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EFFECT OF SEWAGE IRRIGATION ON SOIL PROPERTIES AND YIELD OF POTATO (*SOLANUM TUBEROSUM* L.)

Effet de l'irrigation par les eaux d'épandage sur les propriétés du sol et le rendement en pomme de terre.

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RESUME

*Effet de l'irrigation par champ d'épandage sur les propriétés des sols et le rendement en pomme de terre (*Solanum tuberosum *L.)*

L'utilisation des eaux d'égout municipal pour irriguer les champs est une pratique ancestrale. A Varanasi, ce champ d'épandage reçoit des eaux usées industrielles ainsi que les apports de certaines installations de traitement. Une étude a été conduite en 1987-88 en vue de distinguer les effets des eaux usées traitées et non traitées sur les propriétés des sols et les accumulations des métaux dans les végétaux. Les résultats ont été comparés avec ceux obtenus à l'aide d'une eau de forage. Si la contamination en métaux lourds tels que Cd, Cu, Zn et Fe est observée dans les sols, les tubercules de pommes de terre, par contre, ne dénotent qu'une très faible accumulation de ces métaux, et en tout cas, au-dessous de la limite permise.

ABSTRACT

The use of municipal sewage to irrigate crop fields has been pratised for centuries. Raw sewage of Varanasi city which is mixed with industrial effluents and treated sewage from B.H.U. treatment plant are the most common sources for the irrigation of crop and vegetable fields. In order to study the impact of aforesaid treated and untreated sewage on soil properties and heavy me metal accumulation in vegetables, the present work has been conducted at B.H.U. in the year 1987-1988. The results were compared with tubewell water irrigation (control). Study reveals the contamination of heavy metals such as Cd, Cu, Zn and Fe in soil. However, very low accumulation of heavy metals were recorded in potato tubers which was in all cases below the permissible limit.

INTRODUCTION

The Varanasi city sewage which is mixed with industrial effluents has been used for irrigation of crop and vegetable fields by the local farmers. Since the sewage

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is mixed with industrial effluents it contains a number of toxic substances and heavy metals such as Cd, Cu, Ni, Zn and Fe even after primary treatment.

The application of waste waters to crop land has been used as a conserve and reuse system (DAY & KIRKPATRICK, 1973; ISKANDER, 1970). Depending on the type of sewage, sewage waste waters contain high concentrations of heavy metals (BERROW & WEBBER, 1972; CHANEY, 1973; PAGE, 1974; MELSTED, 1973). Accumulation of heavy metals in soil has been widely discussed (RHODE, 1962; CHANEY, 1973; PAGE, 1974; BAERUG & MARTINSEN, 1977; McKIM, 1978; MATTIGODE & PAGE, 1983;). Effect of heavy metals on soil contamination, accumulation in food crops and adverse effect on crop fields by the application of wastewaters has been reported (ODELIEN & VIGERUST, 1972; HAMILTON & MINSKI, 1973; FLEISCHER *et al.*, 1974; DOWDY & LARSEN, 1975; DAY & TUCKER, 1977;). Waste water irrigation has been evaluated in United States on corn (SOPPER & KARDOS, 1973) and potato (EWERT *et al.*, 1974). Effect of treated and untreated sewage on cereal crops has been studied in Varanasi (DWIVEDI, 1987).

However, there is a paucity of data on soil contamination of heavy metal and its effect on crop and vegetable plants at Varanasi. Therefore, present study has been conducted to evaluate the effect of sewage irrigation on soil properties, heavy metal accumulation and the potato yield.

MATERIALS AND METHODS

The botanical garden of Banaras Hindu University (B.H.U.), Varanasi, India has been selected as the experimental site. Varanasi falls almost in the middle of Indo Gangetic alluvial plain, comes in the North Indian belt of semi arid to sub humid climate. The soil is alluvial, deep flat, well drained and moderately fertile, low in available nitrogen and medium in phosphorus and potassium. The experiment was carried out in the year 1987 and 1988 in winter season (Nov.-Jan.). The plots were divided 2 x 2 m. size and randomized block design was used for the treatments in three replications. Raw sewage was collected from Rajghat, situated at the northern border of the city through which maximum sewage is discharged into river Ganga (TRIPATHI & SIKANDAR, 1981). Treated sewage was taken from B.H.U. treatment plant and tubewell water was used as control. Irrigation was done for six times and NPK fertilizer full doze (120 kg, N; 60 kg, P and 80 kg, K) was applied twice viz. 3 weeks before plantation and after the first earthing up.

Soil samples were collected from 15 cm below the surface layer before starting of the experiment and harvesting of the potato tuber. The soil was analysed for pH, cation exchange capacity and total organic content. Heavy metal analysis such as Cu, Cd, Ni, Zn and Fe of the soil has also been done. Organic matter was determined calorimetrically after wet oxidation with $Na_2Cr_2O_7$ (PEECH *et al.*, 1947). Cation exchange capacity was determined by Na saturation (JACKSON,1962).

The content of Cu and Zn in the soil was determined by atomic absorption spectroscopy after extraction with 0.02 M EDTA solution and 0.2 M hydrochloric acid respectively. The approximate total content of Ni and Cd was obtained by extracting 25 mg. of air dried soil with 50 ml. of 0.005 M diethylene triamine pentaacetic acid (DTPA) solution which was also 0.020 M in $CaCl_2$ and ajusted to pH 7 using tri ethanol amine (BAKER & AMACHER, 1982). Available Fe was also analysed with 5 mM DTPA-TEA, pH 7.3 (LINDSAY & NORWELL, 1978).

Physico-chemical characteristics of sewage and tubewell water and heavy metals contents were determined by Standard Methods APHA (1985). Cd, Cu, Zn, Ni and Fe in the tubers was determined by atomic absorption spectroscopy after dissolving the elements from the ash with HCl (volume : volume 1:3). NPK fertilizer was also analysed for heavy metals by Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

Physico-chemical characteristics of tubewell water (control), treated sewage and raw sewage showed higher concentration of alkalinity, chloride, sulphate, phosphate-P, nitrate-N in raw sewage followed by treated sewage and tubewell water. The maximum temperature was noted 26.05° C in raw sewage in 1987, pH was maximum in raw sewage in 1988. EC 1.15 nmhos/cm was recorded in raw sewage in the year 1987. Dissolved oxygen was maximum 8.19 $mg.l^{-1}$ tubewell water in 1987 and minimum 1.92 $mg.l^{-1}$ in raw sewage in 1988. BOD was maximum in raw sewage 265.2 $mg.l^{-1}$ and minimum in tubewell water 0.60 $mg.l^{-1}$ in 1988. COD was found maximum in raw sewage 524.53 $mg.l^{-1}$ followed by treated sewage and minimum in tubewell water 1.31 $mg.l^{-1}$. Alkalinity was also recorded maximum in 1987 that is 42.73 $mg.l^{-1}$ in raw sewage and minimum 3.56 $mg.l^{-1}$ in tubewell water respectively. Acidity was recorded 63.12 $mg.l^{-1}$ in raw sewage and minimum was in tubewell water, 3.06 $mg.l^{-1}$. Sulphate, phosphate and nitrate values also showed maximum concentration in raw sewage that is 215.64 $mg.l^{-1}$, 5.38 $mg.l^{-1}$, 19.35 $mg.l^{-1}$

respectively. In treated sewage it was 23.44 $mg.l^{-1}$, 68.41 $mg.l^{-1}$, 4.83 $mg.l^{-1}$ in 1988 and tubewell water showed minimum concentration that is 6.02 $mg.l^{-1}$, 0.06 $mg.l^{-1}$, 0.03 $mg.l^{-1}$ respectively. Concentration of Ca and Mg was higher in raw sewage. Concentration of K was higher in treated sewage followed by raw sewage and then tubewell water.

Heavy metal contents were almost nil in tubewell water throughout the experimental period. Raw sewage showed maximum concentration of heavy metals i.e. 1.08 $mg.l^{-1}$ Cu, 0.12 $mg.l^{-1}$ Cd, 0.32 $mg.l^{-1}$ Ni, 1.66 $mg.l^{-1}$ Zn and 14.88 $mg.l^{-1}$ Fe. Treated sewage also showed the presence of heavy metals, 0.99 $mg.l^{-1}$ Cu, 0.10$mg.l^{-1}$ Cd 0.30 $mg.l^{-1}$ Ni, 1.40 $mg.l^{-1}$ Zn and 13.16 $mg.l^{-1}$ Fe. Presence of heavy metals in raw sewage and treated sewage was reported (DWIVEDI, 1987).

Soil pH, cation exchange capacity and organic matter content are major factors controlling availabilities of sluge derived metals (CHANEY, 1973). In addition, a rise in pH often results in a greater soil CEC, thus cation adsorption, increase (COREY *et al.*, 1981). An increasing trend of soil pH in the sewage irrigated fields were noted. Similarly cation exchange capacity and total organic content were also increased.

Heavy metal content of the soil was also increased i.e. 1.02 $mg.l^{-1}$ Cu, 0.11 $mg.l^{-1}$ Cd, 0.31 $m.l^{-1}$ Ni, 1.23 $mg.l^{-1}$ Zn and 16.40 $mg.l^{-1}$ Fe (Table II) by the application of sewage. Increasing concentrations of Cd, Ni has also been reported due to sewage irrigation and liquid sludge application (AZAD *et al.*, 1986; LUTRICK *et al.*, 1976). Concentration of heavy metals in fertilizer was found to be very low ant it did not influence the soil heavy metals (Table III).

Very low concentration of heavy metals were noted in the potato tuber irrigated with the raw sewage. However, in the case of tubewell water irrigation potato tuber did not show any presence of aforesaid heavy metals (Table III).

The maximum tuber yield was recorded in treated sewage irrigation followed by raw sewage and tubewell water. Irrigation of treated sewage in combination with NPK application indicate better potato yield. Similar finding were reported by SHAFER and KICK (1970). Increase in the yield of wheat and paddy crop with treated sewage irrigation was also reported (DWIVEDI, 1987).

Parameters	Tubewell water		Treated sewage		Raw sewage	
	1987 Mean (S.E.)	1988 Mean (S.E.)	1987 Mean (S.E.)	1988 Mean (S.E.)	1987 Mean (S.E.)	1988 Mean (S.E.)
Température (°C)	20.74 (0.05)	21.56 (0.28)	21.77 (0.24)	24.03 (0.12	24.87 (0.34)	26.05 (0.35)
pH	7.25 (0.03)	7.28 (0.30)	7.59 (0.03)	7.64 (0.02)	7.80 (0.01)	7.87 (0.02)
E.C. mmhos cm^{-1}	0.19 (0.02)	0.22 (0.03)	1.29 (0.18)	1.27 (0.17)	1.15 (0.07)	1.13 (0.02)
D.O. mg l^{-1}	8.19 (0.02)	8.06 (0.65)	3.51 (0.05)	35.00 (0.01)	1.95 (1.13)	1.92 (0.10)
BOD mg l^{-1}	0.62 (0.36)	0.61 (0.01)	31.33 (3.37)	33.44 (3.31	259.50 (0.36)	265.26 (4.15)
COD mg l^{-1}	1.31 (0.08)	1.38 (0.05)	128.65 (57.83)	129.17 (0.74)	503.83 (6.02)	524.53 (4.15)
Alkalinity mg l^{-1}	3.56 (0.15)	3.59 (0.16)	78.27 (0.18)	78.41 (0.14)	473.51 (1.29)	472.24 (0.55)
Acidity mg l^{-1}	3.07 (0.03)	3.18 (0.05)	12.88 (0.02)	13.21 (0.31)	63.05 (0.03)	63.12 (0.01)
Chloride mg l^{-1}	2.80 (0.04)	2.82 (1.63)	23.36 (0.29)	23.44 (0.04)	92.40 (0.70)	92.79 (0.10)
Phosphate-P mg l^{-1}	0.06 (0.01)	0.06 (0.01)	4.83 (0.79)	4.83 (0.03)	5.33 (0.05)	5.38 (0.06)
Sulphate mg l^{-1}	6.04 (0.02	6.03 (0.01)	68.06 (0.33)	68.41 (0.23)	215.45 (0.34)	215.41 (0.10)
Nitrate-N mg l^{-1}	0.03 (0.01)	0.03 (0.02)	9.20 (0.04)	9.26 (0.04)	19.37 (0.20)	19.35 (0.05)
Ca mg l^{-1}	3.89 (0.29)	4.18 (0.15)	92.93 (0.77)	92.13 (1.09)	236.87 (0.66)	238.62 (2.05)
Mg mg l^{-1}	4.46 (0.34)	4.50 (0.26)	23.14 (0.14)	23.26 (0.24)	24.70 (0.53)	24.56 (0.13)
K mg l^{-1}	12.56 (5.78)	12.52 (0.02)	38.03 (0.17)	37.60 (0.31)	31.05 (0.01)	31.06 (0.01)
Cu mg l^{-1}	Nil	Nil	0.98 (0.78	0.99 (0.01)	1.08 (0.62)	1.09 (0.61)
Cd mg l^{-1}	Nil	Nil	0.09 (0.01)	0.11 (0.03)	0.12 (0.03)	0.12 (0.01)
Ni mg l^{-1}	Nil	Nil	0.25 (0.07)	0.30 (0.03)	0.32 (0.03)	0.32 (0.07)
Zn mg l^{-1}	Nil	Nil	1.30 (0.04)	1.40 (0.02)	1.66 (0.08)	1.67 (0.02
Fe mg l^{-1}	Nil	Nil	12.70 (0.32)	13.10 (0.58)	14.84 (0.02)	14.86 (0.02)

Table I : Physico-chemical characteristics and heavy metal contents of irrigation water used in potato crop field in the year 1987
(Average of six irrigations)

Parameters	Before irrigation		Tubewell water		After irrigation Treated sewage		Raw sewage	
	1987	1988	1987	1988	1987	1988	1987	1988
pH	7.31 (0.01)	7.34 (0.01)	7.34 (0.02)	7.32 (0.01)	7.63 (0.01)	7.62 (0.01)	7.83 (0.04)	7.82 (0.01
CEC me g^{-1}	12.87 (0.04)	12.91 (0.02)	12.91 (0.01)	12.92 (0.02)	12.91 (0.04)	12.90 (0.01)	12.92 (0.01)	12.92 (0.01)
Total organic content	0.42 (0.01)	0.41 (0.01)	0.43 (0.02)	0.43 (0.01)	0.96 (0.01)	0.96 (0.03)	1.05 (0.01)	1.07 (0.02)
Cu mg kg^{-1}	0.62 (0.01)	0.64 (0.02	0.69 (0.01)	0.71 (0.01)	0.95 (0.02)	0.96 (0.02)	1.01 (0.01)	1.02 (0.02)
Cd mg kg^{-1}	0.07 (0.01)	0.05 (0.01)	0.09 (0.01)	0.09 (0.01)	0.10 (0.01)	0.10 (0.01)	0.10 (0.01)	0.11 (0.01)
Ni mg kg^{-1}	0.21 (0.01)	0.21 (0.01)	0.23 (0.01)	0.23 (0.01)	0.27 (0.02)	0.30 (0.02)	0.30 (0.01)	0.31 (0.01)
Zn mg kg^{-1}	0.57 (0.01)	0.59 (0.02	0.61 (0.02)	0.67 (0.02)	1.01 (0.01)	1.02 (0.01)	1.21 (0.02)	1.23 (0.01)
Fe mg kg^{-1}	4.30 (0.01)	14.20 (0.022)	14.50 (0.03)	14.48 (0.01)	15.47 (0.03)	15.57 (0.01)	16.10 (0.03)	16.40 (0.04)

Table II : Physico-chemical characteristics of the experimental soil before and after irrigations.

Parameters	Tubewell water		Treated sewage		Raw sewage		Heavy metal in
	1987	1988	1987	1988	1987	1988	NPK fertilizer
Cu mg kg^{-1}	0.01	0.01	0.03	0.04	0.05	0.06	0.60
Cd mg kg^{-1}	Nil	Nil	Nil	0.01	0.01	0.01	Nil
Ni mg kg^{-1}	Nil	Nil	0.01	0.01	0.01	0.01	Nil
Zn mg kg^{-1}	0.01	0.01	0.03	0.02	0.03	0.03	2.90
Fe mg kg^{-1}	0.01	0.01	0.04	0.04	0.05	0.06	1.30
Yield of potato tuber tons ha^{-1}	17.10	17.80	28.80	28.90	21.70	22.30	

Table III : Concentration of heavy metals in potato tuber (mg kg^{-1} fresh weight) and yield of potato tuber tons ha^{-1}

CONCLUSION

From the results obyained during present investigatin it may be concluded that

(i) Treated sewage in combination with fertilizers doses gives maximum potato yield.

(ii) Lower yield of potato in tube water irrigation may be due to deficiency of nutrients in the tubewell water irrigated soil.

(iii) During the period of sewage treatement most of the heavy metals are fixed in the soil and a very low concentration is absorbed and accumulated in the potato tuber.

(iv) The lower accumulation of heavy metals in potato may be due to their low concentration in the treated and raw sewage.

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