INVESTIGATIVE STUDIES ON IMPACT OF WASTE WATER IRRIGATION ON SOIL CHARACTERISTICS AND CROP QUALITY

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ABSTRACT

In many arid and semiarid countries, water is becoming a scarce resource and planners are forced to consider any source of water which might be used economically and effectively to promote further development. At the same time with population expanding at a high rate, the need for increased food production is apparent. The potential for irrigation to raise both agricultural productivity and living standards of the poor has long been recognised. In this background, need for alternate water resource for agriculture is gaining attention. One such alternative is reuse of wastewater for irrigation. Many countries have included wastewater reuse as an important dimension of water resources plan.

The farmers are encouraged to irrigate the fields even with industrial effluents. Nevertheless, accumulation of toxic metals on land receiving these wastewaters are of public concern, because of possibilities of their entry into the food chain. Thus, to minimise the threat of land and ground water contamination, in depth studies/care is required to be taken before recommending usage of industry effluents for irrigation.

To overcome these problems, in using wastewaters especially industrial effluents for irrigation, there has to be sound planning and careful management. The new methods of using industrial effluents for planned irrigation with an emphasis placed on conservation and on agricultural utilisation is a new development. While new methods have proved workable in the last two decades, there are still many problems of worthy of investigation. Furthermore, the quality of discharge which varies from industry to industry is required to be assessed for its suitability for irrigation and long-term sustainability.

Keywords:Crops , waste water, soil quality

I. INTRODUCTION

In the struggle by modern industry to eliminate the effects of pollution, up to recent period greater priority has generally been given to treat the waste by conventional and non- conventional methods and discharge the same to waterways by keeping in mind the protection of receiving water bodies.

The discharge of such wastewaters on land for irrigation is now beginning to cause concern. The researchers in the engineering field and agricultural scientists hoping that the problem like pollution of nearby receiving bodies due to run off from agricultural fields where in industrial wastewaters are used for irrigation, changing soil properties due to prolonged use of industrial wastewaters for irrigation, quality and yield of crops affected by toxics and metals present in wastewater, associated health risks on farm workers and possibilities of ground water pollution due to infiltration of contaminants in wastewaters are to be properly addressed before opting irrigation by industrial wastewaters and to solve existing water problem for irrigation.

They further opined that these problems are not new but have increased in magnitude in recent years and thereby felt that the proper planning and management of industrial wastewater on land for irrigation is very much required and is the need of the day.

The stringent implementation of zero discharge concepts for industrial wastewater by authorities, shortage of conventional water sources for irrigation, increase in population and thereby abnormal increase in food demand resulted to think ofdisposal off industrial wastewater on land for irrigation. Many industries especially food and allied industries like

Sugar and Distilleries, the wastewaters of which are rich in organic and nutrient contents, were found to be amicable for use as irrigation water. However, one has to evaluate the beneficial and harmful effects of using such water for irrigation on various components of ecosystem, before suggesting the use of such wastewater for irrigation. Many researchers to date have carried out studies covering these aspects, especially with reference to municipal wastewaters (sewage).

II. Objectives of the Study

Hence it was thought off to carryout research studies to infer the feasibility of using selected industrial wastewaters for irrigation so that reusing of wastewaters will be environmental friendly. Hence the research topic titled "Investigative Studies On Impact Of Waste Water Irrigation. On Soil Characteristics and Crop Quality" was defined with the specific objectives viz:

- To characterize selected industrial effluents, borewell water and soil to be used for experimentation.
- To study and compare the changes in physio-chemical and microbial properties of soil irrigated with industrial effluents and borewell water.
- To assess the impact of wastewater application on germination period and crop yield characteristics.
- To workout possibilities and economics of reusing industrial effluents for irrigation - A case study.

III. BENEFIT OF WASTEWATER REUSE FOR IRRIGATION

Environmental improvements of benefits accrue as a result of several factors including:

- Prevention of surface water pollution, which would otherwise occur if the wastewaters were not used but were discharged into rivers or lake.
- Conservation of fresh water resources, by their rational usage, especially in arid and semiarid areas. Freshwater for urban demand and wastewater for agriculture use.
- Reduction in the degree of ground water exploitation, sea water intrusion in coastal areas.
- Reduction in the requirements for artificial fertilisers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere, those plant nutrients that may eventually pollute the environment if raw wastewater or treated effluent were discharged directly into the environment may serve as usable plant nutrients when applied as irrigation water.

IV. RISKS WITH WASTEWATER IRRIGATION

Based on review findings, various risks associated with using untreated wastewater are:

- Various intestinal diseases are likely to enter food chain through crop, soil and groundwater.
- Certain toxic element present in domestic/industrial wastewater can cause adverse effects on soil and underground aquifer.
- Cooking and keeping quality of vegetables grown with sewage irrigation is adversely affected.
- Clay content in the top layer of soil is reported to increase due to continuous sewage irrigation.
- Vegetables eaten raw; salads, fruits, etc., irrigated with wastewater can lead to variety of diseases in human being.
- Farm workers exposed to raw sewage are more prone to intestinal diseases caused by hookworm, helmenthis, etc.

V. AGRICULTURAL VALUES OF SEWAGE

Cultivated plants require for their growth good mellow top soil containing humus and moisture, a certain amount of nutrients, sunlight, and air. Climate plays an important role and good tillage takes care of the soil. Sewage as applied to land has a fourfold value, for it contains the major fertilizing elements, micro-nutrients (trace elements), organic matter and water. Plant nutrients of importance, such as the major elements like nitrogen, potassium, and phosphorus and the many minor elements, including sulphur, magnesium, calcium, iron, manganese, boron, zinc, copper, etc., are present to some in sewage. Many of these nutrients are in soluble, immediately available form. Soil structure and drainage determine to a large extent, the utilization by the plant of these nutrients by determining the magnitude and vector of a root system.

VI. MATERIALS AND METHODOLOGY

The materials and methodology adopted to carry out the present research work in accordance with the objectives framed as The discussions made include:

- Waste waters considered
- Crops selected for study
- Soils adopted for research
- Treatments adopted
- Dosage of water
- Experimental setup
- Parameters related to agriculture
- Germination studies
- Parameters analysed
- Case study

A. WASTEWATERS CONSIDERED

Two industries Viz. Sugar mills and Distilleries, the wastewaters of which are rich in organic content and also contain nutrients required for crops were considered for experimentation. The disposal of these two wastewaters by conventional methods were found to be not economical and hence presumed that the land application of these wastewaters for irrigation will be techno-economically feasible. These wastewaters were collected from nearby Sugar mill and Distilleries.

B. CROPS SELECTED FOR STUDY:

Based on mode of growth and consumption by the consumers, the following four crops were selected for the present study:

- Tomato
- Radish
- Brinjal
- Chilly

C. SOILS ADOPTED FOR RESEARCH

Three soils of different classes were selected to assess the feasibility of soils for irrigation with industrial wastewaters. Samples were collected from nearby agricultural fields.

D. TREATMENTS ADOPTED

The following treatment conditions were tried in the present study to assess the change in physio-chemical properties of soil and also to access yield of crops, accumulation of nutrients and metals.

- Irrigation with borewell water -Tl
- Irrigation with Sugar mill wastewater (SMWW) -T2
- Irrigation with Distillery wastewater (DWW) -T3
- Irrigation with mixing SMWW + Sewage (l:1) -T4
- Irrigation with mixing DWW + Sewage (l:1) -T5

E. DOSAGE OF WATER

For each crop, for a selected treatment condition and a soil type, to begin with water was applied until the germination. The seeding was done on a soil which was in well tilled, saturated and drained condition. Further the dosage under varied experimental conditions was applied at regular intervals based on the wilting condition of the crops. The dosage was applied each time until the soil was saturated. The frequency of dosage varied from crop to crop and growth stage of the crop. The water/wastewater, whose properties were pre-determined, were dosed at each time and the total quantity applied up to harvesting were recorded.

F. EXPERIMENTAL SETUP

Experimentations were carried out under natural atmospheric conditions and to simulate actual field conditions. Circular pots of diameter 300 mm and depth 203 mm were used.


Fig.I Initial stage of plants Fig. IIAdding Manures and

Sludge to the plants

Fig.III - watering the plants

Fig. IV Flowering period of Brinjal

G. PARAMETERS ANALYSED

The wastewaters, soil samples, crops after harvesting were analyzed as per the standard procedures. The details are summarized below:

- The wastewaters were analysed for various parameters of agricultural importance viz. pH, EC, total solids, organic contents, nutrients and metals as per standard methods.
- To test and classify the soil, the soils were subjected to sieve analysis. The soil samples were also analysed for the physio-chemical properties, metal concentration before seedling and at the end of harvesting.
- Crops samples were collected after harvesting and were analysed for the properties to assess metal accumulation etc.

VII. SOIL CHARACTERISTICS

Soil samples collected from three different sources were analysed for their geotechnical properties and physiochemical properties of importance. The corresponding results are respectively tabulated in Table I.

Table I : Geotechnical Properties and Classification of Soils

S.N	Parameters	Soils		
		Soil I	Soil II	Soil III
1	Field density In place density (gm/cc) In place dry density (gm/cc)	1.68 1.98	1 78 1.70	1 87 1.71
2	Specific gravity (G)	2.68	2.64	2.60
3	Differential free swell (%)	14.00	20.00	5.00
4	Liquid limit (%)	26.00	30.44	21.25
5	Plastic limit (%)	20.00	22.82	Non-plastic
6	Plasticity Index (%)	6.62	7.62	Non-plastic
7	Permeability (cm/sec)	$1x10^{-7}$	$0.78 x10^{-3}$	$0.81x10^{-3}$
8	Compaction Test (Light) Y_{dmax} (gm/cc) OMC (%)	1.75 11.00	1.94 13.20	1.83 11.30
9	Hydrometer analysis % Clay %Silt	- -	18.90 10.10	5.00 27.50
10	Direct Shear Test C (kg/cm^2) ø (Degree)	0.40 40^0	0.25 30^0	0.21 30^0
11	Sieve analysis % of Gravel % of Sand % of Silt and Clay C_u C_c	46.8 24.1 29.1 4.8 2.1	2.20 68.80 29.00 2.52 0.92	8.50 59.00 32.50 2.40 1.25

	Soil Classification	Gravely soil	Clayey Soil	Silty Soil

A. CHARACTERISTICS OF WATER AND WASTEWATER

Two wastewaters viz: DWW and SMWW were used for experimentation. Further to take care of availability of wastewater during the seasons when Sugar mills and Distilleries will not be working, feasibility studies by mixing these wastes separately with sewage in 50 % each were also used for experimentation (T4 and T5).

Table II : Physio-Chemical Characteristics of various waters used

Parameter	Borewell Water	T1	T2	T3	T4
pH	7.23	6.80	5.58	4.37	6.39
EC,µmhos/cm	790.00	2177	717	Nil	1948
BOD, mg/l	Nil	112.13	910	43520	500
DO, mg/l	7.80	0.63	Nil	Nil	0.32
Total Nitrogen,mg/l	0.2	10.3	27.3	1110	18.83
Nitrate Nitrogen, mg/l	0.12	8.83	22.5	753.3	15.77
Phosphate,mg/l	0.08	3.88		38.00	4.65
Calcium, mg/l	15.0	174	86.33	8.50	131.17
Potassium mg/l	1.20	18.62			9.33
Carbonate, mg/l	NO	76	75.83	Nil	
Chlorides, mg/l	72	348			
TDS, mg/l	803	2222	709	8236	
Iron, mg/l	0.25	2.13	1.50	Trac	
Copper, mg/l	0.50	1.57			
Manganese, mg/l	0.65	1.38			
Zinc, mg/l	0.42	0.60	0.28	Trac	

The following observations were made.

- The pH of 7.23 was recorded in bore well water. These pH values corresponding to treatment T2, T3, T4, T5 were respectively 5.58, 4.37, 6.39 and 5.79.

- Borewell water was found to be free from organic content. The high organic content (BOD) was noted in DWW (43560 mg/l) followed by T2 (800 mg/l). The BOD values of 43520, 500 and 21843 were recorded in sewage, T4 and T5 respectively.

VIII. RESULTS AND DISCUSSIONS

Under varied experimental conditions viz: Soil and treatmenttypes, crop cycle, crops grown, the growth characteristics viz: leaf number and plant height were recorded and feasibility/suitability of treatment types adopted with respect to these two parameters are discussed in further subsections. The effect of treatment type on germination percentage of various crops considered for study is also discussed under this section

A. EFFECT ON LEAF NUMBERS

Leaf numbers per plant with different crops and crop cycles grown in pots using three different soils for different treatments employed were counted (Mean of 3 replications) and recorded in Tables 5.1 to 5.5. For clarity of discussions, the results are also represented by bar charts (Fig5.1 to 5.5). Based on the observations following inferences have been drawn.

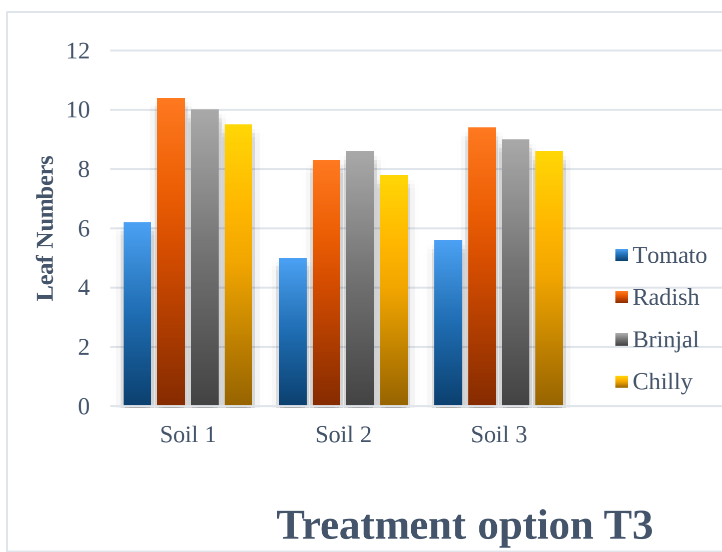
Crop	Leaf Numbers/Plant		
	Soil-I	Soil-II	Soil-III
Tomato	5.30	3 .64	4.5
Radish	9.2	7.5	8.6
Brinjal	7.9	7.0	7.3
Chilly	8.2	7.2	7.7

Crop	Leaf Numbers/Plant		
	Soil-I	Soil-II	Soil-III
Tomato	6.85	6.00	6.57
Radish	11.0	9.5	10.35
Brinjal	10.5	9.3	10.2
Chilly	10.6	8.3	9.5

Table III : Effect on leaf number (On Harvesting: Mean of 3 Replications): Tl

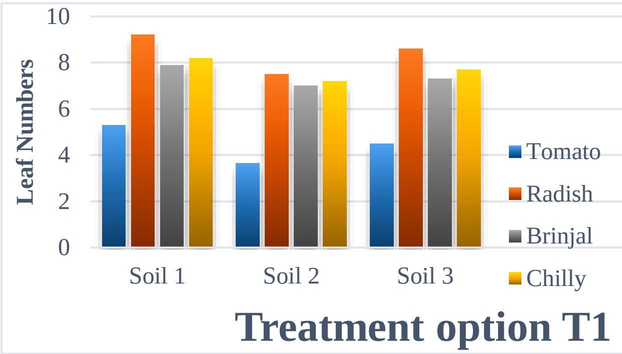
Table IV : Effect on Leaf Number (On Harvesting: Mean of 3 Replications):T2

Crop	Leaf Numbers/Plant		
	Soil-I	Soil-II	Soil-III
Tomato	6.30	5.41	5.82
Radish	10.4	8.6	9.4
Brinjal	9.5	8.3	9.0
Chilly	9.7	7.6	8.5



Generally, from the results it was found that leaf numbers per plant for all varied experimental conditions increased from crop cycle I to III. Logically, it was inferred that this increase in leaf number from cycle to cycle may not follow the same trend with continuous application of wastewaters on soils. The leaf numbers per plant for a given treatment and soil type and for a particular crop has to attain certain constant value reaching saturation.

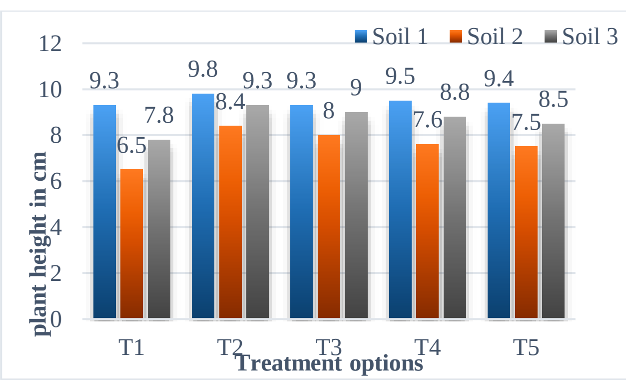
Leaf numbers per plant grown in soil I with Treatment T2 for crop Radish corresponding to crop cycle III was 11 and was 9.2 for Treatment T1. The corresponding values for soil II were 9.5 and 7.5 respectively.



Accordingly, for Tomato, wherein least leaf numbers per plant were observed were respectively 6.85, 5.30 and 6.0 and 3.64. Thus for the given characteristics of wastewaters and soils used, the best possible sequence of feasibility was recorded and is as follows: Gravely soil > Clayey soil > Silty soil, T2>T4>T3>T5>T1, Radish >Brinjal>Chilly> Tomato.Also, from observations, it was inferred that Sugar mill wastewater and its combination with sewage can be more effectively reused for irrigation/farming.

Effect on Plant Height

Another best indicator to evaluate the feasibility of reusing wastewaters for irrigation is plant height. Thus, plant heights on harvesting of each crop cycle under varied experimental conditions were measured. The Table 5.6 summarizes the effect on plant height so observed. The Figures 5.6 to 5.90000 throws light on effect of soil type and trea1111tments adopted on plant heights of crops grown. The trends similar to leaf numbers have been observed. Thus it was inferred that the factors influencing the leaf numbers were also affecting the plant height. With treatment T2 and soil I (optimum combination), the plant heights are 27.5, 17, 35.5 and 9.8 cm for Radish, Brinjal, Chilly and Tomato respectively. Obviously the height of Chilly plant even though recorded as highest by its natural growth compared to the other crops considered, the relative sequence was



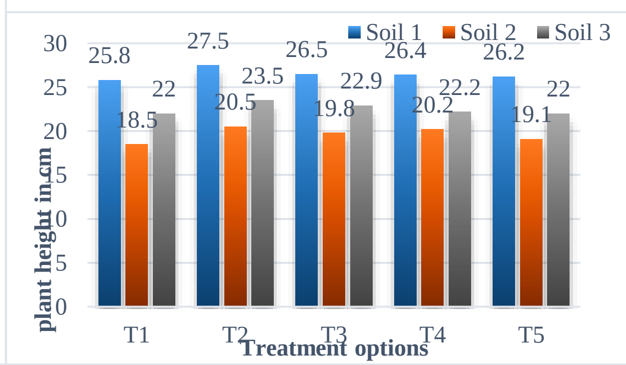


Chart I : Plant Height on Harvesting: (Crop: Radish)Chart II : Plant Height on Harvesting: (Crop: Brinjal)

- considered similar to that of leaf numbers, 25.8, 16.4, 34 and 9.3 cm were the plant height of Radish, Brinjal, Chilly and Tomato respectively with treatment T1.

- The soil II which exhibited the least growth feasibility compared to other two soils under all the treatments adopted. 20.5, 30.8, 25.4 and 8.4 cm were the plant heights for Radish, Brinjal, Chilly and Tomato respectively with treatment T2. These values with Tl were 18.5, 10.2,22.8 and 6.5 cm.
- **Effect on Germination Percentage:**

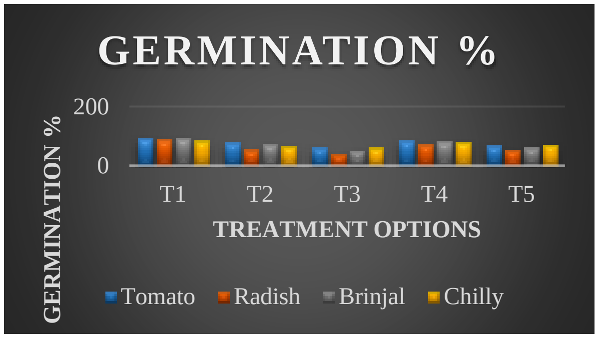


Chart III : Effect on germination percentage

To evaluate the effect of reusing the different wastewaters and combination and with control (T 1) on germination percentage, the experiments were carried out in the laboratory as quoted in Chapter Ill. The results so obtained are summarized in Table 4.16 and are also shown in Fig. 4.10. The results indicated the better germination percentages with treatment Tl (control) followed by T4, T2, T5 and T3. It was inferred that the pH plays an important role on germination percentage. The inverse relationship between pH and germination percentage has been observed. The germination percentages recorded for Brinjal (highest) for treatments Tl to T5 were respectively 97, 77, 55.5, 84.6 and 65.5% Corresponding values for Chilly (least) are respectively 88.3, 70, 65.5, 82.5 and 73 4%

XI. CONCLUSION

Water is a crucial factor for ensuring good harvest, therefore farmers are encouraged to utilise all available land and irrigate the field even with the marginal water. In the areas where water is scarce, the reusing of sewage and industrial effluents for irrigation is found to be best alternative. On the otherhand, safe disposal of industrial wastewater has become a challenge for industrial managers and for scientists also. To overcome the treatment and disposal of industrial effluents, the society thoughtof reusing the industrial effluents for irrigation, as these effluents contain considerable amounts of nutrient which may prove beneficial for plants. The accumulation of metals present in the effluents are of public concern because of possibilities of their entering into food chain. Therefore, it is required to assess the effect of reusing of industrial effluents for irrigation on soil system, yield of crops and their quality and possibilities of subsurface water pollution before recommending the reusing of industrial effluents for irrigation. Thus, the present study was undertaken to judge the suitability of different industrial effluents viz: Sugar mill wastewater, Distillery wastewater and mixtures of these with sewage for irrigation and their impact on soil-water plant system. Based on the findings of the present study the following conclusions have been drawn.

- The studies on germination percentage with various treatment options reveal that the control irrigation (borewell water irrigation) results in optimum germination percentage of various crops followed by T4, T2, T5 and T3. The analysis of such a behavior lead to a conclusion that the pH of wastewaters at neutrality and wastewaters with lesser concentration of various physio-chemical parameters is favorable for better germination. Further, it is concluded that the complex inorganic and organic elements present in concentrated wastewater will not be easily available for plants and they may be injurious to seed germination and seedling growth .Therefore it is suggested to use Sugar mill wastewater and Distillery wastewater for irrigation after diluting them with sewage/water wherever possible. The germination percentages observed varied from 88.3 to 95.8 % for T1 (pH: 7.23), 58 to 82 % for T2 (pH 5.58), 42.5 to 62.8 % for T3 (pH 4.37), 75.2 to 88.4 % for T4 (pH :6.39) and 55.8 to 73.4 % for T5 (pH: 5.79).

- The analysis of results of nutrient uptake by crops lead to a conclusion that nutrient uptake by the crops is independent of soil type and initial concentration of the nutrients in wastewaters and uptake is a characteristic function of particular crop.

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