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REVIEW ARTICLE

Eco-friendly utilization of wastewater in agriculture

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SUMMARY : The availability of water is unevenly spread across the country and there is an urgent need to utilize the alternate sources of water for agriculture in order to meet the demand. Increasing industrialization and urbanization in India has brought in its wake the major problem of safe disposal of wastewater. Good quality of water is inadequate when for normal living and is getting polluted due to industrial discharge including those of distilleries, paper and pulp, tannery, textile and other industries. Hence, efforts should be made in future for proper treatment and safe disposal of wastewater and use in agricultural land in order to increase our food grain production and enhancing environmental quality. Characterization of wastewater of various industries, effect of wastewater use on soil and crops and management strategies to be adopted has been reviewed hereunder.

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The rapid industrialization in developing countries had led to tremendous pressure on the available finite water resources. This phenomenon is quite evident in the areas where water intensive industrial units like distilleries, paper and pulp, tannery, textile, etc., thrive rapidly. Among the various kinds of pollution caused by industrialization, the problem of water pollution due to industrial effluents has attained greater dimensions in India. Indiscriminately discharged industrial effluents naturally affect the water quality as well as natural ecosystem. In India, the estimated per capita water availability has also declined from 6008 m^3 a year in 1947 to 2266 m^3 in 1997 (TERI, 1998). This declining figure gives a broad indication of the growing water scarcity in the country in the last 50 years since independence. Therefore, these problems can be overcome by means of proper utilization of wastewater because the wastewater acts as source of plant nutrients, irrigation and thus alleviate the food grain demand.

Need for utilization wastewater in agriculture :

A number of industries produce large volume of wastewater requiring proper disposal. Lack of suitable treatment technologies and disposal facilities is a major hindrance to industrial expansion. The recycling options of wastewater includes land application, use in irrigation, forestry, application to constructed wetlands or artificial marshlands. Sometimes, industries produce highly toxic effluents, which can neither be thrown into water bodies not used for agricultural purpose as the toxic elements may enter the food chain through plants, animals and fish. Wastewater of some industries has useful characteristics and has the potential to improve soil productivity (Kansal, 1994). This effective management of wastewater brings economic benefits and protects fragile ecosystems from degradation. Thus, the following are the objectives for utilization of wastewater for agricultural purposes:

- Increasing demand of water for agricultural purposes.
- Irrigation to crops in areas where water is scarce.
- Recycle it as irrigation water due to its possible nutrient value.
- Disposal problem of industrial effluents.

Characteristics of different industrial wastewater:

Mainly distilleries, paper and pulp, tannery, textile, food processing, meat processing, coir, printing, chemical and fertilizer industry effluents are the major potential sources of wastewater discharge. The characteristics of different industrial wastewater (Table 1) discharged from industries of varying nature and households vary according to their sources.

Wastewater utilization :

Large and regularly produced industrial wastewater are recycled or reused for different purposes after proper treatment. Its common uses are in agriculture for irrigation as well as crop fertilization, application for forest land, in land reclamation and other related uses. These effluents supply major and minor nutrients required for plant growth as well as supply water requirements for crop growth.

Distillery effluents :

Sugar industry is mushrooming as a result of which large amounts of molasses are produced every day. This by-product is used as a feedstock in alcohol industries. During the process of distillation, huge quantities of distillery wastes known as spent wash are produced and there is disposal problem of this waste. In distillery industry, for the production of every litre of alcohol, 12-14 litres of effluent is discharged. So, every distillery unit is discharging 5-10 litres of effluent every day (Devarajan and Oblisami, 1995). The total effluent generated by 205 distilleries in a year amounts to nearly 40 billion litres, which can provide 52,000 t of N, 8,000 t of P and 4,80,000 t of K annually. Thus, the manurial value of this effluent can profitably be used as supplement to the fertilizer when used along with irrigation water in proper dilution. This will solve the twin problem of disposal and also substitute some quantity of fertilizer (Joshi *et al.*, 1996). The effluent when diluted suitably (1: 10 to 1: 50) reduced its BOD and EC amenable for irrigation to crops. The nutrient of soil and yield of crops were increased and there was no adverse effect on soil physical, chemical and biological properties (Augustine Selvaseelan *et al.,* 2001).

Devarajan and Oblisami (1995) reported that the distillery spent wash application in rice increased the availability of N, P, K, Ca, Mg, micronutrients and organic matter contents in soil. Rajukannu *et al.* (1996) revealed that application of distillery spent wash @ 5 lakh lit ha^{-1} to the air-dried non-saline sodic soil followed by two or three leachings with water, could effectively reclaim sodic soil and suggested a fair period of 60 days from the days of its application and transplanting of rice seedlings for the establishment of crop. Mohamed Haroon and Subash Chandra Bose (2004) reported that the untreated distillery effluent at the rate of 0.15 million lit ha^{-1} can be used as an amendment for the reclamation of non-saline, calcareous alkali soil.

Joshi *et al.* (1996) reported that effluent treatment at 20% dilution with 50% NP application had shown the best yield (5.3 t ha^{-1}) in case of maize, saving 50% N and P and 100% K. Rajukannu *et al.* (1996) reported that application of distillery effluent to sodic soil significantly increased the number of productive tillers and grain yield of rice. Rajannan *et al.* (1998) reported that irrigation with 50 times diluted spent wash recorded higher juice purity, brix and yield of sugarcane CoC. 771 and also reported that distillery spent wash at 40 to 50 times dilutions increased the yield of banana, oilseed crops and rice. The maximum grain yield was recorded in rice variety

Table 1 : Characteristics of different industrial wastewater

Parameters	Units	Distillery[1]	Paper and pulp[2]	Tannery[3]	Textile[4]	Sewage[5]
pH		8.9	8.4	7.0-9.0	9.8-11.8	8.00
EC	dSm^{-1}	27.5	1.6	-	8.0-10.0	1.15
BOD	mg lit^{-1}	40000	175	1000-3000	680-840	2108
COD	mg lit^{-1}	102000	1439	2500-4000	1160-1790	1720
TS	mg lit^{-1}	92505	1818	-	5112-7180	3900
TDS	mg lit^{-1}	5975	1044	11000-16000	-	-
TSS	mg lit^{-1}	86530	774	2000-4000	155-1950	-
Nitrogen	mg lit^{-1}	1988	20 (ammonical)	-	45-50	196
Phosphorus	mg lit^{-1}	428 (Phosphate)	3	-	20-25 (Phosphate)	2.24
Potassium	mg lit^{-1}	10010	12	-	1.2	-
Chloride	mg lit^{-1}	10400	776	6000-9500	300-570	8.60 (Cl)
Sulphate	mg lit^{-1}	2980	384	2400-4000	660-1600	-
Sodium	mg lit^{-1}	640	575	-	78.7	-
Chromium	mg lit^{-1}	-	-	7.2-26.2	-	-
Oil and grease	mg lit^{-1}	-	-	1.5-4.0	-	-

TSS - Total suspended solids, TDS - Total dissolved solids, TS - Total solids,
[1]Devarajan and Oblisami (1995), [2]Pushapavalli (1990), [3]Mahimairaja *et al.* (1998), [4]Ramachandran (1994), [5]Ramanathan *et al.* (1977).

ADT 42 due to 75 times diluted distillery spent wash treatment, which was on par with 100 times diluted spent wash applied plot (Chinnusamy *et al.*, 2001).

Paper and pulp mill effluent:

Paper and pulp industry is one of the largest consumers of water and most of the water used is discharged as a waste. In India, there are about 305 paper mills with an installed capacity of 3014 lakh tones of paper. A quantity of 90, 000 gallons of water is required to produce one tonne of paper and the discharge of effluent is upto 80,000 gallons (Dubey and Joshi, 1980). Liquid wastes such as brown stock wash, caustic extractions and combined chlorination of hypochlorotic wastewater are produced in large quantities during the manufacturing of paper in the kraft paper mill. The effluent is alkaline and rich in organic and inorganic compounds. Disposal of this wastewater has been a problem as it contains high amounts of suspended solids, high BOD, COD and lignin. At the same time, agriculture is in need of water for irrigating lands. Paper mill waste water through crop irrigation seems to be an appropriate approach as soil has capacity to retain the lignin and coloured bodies through its physico-biochemical reactions besides providing water for agriculture (Solaimalai *et al.*, 2002).

The soil amendments had a favourable effect on the P and K uptake of rice in acid soil. The use of 50% diluted clarified effluent was found superior to raw effluent irrigation more particularly in neutral soil (Velu *et al.*, 1998).The application of paper and pulp mill effluent to sugarcane tended to increase soil enzyme activities like amylase, invertase, cellulase, dehydrogenase and phosphatase. More microbial activity in the rhizosphere was observed in the plants irrigated with 50-75% effluent concentration. The retention of moisture necessary for growing sugarcane in sandy soils with effluent irrigation was attributed to humification and mineralization of organic matter (Augustine Selvaseelan *et al.*, 2001). Paper mill effluent irrigation also increased the beneficial organisms like *Azospirillum*, *Azotobacter* and *Rhizobium* (Dhevagi *et al.*, 2003).

Narasimharao and Narasimharao (1992) found that paper mill effluent water could be safely used for irrigation of rice and cotton on alluvial soil having loamy to sandy loam texture as these crops are tolerant to salinity and are able to give economic yields in these areas. But irrigation of tobacco and chilli with this paper mill effluent water led to poor quality produce and reduced crop yield. In rice, the grain yield was increased due to effluent irrigation by 25% than that of well water irrigation. Effluent tended to decrease the calcium uptake of rice in neutral soil and increased the Na uptake in acid soil. Better germination percentage, shoot and root length and vigour index of seedlings at 75, 50 and 25% of treated effluent were observed in maize, blackgram, greengram and soybean (Dhevagi, 1997).

Tannery effluents:

Tanning industry is one of the major sources of pollution as it disposes large quantities of effluents rich in chromium and sodium into rivers and on land (Naidu and Mc Laughlin, 1993). In India, 17,000 tonnes of hides are converted into leather per day. For producing one kg of finished leather, the tanning industry lets out 30-35 L of effluents with high load of chromium, sodium, calcium, ammonium, magnesium, sulphates, chlorides and bicarbonates with organics like fats, dyes and acids (Singaram, 1995).

Effect of tannery effluent dilutions with well water irrigation with and without trash mulch on millable cane production revealed that maximum population of 1,32,000 millable canes ha^{-1} was recorded by well water irrigation and it was followed by 1,17,000 ha^{-1} in tannery effluent dilution with well water in 25:75% combination. Cane length and yield were also in similar trend (Kathiresan *et al.*, 1998). Non-edible crops like flower crops may be suitable for tannery effluent irrigation since the risk of heavy metals entering into the food chain is largely avoided. Growth and marketable flower yield of crops were significantly higher with 50% tannery effluent followed by 100% tannery effluent irrigation than well water irrigation. The crops *viz.*, GundumaIli, JathimaIli and Tuberose showed a high degree of tolerance towards sodicity caused by tannery effluent irrigation, whereas Nerium was found relatively sensitive towards tannery effluent irrigation. Root crops accumulated more chromium and sodium followed by leaves and flowers suggesting that Cr was less mobile within plant (Mahimairaja *et al.*, 1999).

Irrigation with tannery effluent impaired soil productivity and inhibited biological activities of soil microbes at high concentration, when effluent was diluted with water and used for irrigation, it acted as a growth adjutant and simultaneously helped in disposal of a part of the wastewater (Augustine Selvaseelan *et al.*, 2001). Kumaran *et al.* (2003) reported that eucalyptus, casuarina, pungam and neem trees were well established in tannery effluent affected areas and teak establishment was poor. Grain yield of maize was increased with increase in dilution of tannery effluent upto 50 times and applications of amendments especially composted coir pith at the rate of 25 t ha^{-1} (Thangavel *et al.*, 2003).

Textile effluents:

Textile industries use large quantity of water during the manufacturing of fabric. The average quantity of water used to process 1 kg fabric is 150-200 litres. Much of these waters will come out as wastewater. In the process of boiling, bleaching and drying, various chemicals such as soda ash, caustic soda, HCl, H_2SO_4, sodium peroxide, hazardous polluting organic chemicals apart from high concentrations of various cations, anions and heavy metals.

Jothimani *et al.* (1998) studied the response of green gram (CO 4) to bio treated dye factory effluent (bio-fungal, bio-bacterial, chemical, chemo+bio-fungal and chemo+bio-bacterial) in clayey loam soil and reported that chemo and bio treated effluent recorded significantly higher symbiosis, vigour index, number of pods plant^{-1}, root and shoot length. Application of diluted effluent improved the groundnut germination and increased the chlorophyll, carbohydrate and protein contents and the biologically treated effluent enhanced the yield and quality of many cereals and pulses. This effluent when passed through fly ash can be safely used for afforestation (Augustine Selvaseelan *et al.*, 2001). Increase in soil pH, organic carbon, calcium and sodium concentration and decrease in water holding capacity due to addition of textile effluents have been reported. The soil flooded with dyeing factory effluents contained more N, P and K content when compared to other soil (Solaimalai *et al.*, 2002). Vijayakumari (2003) reported that dilution of textile effluent and water (25:75) resulted significantly in higher germination percentage, vigour index, shoot and root length of soybean crop.

Sewage effluent:

Sewage includes wastewater from residents, commercial buildings and institutions such as schools and hospitals. The volume of sewage effluent varies from country to country depending upon the standards of living, human habits and availability of water supplies. In India, about 3800 m.lit of sewage water is available every day which can provide about 0.3 million tones of NPK (Bhardwaj and Gaur, 1985).

Ramanathan *et al.* (1977) reported that application of sewage effluents resulted in a considerable increase in hydraulic conductivity value of 6.27 cc h^{-1} non-capillary porosity 16.20%, total porosity 58.20% and aggregate stability 50.50% as compared to well water irrigated field. Application of sewage effluent resulted in marked increase in soil organic carbon content (1.02 and 0.97%) compared to ordinary water (0.72 to 0.65%) during the first year as well as in the second year experiment, respectively, and also increased the green fodder and dry matter yield of BN 2 hybrid grass (Malarvizhi and Rajamannar, 2001). Chandrasekaran and Rajkannan (2003) found that water holding capacity of soils was found to be increased by the continuous application of sewage irrigation.

Other industrial effluents:

In addition to utilizing the wastewater released from distillery, paper and pulp, tannery, textile and sewage, the effluents of fertilizer, zinc smelter, photofilm factory and dairy plant effluents can also be used for irrigation.

Application of fertilizer factory effluent to the soil resulted in significant increase in nutrient contents of the soil. Irrigation with 2.5 and 5% effluents of fertilizer factory wastewater enhanced the growth and development of rice (Augustine Selvaseelan *et al.*, 2001). Zinc smelter effluent, when diluted with well water, had no adverse effect on germination of common *Kharif* crops like maize, sorghum and blackgram and *Rabi* crops like wheat, barley and mustard (Totawat and Chauvan, 1992).

Application of diluted photofilm factory effluent slightly inhibited the seed germination, seedling development, reduced the chlorophyll content and carbohydrate and protein synthesis in crops like maize, sorghum, etc. (Manonmani *et al.*, 1992).

The effect of various concentrations of dairy effluent of seed germination of wheat, gram, oat, berseem, pearl millet and sorghum was studied and found that germination percentage was maximum in 25% dairy effluent concentration (Gautam *et al.*, 1992).

Management techniques for irrigation with wastewater are given below :

Gypsum application:

Due to its low solubility (0.25-0.30%) and cost, gypsum is suitable for correcting a favourable Ca : Na ratio or Ca : Mg ratio.

Leaching:

It is the fraction of irrigation water that must be leached through the root zone of the crop to keep the salinity of the soil below a specific limit.

Crop selection:

To overcome the toxicity and other hazardous problems, selection of suitable crops is important. Salt tolerant crops like barley, cotton and sugarbeet are moderately tolerant. Crops like safflower, wheat, soybean, etc. can be grown if irrigation water is saline. Crops like datepalm, sugarbeet and berseem, etc. can be grown if irrigation water is more of boron.

Sowing on the side of the ridges is advisable.

Fertilizer application:

Additional dose of inorganic N does not change salinity tolerance and the response is rather reduced. Addition of phosphorus reduces the toxicity of chlorine.

Method of irrigation:

Poor quality water is not suitable for use in sprinkler irrigation. Less application of saline water with frequent interval results in restricted salt build up. Any flood irrigation system involves complete coverage of the soil surface with treated effluent and is normally not an efficient method of irrigation. This system will also contaminate vegetable crops growing near the ground and root crops and will expose farm workers to the effluent more than any other method. Thus, from both the health and water conservation points of view, border irrigation with wastewater is not satisfactory. Furrow irrigation, on the other hand, does not wet the entire soil surface. This method can reduce crop contamination, since plants are grown on the ridges, but complete health protection cannot be generated.

Drainage:

In order to maintain a satisfactory salt balance in the root zone, excellent drainage of soil is most essential.

Overaged seedlings:

Transplantation of rice with overaged seedlings is better establishment in salt affected soil which results in better establishment.

Mulching:

Mulching with locally available plant materials helps in reducing the salt affected problems by reducing the evaporation and by increasing infiltration. Salts are leached into lower layers even with rainfall by application of mulches.

Crop rotation:

Inclusion of crops such as rice in the rotation reduces salinity.

Conclusion:

The ever-increasing demand for food, fuel and fodder by a growing population and urbanization, call for a quantum jump in agricultural production. But this challenge is to be met without degrading land and water resources of the country. A need has arisen to use the alternate sources of water for agricultural purposes in order to meet the demand and supply gap without polluting the environment. Utilization of treated industrial effluents is having a greater potential to solve both these problems. Proper treatment of effluents and agronomic management strategies has to be developed by holistic and multidisciplinary approach to suit the each polluted area for using the land water resources effectively on a long term basis. The basic approach should be made to increase the agricultural productivity on the one hand and to avoid soil sickness and health hazards on the other hand. Generally, it has been observed that treated wastewater when used in low concentration with canal/tube well water will have an encouraging effect on crop growth and yield.

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