected from the nearby crop lands (EC 10 dS m^{-1}, SAR 11) while the effluents from *Eucalyptus* and perimeter interceptor drain (EC 32dS m^{-1}, SAR 69) were used for irrigating *Atriplex* species. Tree plantations were successful in reducing the water table from 0.6 to 2.3 m while consumptively using saline-sodic water. But after 5 years of the drain water reuse, substantial buildup of sodicity, boron and salinity occurred throughout soil profile to extent that the trees were unable fully to extract available soil water. *Eucalyptus* is first plant species followed by *Salicornia* as second and the final species. Although *Salicornia* efficiently used saline irrigation water, yield of its oil bearing seeds were lower.

Choice of a certain reuse option under the SBC system chiefly depends on the drainage water (quality, time of availability and quantity), crop tolerance to the salinity and availability of the fresh water resources. Drainage water reuse is challenging from the perspective of the irrigation management, where water is both sodic (SAR > 15) and saline (EC 4 dS m^{-1}). Cyclic strategy of drainage water reuse involves irrigation of salt-sensitive crops with some good-quality water followed by the irrigation of salt-resistant crops with saline water. Usually, saline water is used after seedling establishment of the salt-resistant crops. After harvest of the salt-resistant crops, irrigation with low-salinity water is applied in the field to leach undesirable salts from upper portion of soil profile to provide a suitable environment for growth of subsequent salt-sensitive crops. Serial strategy is executed through developing (i) the crop rotation plan which could make the best use of available low and high electrolyte waters and (ii) irrigation plan for entire crop rotation duration that could be based on the crop tolerance against irrigation water sodicity, salinity and salt sensitivity of selected crops at various growth stages. The field studies conducted in different areas of the world involving cyclic reuse of the saline drainage water for irrigation have demonstrated that this strategy is sustainable on wide range of soils, provided the problems of poor aeration, soil crusting and tilth are dealt with an optimum management.

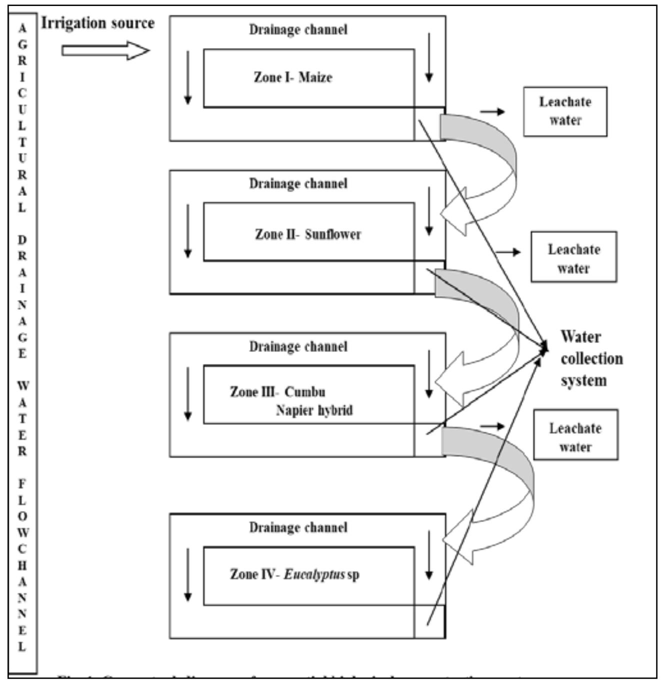

Figure 1: Conceptual diagram of Sequential Biological concentration system

The drainage water reuse in the SBC system is attractive management option that are proposed for many irrigated agricultural areas. Suitability of the crop for reuse system are based upon on the influence of $NaSO_4$ dominated water on plant sustainability mineral elements and biomass production that are chiefly important for the forage quality. Implementation of reuse of the drainage water system needs sustainable cropping system that incorporated useful salt tolerant agronomic species.

The SBC systems for management of the drainage effluent are unlikely to function effectively in the areas with deeper water table levels or/and deep, permeable profiles underlain by the aquifers. The large components of leachate could by-pass tile drains and escape to greater depths in profile, thus making systems operate poorly. A field study that are conducted at red rock ranch, where most of the fields had been irrigated with the drainage water for 5 to 6 years and soils were in poor physical condition. In that study, the tall wheat grass grew well under the highly saline conditions (18–20 dS m^{-1}), as well as the creeping wild rye in the field with lower salinity. The salt tolerant alfalfa cultivars (*Medicago sativum*, mix of vars. 'Salado' and '801S') also grew well and forage quality were very high, but only under irrigation with non-saline or blended drainage water resulting in the soil salinity less than 7 dS m^{-1} of EC_e.

Multi-year field study resulted as, the plant species *viz*., *Lactuca sativa, Lycopersicon esculentum, Helianthus annuus, Medicago sativa*, *Gossypium hirsutum*, *Distichlis spicata*, *Salicornia bigelovii* and *Brassica napus*, grow well under the drainage water reuse system. The drainage water quality reduced along water reuse path, with some sulphate dominated salinity change from, EC 4.5 dS $m^{-1}$to 15.2 dS m^{-1}; soluble boron from 3.4 mg L^{-1} to 14.5 mg L^{-1} and soluble Selenium from 0.08 mg L^{-1} to 1.18 mg L^{-1}. The soil salinity and the concentration of selenium and boron enhanced with decreased quality of the reused drainage water.

Conclusion

Agricultural drainage water under Sequestional Biological Concentration system may be used as irrigation source by integrating the organic amendments along with the inorganic fertilizers for saline tolerant crops may result in better crop production.

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