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Wastewater irrigation effects on soils of Bundi district in Rajasthan

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Abstract
The objectives of present study were to determine the effects of wastewater irrigation effects on physical, chemical and biological indicators of soils of Bundi district of Rajasthan to assess soil quality in reference to tube well water. However, the quality of water and conditions under which water is used are varying significantly. A quarterly survey was conducted and 40 soil samples from wastewater and 08 from tube well irrigated sites were collected. The different soil properties of wastewater and tube well water irrigated soils were determined. The sand content, soil pH and soil dehydrogenase activity were decreased due to wastewater irrigation. The soil porosity, EC, OC, available-NPK, SO^{-}_{4}, Cl^{-}, heavy metals (Mn, Fe, Zn, Cu, Ni, Cd, Pb and Cr) were observed higher in wastewater irrigated soils as compared to reference tube well water irrigated soils. A slight decrease was observed during monsoon, it might be due to dilution effects. Highest values were observed in summer of all study sites. Some parameters found above as the prescribed permission limits of Indian standards.

Keywords: Wastewater irrigation, soil quality, NPK& S, heavy metals

1. Introduction
The urban and peri-urban agriculture fields of Bundi district depends on wastewater up to a certain extent as a source of irrigation water especially during summer season. The major sources of wastewater generated are municipal, agro-industries, tourism, mining etc. in Bundi. About 600ha land is under wastewater irrigation. The quantity of wastewater used is often untreated and semi-treated. The major crops of the study area are rice, wheat, vegetable, green fodder and fruit trees. Along with the increasing population's improved living conditions, urbanization, industrial and economic development a huge amount of wastewater is generated daily in urban areas by different sources and has increased (Qadir *et al*., 2010) [22]. Similar study in Kota also indicated that urban and peri urban agriculture fields depends on wastewater irrigation particularly during summer season (Aswal *et al*., 2022) [3].

In most of the countries, urban and peri-urban agriculture depends on wastewater as a source of irrigation water and nutrients up to a certain extent. The quality of water and conditions under this water is used vary significantly. In many cities of our country, much of the wastewater from different sources tends to be untreated, whereas in big cities, treated wastewater is used (Minhas *et al*., 2015) [18].

Wastewater irrigation is known to contribute significantly to the OM, NPK&S, heavy metal contents of soils. Heavy metal accumulates in soils and subsequently in vegetation by long-term wastewater irrigation has a potentially detrimental effect on soil quality (Mapanda *et al.*, 2005) [16]. In another studies the effects of wastewater irrigation on the accumulation of heavy metals (Co, Cr, Cu, Mn, Ni, Pb and Zn) in soils (Mohanty *et al*., 2021; Aswal *et al.*, 2022) [21, 3] and vegetables from agriculture lands of Kota were assessed (Aswal *et al*., 2022) [3].

The wastewater and industrial waste disposal are worldwide problem and are often drained to agricultural lands where they are used for growing different crops including vegetables. It is considered a rich source of organic matter and other nutrients, but it increases the levels of heavy metals, such as Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd and Co, in the receiving soils (Rattan *et al*., 2005 and Aswal *el al*, 2022) [23, 3], many of which are non-essential and are toxic to plants, animals and human beings (Kanwar and Sandha, 2000) [9]. The long-term application of treated and untreated wastewater has resulted in a significant buildup of heavy metals in the soil (Khan *et al*., 2008; Ullah *et al*., 2012; Minhas *et al.*, 2015 and Aswal *el al*., 2022) [10, 32, 18, 3] and in vegetables, which are subsequently transfers to the food chain and causing a potential health risk to consumers (Sharma *et al*., 2007) [15].

2. Materials and Methods
2.1 Study area
Bundi district of Rajasthan is located at eastern southern Rajasthan in India, with a long and hot summer, low rainfall and a short mild winter. The temperature varies from 7 °C to 48°c with the annual precipitation of 700mm. The soils of Bundi are sandy clay loam. The climate of the study area is typically sub–humid and sub-tropical. The coordinates of randomly selected 10 sampling points are near N 25° 26.090, E 75° 39.095. Major food grain, pulses, oilseeds are rice, wheat, mustard, chickpea, pea and vegetable crops are spinach, brinjal, tomato, okra, cabbage, cauliflower, chilly, bottle guard, radish, cucumber, coriander etc. are under wastewater irrigation.

2.2 Survey work
A quarterly survey was conducted in Bundi district at ten different study sites along with reference site. The samples of wastewater and soil were taken from the 10 randomly selected points, where both wastewater and reference tube well water irrigation were used for vegetable cultivation.

2.3 Sampling
Soil samples were collected at the surface depths of 0-15cm using stainless steel auger sampling tools and plastic buckets to avoid any contamination of samples with traces of elements from the tools. At each sampling site, scrape away surface debris and collect the soil samples. The collected soil samples were immediately analysed for dehydrogenase activity than air dried, grounded with wooden mortar and pestle, passed through 2 mm sieve and stored in plastic bags for further analysis.

2.4 Digestion of Soils samples
The soil samples were digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whitman filter paper No. 40. Each sample solution was made up to a final volume of 50 ml with distilled water and concentration of heavy metals were analysed by atomic absorption spectrophotometer (ASS: model AA6300, Shimadzu).

The soil properties were evaluated by the standard methods according to the USDA. All soil samples were analysed for texture, BD, Porosity, EC, pH, OC, dehydrogenase activity, available-NPK and Mn, Fe, Zn, Cu, Ni, Cd, Pb and Cr *etc*.

3 Results and Discussion
3.1 Physical characterization of soils
The observed mean values of sand, slit and clay of Bundi irrigated with wastewater were 47.93, 16.07, 36.00 and tube well water were 55.45, 14.81, 29.74 respectively. The observed soil texture of Bundi was sandy clay loam; soil bulk density (gcc^{-1}) of wastewater and tube well irrigated soils were 1.42and 1.51. The wastewater irrigated soils have lower BD as compared to tube well water irrigated soils. This can be attributed due increase in total porosity and aggregate stability in wastewater irrigated soils due to addition of organic matter.

The particle density (gcc^{-1})) of the districts of wastewater and tubewell irrigated soils were 2.55 and 2.61. The wastewater irrigated soils have lower particle density as compared to tube well water irrigated soils. The porosity (%) of wastewater and tubewell irrigated soils were 44.43 and 42.23 of Bundi. The wastewater irrigated soils have higher porosity as compared to tube well water irrigated soils. This can be attributed due increase in total porosity and aggregate stability in wastewater irrigated soils due to addition of organic matter (Mathan *et al*., 1984; Kharche *et al*., 2011 and Khan *et al*., 2011, Singh, 2012, Mohanty *et al*., 2021 and Aswal *et al*., 2022) [17, 12, 11, 21, 3].

3.2 Chemical characterization of soils
The pH of wastewater and tube-well water irrigated soils during Ist, IInd, IIIrd and IVth survey were 7.27, 7.24, 7.54, 7.63 and 8.25, 7.81, 7.92, 8.20 of Bundi.

The EC (dSm^{-1}) of wastewater and tube-well water irrigated soils of Bundi urban sites was determined. The observed EC mean values of wastewater irrigated soils during Ist, IInd, IIIrd and IVth survey were 1.87, 1.72, 1.76, 1.79 and 1.28, 1.10, 1.28, 1.26of Bundi. The organic carbon (gkg^{-1}) of the soil of wastewater and tube-well water irrigated fields during Ist, IInd, IIIrd and IVth survey were 10.68, 9.83, 11.2, 11.43 and 3.37, 3.09, 3.38, 3.40 of Bundi.

Available nitrogen ($kgha^{-1}$) status of soil of wastewater and tube-well water irrigated fields during Ist, IInd, IIIrd and IVth survey were 359.1, 330.4, 409.7, 417.9 and 113.5, 121.7, 115.2, 122.4 of Bundi.

The available phosphorus ($kgha^{-1}$) of soil of wastewater and tube-well water irrigated fields during Ist, IInd, IIIrd and IVth survey were 46.85, 43.11, 53.45, 54.52 and 16.47, 16.14, 15.64, 16.43 of Bundi.

The available potassium ($kgha^{-1}$) of soil of wastewater and tube-well water irrigated fields during Ist, IInd, IIIrd and IVth survey were327.7, 301.5, 373.8, 381.3 and 186.7, 182.9, 177.3, 186.2of Bundi.

The observed pH, EC, NPK in wastewater and tube-well water irrigated soils were differed as per time and location. A slight decrease was observed during monsoon, it might be due to dilution effect of monsoon. Highest values were observed in summer at all four study sites. The pH of tube well water irrigated soils was higher than wastewater. Decrease of pH of wastewater irrigated soils are perhaps due to the effect of acidic nature of wastewater used for irrigation and EC, OC and NPK of wastewater irrigated soils were higher than tube-well water irrigated soils due to higher load of soluble salts and metallic ions in wastewater.

A slight decrease in EC, OC and NPK was observed during monsoon, it might be due to dilution of water and transportation of OM, NPK and soluble salts with rain water. Highest values were observed in summer. The increase in EC, OC, available NPK of wastewater irrigated soils are perhaps due to higher amount of OM, available NPK and soluble salts in wastewater used for irrigation (Totawat, 1991; Totawat *et al.*, 1994, Baddesha *et al*., 1997; Saha and Mandal, 1998; Mitra and Gupta, 1999; Brar *et al.*, 2000; Khurana *et al.*, 2004; Minhas and Samra, 2004; Bhat *et al*., 2011; Singh *et al.*, 2011 and Khurana, Singh, 2012 Mohanty *et al*. and 2021 Aswal *et al*, 2022) [29, 30, 4, 25, 20, 6, 13, 19, 5, 21, 3].

3.3 Biological characterization of soils
The activity of dehydrogenase enzyme ($\mu gTPFd^{-1}g^{-1}$) of soils from wastewater and tube-well water irrigated vegetable fields during Ist, IInd, IIIrd and IVth survey were 0.99, 0.91, 1.13, 1.15 and 0.45, 0.44, 0.43, 0.45 Bundi. The DHA of wastewater irrigated soils was higher than tube-well water irrigated soils. The increase in DHA of wastewater irrigated soils was perhaps due to higher amount of organic matter in wastewater used for irrigation.

The DHA of wastewater and tube-well water irrigated soils were differed as per time and location. Decrease in DHA was observed during summer and monsoon that might be due high temperature and toxic concentration of heavy metals in summer and dilution effect of monsoon. Highest values were observed in winter and spring season that might be due to favourable environmental conditions for microbes. The reduction in DHA in soils in summer season might be due to the build- up of heavy metal toxicity in soils irrigated with wastewater (Casida *et al*., 1964; Rao *et al*., 1993; Tripathi *et al*., 2007; Salazar *et al*., 2011; Subhani *et al*., 2011; Cirilli *et al*., 2012; Yuan and Yue, 2012 and Aswal *et al*, 2022) [7, 31, 26, 28, 8, 33, 3].

Table 1: Impact of wastewater irrigation on soil physical properties of Bundi

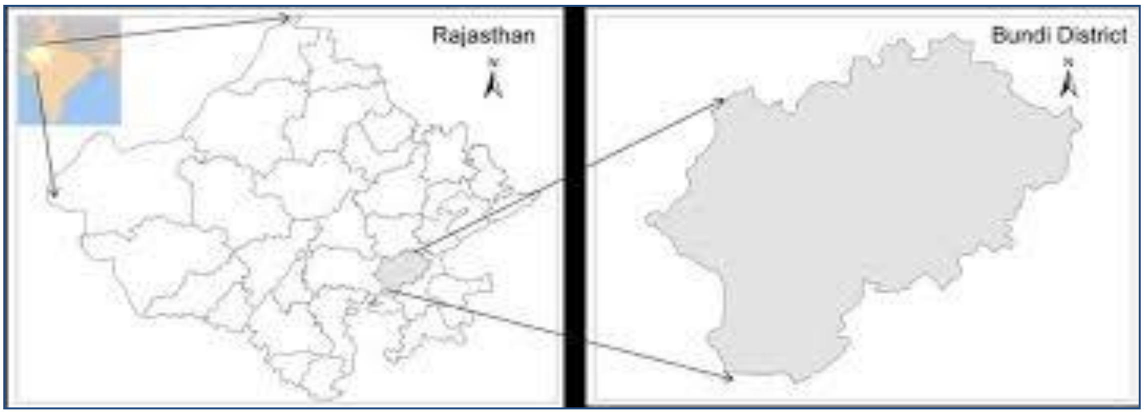
Location Unit	Sand %	Silt %	Clay %	Texture Class	BD (g cm^{-3})	PD (g cm^{-3})	Porosity %
Wastewater irrigated soils							
WW-1	51.43	14.32	34.25	Sandi clay loam	1.43	2.57	44.36
WW-2	51.18	14.24	34.58	Sandi clay loam	1.43	2.57	44.36
WW-3	50.02	15.11	34.87	Sandi clay loam	1.42	2.56	44.53
WW-4	49.36	15.53	35.11	Sandi clay	1.42	2.56	44.53
WW-5	48.05	16.29	35.66	Sandi clay	1.42	2.55	44.31
WW-6	47.04	16.57	36.39	Sandi clay	1.42	2.55	44.31
WW-7	46.72	16.72	36.56	Sandi clay	1.41	2.54	44.49
WW-8	46.18	16.97	36.85	Sandi clay	1.41	2.54	44.49
WW-9	44.97	17.25	37.78	Sandi clay	1.41	2.53	44.27
WW-10	44.32	17.72	37.96	Sandi clay	1.40	2.53	44.66
Mean	47.93	16.07	36.00	Sandi clay	1.42	2.55	44.43
Tube well water irrigated soils							
TW-1	55.99	14.65	29.36	Sandi clay loam	1.51	2.62	42.37
TW-2	54.92	14.96	30.12	Sandi clay loam	1.50	2.59	42.08
Mean	55.455	14.81	29.74	Sandi clay loam	1.51	2.61	42.23

Table 2: Effect of wastewater and tube well water on soil chemical and biological properties of Bundi

Survey No.	EC (dSm^{-1})	pH	OC (g kg^{-1})	NO_3^- ($mgkg^{-1}$)	P_2O_5 ($mgkg^{-1}$)	Mn ($mgkg^{-1}$)	DHA (μg TPF d^{-1} g^{-1})
Effect of wastewater							
I	1.87	7.27	10.68	359.1	46.85	327.7	0.99
II	1.72	7.24	9.83	330.4	43.11	301.5	0.91
III	1.76	7.54	11.20	409.7	53.45	373.8	1.13
IV	1.79	7.63	11.43	417.9	54.52	381.3	1.15
Effect of tube well water							
I	1.28	8.24	3.37	113.5	16.47	186.7	0.45
II	1.10	7.81	3.09	121.7	16.14	182.9	0.44
III	1.28	7.92	3.38	115.2	15.64	177.3	0.43
IV	1.26	8.20	3.40	122.4	16.43	186.2	0.45

Table 3: Effect of wastewater and tube well water on accumulation of heavy metals in soils of Bundi ($mgkg^{-1}$)

Survey No.	Mn	Fe	Zn	Cu	Ni	Pb	Cd	Cr
I	327.7	3.39	14.81	4.06	4.39	6.633	7.520	0.834
II	301.5	3.05	12.70	3.49	3.77	5.68	6.45	0.71
III	373.8	3.37	13.21	3.63	3.92	5.91	6.70	0.74
IV	381.3	3.96	14.13	3.88	4.20	6.33	7.17	0.80
I	186.7	1.923	3.363	2.90	2.07	3.739	0.324	0.053
II	182.9	1.911	2.359	1.89	2.06	3.728	0.323	0.053
III	177.3	1.99	3.39	1.93	2.11	3.80	0.33	0.05
IV	186.2	1.69	3.414	2.97	2.15	3.878	0.336	0.055
MPL*			3000- 5000	10-300	6.0-60		10 -70	0.07-1.10



4. Conclusions and Recommendations

The result reveals that untreated wastewater is the primary source of pollution to the soil and leads to an increase the concentration of metals in soils and vegetables. The wastewater irrigation has importance throughout the world due to limited water sources and wastewater treatment costs for discharge. It contains a high amount of organic matter, nutrients and heavy metals. In our study, the wastewater irrigated vegetables cultivated soil samples taken had increased concentrations of metals in all the soils. A significant accumulation of toxic heavy metals in soils samples is due to the sewage water irrigation in Bundi region.

The concentrations of the metals in the soils will provide baseline data and intensive sampling is required for the quantification of the results not only in Bundi but throughout the country. To avoid the entrance of metals into the food chain, municipal or industrial waste should not be drained into rivers and farmlands without prior treatment. The continuous monitoring of the soil, plant and water quality are prerequisites for the prevention of potential health hazards to human beings.

An urgent need exists to strictly monitor the wastewater and the groundwater of the study area and to develop different strategies to prevent the accumulation of heavy metals in food crops that may ultimately minimize the chronic health risk to the exposed population.

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6. Competing Interests

"Authors have declared that no competing interest exists".

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