Effects of Treated Wastewater on Vegetative Growth and Pigmentation of Forage Crops

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Research Article

Keywords: Industrial Wastewater, Sorghum, Pennisetum, Hordeum, Viability, Vigour index, Chlorophyll, Caretenoids

Posted Date: March 30th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-274777/v1

Abstract

Purpose: The present investigation was undertaken to evaluate the possibility of whether treated wastewater from industrial units could safely be used to irrigate crop plants and solve the problem of liquid effluent disposal in an eco-friendly manner.

Methods: In this study select to evaluate the effects of effluents of textile, pharmaceutical and granite industry and on the germination (early growth) of selected forage crops like *Sorghum bicolor*, *Pennisetum typhoideum* and *Hordeum vulgare*. The present investigation involves the analysis of soil, water and plant analysis like chlorophyll, cartorenoids and growth.

Results: The results revealed that pH, EC and chlorides and several other parameters were within the usual range of water used for irrigation purposes. The percentage of germination and vigor index was maximum for bajra and barley. The physico-chemical parameters of soil and wastewater were found to be within the usual range of tolerance limits for the industrial effluent on land prescribed by BIS except for TSS and hardness in some samples. The germination percentage and vigor index of jowar, bajra and barley were higher in granite industry water samples. The plant length of all crop samples had significant heights in all the samples. The total chlorophyll and carotenoid content were also found to be significant amounts in the leaf samples of all the crops grown in different water samples.

Conclusion: Treated wastewater can be a prospective source of organic matter and nutrients that could increase the quality of soil, thus may be a beneficial alternative resource to freshwater for irrigation purposes in the offseason. Hence there are great possibilities for growing highly profitable forage crops using treated wastewater in the offseason.

1. Introduction:

Environmental pollution creates health issues and has become a global problem and among the various types of pollution, more particularly, water pollution by the waste discharge of industries offers terrific problems to aquatic and agro-ecosystems by affecting directly or indirectly and ultimately animal and human life (Ivy et al., 2015). Now-a-days many industries often discharge their wastes into the water without any treatment or after partial treatment and it leads to disposal problems. The utilization of industrial wastes after proper treatment for the agricultural purposes could provide a solution to the disposal problems. Hence, the present study aimed to assess the possibility of whether treated wastewater from the textile, pharmaceutical and granite industries could safely be used to irrigate crop plants and solve the problem of effluent disposal of various industrial sources in an eco-friendly manner.

The chemical constituents present in liquid Wastewatermake the environment more hazardous particularly fabric industries release wastewater that contains a large variety of dyes and chemicals (Chequer et. al., 2013; Sivaram et. al., 2018; Mia et. al., 2019). The complex composition of pharmaceutical wastewater is consists of high concentration of organic matter, microbial toxicity, high salt, and it is difficult to biodegrade rapidly. Even after secondary treatments, there are still trace amounts of suspended solids and dissolved organic matter (Guo et. al., 2017; Rana et. al., 2017; Kumari and Tripathi, 2019). Many gigantic polluting and turbid effluent releases from granite cutting plant. This effluent mainly contains many solid wastes that it is harmful to the environment. Hence, it requires treatment techniques before disposal (Al-Jabari and Maher, 2002; Sharad, 2015). In relation to irrigation water the component of water (quality) is to be present at the optimum level for suitable growth of plants (Qureshimatva and Umerfaruq, 2015; Zaman et. al., 2018). Treated wastewater may supply essential organic matter and mineral nutrients to the soil by leaching that are beneficial to crop yield production, and not only reduce the cost of fertilizer application apart from this avoid the chemical inputs to soil (Van der Hoek et. al., 2002, Hossain et. al., 2017). The use of wastewater may have both positive and negative impacts on crop production and soil resources (Duran - Alvarez and Jimenez - Cisneros, 2014; Maria and Ines, 2017). However, these impacts vary from region to region depending on the volume and source of the wastewater (WHO, 2005). Yield and Wastewaterresource use efficiency of cultivated crop depend on blooming, plant establishment and vigor of seeds that defines their ability to germinate and establish seedlings hastily in the field (Finch-Savage and Bassel, 2016, Uzma, 2016).

Plant health and nutrient status of plant were indicated by plant pigments in terrestrial ecosystems and crucial for sustaining life on the planet (Croft and Chen, 2017). The chlorophyll content of leaf tissue is a good index of photosynthetic activity (Choudhary and Kohri, 2003, Pavlovic et. al., 2014). This crucial pigment also plays a role as an index of plant growth and production of organic matter (Lahai et. al., 2003, Lima et. al., 2017). The concentration of chlorophylls and carotenoids vary in plants and it helps to differentiate healthy plant with unhealthy ones. Usually healthy plants with a large amount of chlorophylls are expected to than unhealthy ones (Ghosh et. al., 2018; Liu et. al., 2019). Chlorophyll concentration usually is a good indicator of plant nutrient stress, photosynthesis and growing periods and growth status of the crops, also it is an important condition for the exchange of mass and energy from the outside world. Hence, the real-time monitoring of the content of chlorophyll is a key step to complete yield analysis (Rao and Rao, 2007). The quantification of chlorophyll provides imperative information about the effects of environments on plant growth (Schlemmer et. al., 2005). The chlorophyll content in a plant is an indicator for crop growth and development. Hence, accurate determination and assessment of chlorophyll concentration in leaves are essential (Bannari et. al., 2007).

The present investigation was conducted to determine the effectiveness and variations of applying treated industrial wastewater on the following forage crops, jowar (*Sorghum bicolor*), bajra (*Pennisetum typhoideum*) and barley (*Hordeum vulgare*). The jowar forage is a valuable fodder it is relished by ruminants and outstandingly drought resistant and grows where maize cannot able to grow because of high temperatures or dry conditions (ICAR, 2021). Bajra plant is a rapidly growing and disease-resistant fodder crop. The crude protein content of green bajra varies from 6 to

20%. The fresh forage is fairly well digested by ruminants (Kumar et. al., 2012). Barley forage is grown in a wide range of climates. Barley is of utmost importance for livestock feeding, which accounts for about 85% of barley production (OECD, 2004). Hence, for the present work based on the literature survey select three forage crops.

2. Materials And Methods:

2.1. Sample collection and study site:

Mysore district in Karnataka, India, is located between latitude 11°45' to 12°40' N and longitude 75°57' to 77°15'E. It has an area of 6,854 km². The temperature in the district varies from 15°C in winters to 35°C in summers. Mysore district receives an average rainfall of 785 mm. Industries in Mysore district are mainly concentrated around the cities of Mysore and Nanjangud town.

Karnataka Industrial Areas Development Board (KIADB) has established six industrial areas in Mysore District.
Nanjangud is a home town to many industries spread across 532 acres (2.15 km^2) which includes 36 major industries, 12 medium industries and 35 small-scale units (Fig. 1).

A pair of new, disposable gloves was worn each time when a different location is sampled. The gloves were carefully donned immediately after the collection of samples. Water samples were collected from different industrial sites includes textile, pharmaceutical and granite industries of Nanjangudu in a 10 L can which was previously washed with 10% HNO_3 for 48 hr and labelled. The samples were taken in the afternoon between 1 pm to 3 pm and brought to the laboratory for physicochemical parameters analysis. For soil sample collection, multiple sampling spots were selected in the field based on the visual observation; the surface litter at the sampling spot was removed. A 'V' shaped cut was made to a depth of 15 cm in the sampling spot and the soil was collected to use. Samples were mixed thoroughly and foreign materials like roots, stones, pebbles and gravels were removed. Quartering was done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters were discarded and the remaining was mixed and used as a sample. The samples were collected in a polythene bag and bring to the laboratory.

In the case of seed samples, the good quality seed were collected from the local seeds distributing market (Devraja market, Mandimohalla) Mysore. All study samples were collected in the month of January 2020 for this work.

2.2. Analysis of wastewater samples:

The physico-chemical parameters of wastewater samples such as pH, electrical conductivity, total solids, total dissolved solids and other parameters were analysed using a standard protocol. The temperature of the samples was noted at the time of sampling using a precision thermometer (0.1°C accuracies). Standard error is ± 0.1°C. The pH and electrical conductivity of the samples were analysed using standard calibrations. The standard errors are ± 0.1 and ± 2 micro mhos cm^{-1} for both pH and electrical conductivity respectively. The alkalinity is determined by the APHA standard titration method and the following formula was used Alkalinity = Total HCl×0.1N HCl×1000×50/ ml of the sample taken.

1. **Total hardness -** The total hardness of water sample was measured by the EDTA titrimetric method (Shardend and Ambasht, 1991) and using the formula Hardness (mg/l) = EDTA used (ml) × 1000/ ml of the sample taken. Total suspended solids, total dissolved solids and total solid of water sample were determined by gravimetric method.
2. **The Dissolved Oxygen (DO)** - DO of water sample were analysed using Wrinkle titration method and calculated by using the following formula,

DO (mg/l) = (8*× 1000× N) × v/ V

1. **Biological Oxygen Demand (BOD)** - The BOD was determined by Winkler titration method (5 days incubation at 20 ^{0}C) and by using the following formula

BOD (mg/l) = [{(DO2-DO1) ×100} (DO2-DO0)}]

1. **Chemical Oxygen Demand (COD)** - The COD was determined by using Wrinkler idometric method and by using the formula,

COD of the sample (mg/l) = 8×C× (B-A)/S

1. **Total Chloride -** The Total Chlorides was determined by Argentometric Titration method and estimated using the following formula,

Chlorides in mg/L= (A-B) ×N× 35.45 × 1000/Vol. of water sample

1. **Dissolved Carbon dioxide** - The dissolved carbon dioxide is determined by potentiometric titration method and estimated by using the formula,

Dissolved CO_2 in mg/L = volume of NaOH × N of NaOH × 1000/20

2.3. Analysis of soil samples:

The colour of the soil was determined by a comparison of the soil sample with the color chips in the standard Munsell soil color charts. Soil texture is determined by jar method and percentage of soil measured by using the formula

Soil % = Layer height / total height of soil

The physicochemical properties of soil such as colour, temperature, moisture content, pH, electrical conductivity and soil texture were self analysed whereas for the micronutrients such as organic carbon, nitrogen, phosphorus, potassium oxide, sulfur, zinc, boron, iron, manganese, copper and others was tested at government soil testing laboratory in Mysore.

2.4. Analysis of physical purity and rate of imbibition in seeds:

The purity analysis of a seed sample was done by random cup method by using the formula,

% components = Weight of individual component/weight of all components × 100

The seeds are soaked in water samples for different time intervals and record initial and final weight of seeds was measured by using the following formula,

% of water absorbed = final weight – initial weight/initial weight × 100

2.5. Analysis of vegetative growth/vigor index in plant:

Five test solutions, viz. tap water sample, 0% (Control), 25, 50 and 100% were prepared by diluting effluents of each type with distilled water for treatments. It is used to investigate the effects of wastewater on the germination and early growth of the seedlings. Twenty-five healthy and quality seeds of each species were evenly placed in each of fifteen Petri dishes which contained water-soaked filter papers to show germination. These were allowed to germinate at room temperature and germination counts were made at daily intervals until the germination ceased. The measurement of root length and shoot length was taken after 4 days and calculated for vigor index. For pot samples, 20 healthy and undamaged seeds of each species were sowed in each of 15 small plastic pots to show the effects of different effluents on the germination and early growth. These five test solutions were used as irrigation water in pots. The plant height and leaf size were noted at every two days intervals.

2.6. Estimation of chlorophyll and carotenoid contents:

The Quantitative estimation of chlorophyll-a, chlorophyll-b and total chlorophyll was carried out by DMSO method (Hiscox and Israelstam, 1978). One gram of fresh leaf material was taken and cut into small pieces then suspended it in test tubes containing 4 ml of DMSO. Test tubes were incubated at 60 ^{0}C for 20 min. The supernatants were pooled and volume was made up to 10 ml by adding DMSO. The chlorophyll extract was read in a spectrophotometer at 662 nm, 645 nm and 470 nm for chlorophyll a, b and carotenoids, respectively. The amount of chlorophyll a, chlorophyll b and total chlorophyll was calculated by using the formula of Wellburn and Lichtenthaler (1984).

Chl. a (mg / L) = $11.75 \times A_{662} - 2.35 \times A_{645}$

Chl. b (mg/L) = $18.61 \times A_{645} - 3.96 \times A_{662}$

Total chlorophyll = Chl. a + Chl. b

Total carotenoids (mg/L) = $1000 \times A_{470} - 2.27 \times Ca - 81.4 \times Cb / 227$

Where, Ca = Total chl. a, Cb = Total chl. b

3. Results:

3.1. Physico-chemical parameters of wastewater samples:

The physicochemical analysis of the wastewater samples revealed that the wastewater samples were almost within the tolerance limits of irrigation water standards prescribed by the Bureau of Indian Standards (BIS) for industrial effluents on land. The temperature of distilled water and tap water was at normal room temperature of 25 ^{0}C. The temperature of industrial wastewater samples was within the prescribed BIS standards. The temperature was 28 ± 2 ^{0}C for all the three wastewater samples (WWS). The water samples of tap, distilled and WWS-1 had no colour. The WWS-2 and WWS-3 had milky white and pale yellow colour respectively. The water samples of tap and distilled water had no odour whereas the WWS-1, WWS-2 and WWS-3 had chemical and bleach odour. The water samples had different pH levels. The distilled water should be neutral with a pH of 7.0, but because it absorbs carbon dioxide from the atmosphere, it was slightly acidic with pH of 6.08. The WWS-2 had the highest pH level of 8.01 among all the samples (Table – 1).

The electric conductivity of the water samples was tested in laboratory using electric conductivity meter (EQ660B). The results reflect that the mean of WWS-2 had maximum conductivity among all samples, which is 1.72 ± 0.05 mS. The alkalinity of the TW, WWS-1, WWS-2 and WWS-3 is ranging from 390, 420, 620, 500 mg/L were recorded respectively. Water containing chloride concentrations of less than 150 mg/L of chloride are safe for most crops. The chloride contents in TW, WWS-1, WWS-2, WWS-3 were estimated as 469, 367.26, 52.60, 52.60 ± 2 mg/L. Total hardness is the measurement of mineral content in water samples. From the tests conducted the WWS-2 had the highest total hardness of 420 mg/L, whereas, the samples DW, TW, WWS-1 and WWS-3 had total hardness of 5, 281, 187, and 196 ± 2 mg/L (Table – 1).

It was found that WWS-2 had the highest Total Dissolved Solids (TDS) of 1800 mg/L, whereas other samples i.e., DW, TP, WWS-1 and the WWS-3 had TDS of 40, 500, 1050, 1550 ± 5 mg/L respectively. Total suspended solids are the solids dissolved in water that can be trapped by a filter. The WWS-3 had highest value of TSS was 700 mg/L. Whereas, other samples like DW, TW, WWS-1, WWS-3 had 20, 102, 134, 650 ± 5 mg/L respectively. Total dissolved oxygen (TDO) is the measure of amount of gaseous oxygen dissolved in an aqueous solution. Ensuring sufficient levels of dissolved oxygen in the irrigation water improves a plants overall health. The TDO of DW, TW, WWS-1, WWS-2 and WWS-3 are 20.8, 31.36, 24, 7 and 17.2 ± 2 mg/L.

Total dissolved carbon dioxide is the carbon dioxide present in water in the form of a dissolved gas. The WWS-1 and WWS-3 had exhibited absence of dissolved carbon dioxide. Whereas, TW and WWS-2 had dissolved CO_2 is of 0.057 and 0.025 were recorded respectively. Chemical oxygen demand (COD) is the measurement of the oxygen required to oxidize soluble and particulate organic matter in water. The COD of WWS-3 was highest in all samples i.e., 195.2 mg/L. The other samples TW, WWS-1 and WWS-2 had COD level as 142.4, 174.4 and 126.4 ± 2 mg/L Biological oxygen demand is the measurement of the amount of dissolved oxygen that is used by aerobic microorganisms when decomposing organic matter in water. The BOD of TW, WWS-1, WWS-2 and WWS-3 are 11, 56, 63 and 79 ± 2 mg/L (Table – 1).

3.2. Physico-chemical parameters of soil samples:

The collected soil samples contained maximum amount of silt viz, 57%, clay 33% and sand 10%. Hence from the soil texture chart it is identified as silty clay loam soil. Silty soil is usually more fertile than other types of soil; it promotes water retention and air circulation. From the physical analysis of sample it was found that it has pH of 8.06 and electrical conductivity 0.27 mS/cm.

In the chemical analysis revealed that phosphate amount was maximum i.e., 15 mg/Kg followed by sulphur 8.15 mg/Kg, potassium 6.11 mg/kg, iron 5.72 mg/Kg, manganese 1.53 mg/Kg, organic carbon 1.52 mg/Kg, copper 0.40 mg/Kg, nitrogen 0.35 mg/Kg, boron 0.20 mg/Kg and zinc 0.18 mg/kg (Table – 2).

3.3. Analysis of physical purity and rate of imbibitions in seeds:

The Imbibitions tests was conducted and observed that barley seeds in WWS-1 exhibited highest percent of imbibitions (67.67%) followed by WWS-3 which had imbibitions percent of 63.90%, control water TW had 61.41% of imbibitions, WWS-2 which had the lowest rate of imbibitions i.e., 60.83% (Fig.
2).
In case of bajra seeds in which TW exhibited highest percent of imbibitions (32.31%) followed by WWS-3 with 27.09%, WWS-1 with 24.33% and WWS-2 had 26.60% of imbibitions.
In contrast, the jowar seeds TW showed 26.56% of imbibitions rate followed by WWS-1 (24.20%), WWS-3 (24.15%) and WWS-2 (21.74%).
Overall comparison revealed that the imbibitions percentage of barley seeds stand first with the treatment of all the water samples and it is followed by bajra seeds, it is exhibited low rate of imbibitions compare to barley, but the jowar seeds shown the least imbibitions percentage among the three seed sample (Fig.
2).

3.4. Analysis of vegetative growth/vigor index in plant.

The vigor index in jowar seeds samples was highest (1665) in WWS-3 at 100% conc. and lowest (707) in WWS-1 at 25% conc. whereas, WWS-2 exhibited higher results at all concentrations (Table – 3). The vigor index in bajra seeds samples was highest (1775) at 50% conc. and lowest (604) at 25% concentration. Whereas, an average in all the samples of WWS-3 (Table – 3). The vigor index in barley seeds samples was highest (1545) in both WWS-2 and WWS-3 at 50% conc. and lowest (1065) in WWS-1 at 25% conc. And it showed better results in all the other samples (Table – 3). The all the seeds grown in TW (tap water) which is the control water sample had shown very less vigor index among all the water samples. It is indicated that seeds irrigated with industrial wastewater sample have better growth results than the tap water sample. The length of roots and shoots had shown different developmental variations in different samples. It was also observed that vigor index was higher in higher concentrated wastewater samples but the variations also merely depend on the type of seed selected (Fig. 3).

In the present study it was found that plant height was maximum in the Wastewatersamples the control i.e. tap water sample. In the tap water sample barley plant had maximum height (0.2m) and jowar plant height was minimum (0.19 m). In WWS-1 the barley plant was (0.215m), jowar (0.21m) and the bajra shortest (0.195m) height.

In WWS-2 the barley plant had maximum (0.24m) height followed by jowar plant (0.21m) and bajra plant (0.2m) height.
In WWS-3 jowar and barley both had maximum (0.23m) height followed by bajra plant sample.

In forage crops sufficient leaf surface area is needed to capture sunlight and continue photosynthesis. In the present work the leaf surface area of jowar and barley in TW was maximum (7.5cm^2) and bajra lowest (6cm^2). In WWS-1 bajra had the maximum surface area (6.5cm^2) and jowar, barley (5cm^2). In WWS-2 all the plants samples had relatively lower surface area. In WWS-3 all the plants exhibited preferable results, jowar (5cm^2), bajra (6.5cm^2) and barley (6.2cm^2) (Table 4).

Table 1
Physicochemical parameters of wastewater samples. Note: BIS,- Bureau of Indian Standards; DW- distilled water; TW-tap water; WWS- wastewater sample; NA, not applicable; * Absent

Parameters	UNIT	DW	TW	WWS-1	WWS-2	WWS-3	BIS
Temp	^0C	25	25	28	28	28	**40**
Colour	NA	*	*	*	Pale yellow	Milky	*****
Odour	NA	*	*	Foul	Foul	*	*****
pH	NA	6.08	6.90	7.50	8.1	7.75	**5.5–9**
EC	mS	0.25	1.0	0.86	1.75	1.16	**NA**
Alkalinity	mg/L	NA	390	420	620	500	**NA**
Chlorides	mg/L	NA	469	367.26	52.60	52.60	**600**
Hardness	mg/L	5	281	187	420	196	**300**
TDS	mg/L	400	500	1050	1800	1550	**2100**
TSS	mg/L	20	102	134	650	700	**200**
Tdo	mg/L	20.8	31.3	24	8	17.2	**NA**
$TDCO_2$	mg/L	NA	0.05	NIL	0.025	NIL	**NA**
COD	mg/L	0.0	142	174.4	126.4	195.2	**250**
BOD	mg/L	NA	11	56	63	79	100

Table 2
Physico-chemical parameter of soil samples.

Sl. No.	Unit	Parameters	Value
1.	-	pH	8.06
2.	mS/cm	EC	0.27
3.	mg/Kg	OC	1.52
4.	mg/Kg	N	0.35
5.	mg/Kg	P_2O_5	15
6.	mg/Kg	K_2O	611
7.	mg/Kg	S	8.15
8.	mg/Kg	Zn	0.18
9.	mg/Kg	B	0.20
10.	mg/Kg	Fe	5.72
11.	mg/Kg	Mn	1.53
12.	mg/Kg	Cu	0.40
13.	%	Clay	32.69
14.	**%**	Silt	57
15.	**%**	Sand	9.61

Table 3
Vigour index of jowar, bajra and barley plants grown in different concentrations of wastewater

Sl. No.	Sample type	Days of observation	No. of test seeds	JOWAR											
				(WWS-1)				(WWS-2)				(WWS-3)			
				MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) × PG	MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) × PG	MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) × PG
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	4.25	2.82	100	707	10.19	6.44	96	1596	8.79	5.74	96	1394.88
4.	50%	5	25	4.36	3.83	92	753	8.89	5.94	92	1364.36	9.68	5.20	96	1428.48
5.	100%	5	25	5.73	3.35	88	799	8.60	5.14	84	1154.16	10.60	7.50	92	1665.2
				BAJRA											
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	4.1	2.2	96	604.8	9.5	6.1	100	1497.6	6.8	4.7	92	1058
4.	50%	5	25	7.4	5.1	92	1150	7.5	4.2	96	1123.2	11.2	8.1	92	1775.6
5.	100%	5	25	8.6	3.8	92	1140.8	8.2	4.8	92	1196	9.9	5.1	88	1320
				Barley											
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	6.9	4.2	96	1065.6	8.2	6.3	96	1392	8.2	6.3	92	1334
4.	50%	5	25	8.3	6.9	92	1398.4	10.2	5.9	96	1545.6	10.2	5.9	96	1545
5.	100%	5	25	11.2	5.9	84	1436.4	9.3	6.5	88	1390.4	9.3	6.5	92	1453.6

Table 4
Plant height and surface area of leaf in jowar, bajra and barley plants grown in different concentrations of wastewater

Water Sample types	Height of plants (15th day)	No. of leaves in plants			Avg. leaf length (cm)			Avg. leaf width (cm)			Avg. leaf SA (cm^2)		
		6th day	10th day	15th day	6th day	10th day	15th day	6th day	10th day	15th day	6th day	10th day	15th day
JOWAR													
TW	0.19 m	3	4	8	9.03	12	16	0.9	1.1	1.5	5	6	7.5
WWS-1	0.21 m	2	3	4	5.46	7.4	10.2	0.7	0.8	1.0	3.5	4	5
WWS-2	0.21 m	3	4	5	5.66	6.5	9.8	0.83	0.9	1.1	3.5	4	4.5
WWS-3	0.23 m	3	4	6	6.36	11.2	13.6	0.83	0.96	1.3	4	4.5	6
BAJRA													
TW	0.195m	2	3	5	5	6.8	9.5	0.5	0.8	1.1	4	4.5	6
WWS-1	0.195 m	2	3	5	4.2	6.6	9	0.4	0.6	0.9	4	4.5	6.5
WWS-2	0.2 m	2	3	4	3.8	5.9	7.6	0.4	0.5	0.8	3	4	5.5
WWS-3	0.19 m	3	4	4	4.8	7.1	9.2	0.5	0.7	1.0	4.5	5	6.5
BARLEY													
TW	0.2 m	3	5	7	7.2	8.5	10.2	0.4	0.4	0.5	5	6	7.5
WWS-1	0.215 m	3	4	6	6.9	8.1	9.1	0.3	0.4	0.5	3.5	4	5
WWS-2	0.24 m	4	5	6	7.5	8.6	9.5	0.83	0.9	1.1	3.5	4	4.5
WWS-3	0.23 m	3	4	6	6.36	11.2	13.6	0.83	0.96	1.3	4.5	4.9	6.2

3.5. Estimation of Chlorophyll and Carotenoids:

From the present investigations it was found that total chlorophyll in jowar plant was maximum (172.53µg/g) in WWS-1 followed by WWS-2 (169.21µg/g) and WWS-3 (144.74µg/g). In the control water (TW) the total chlorophyll content was too less (107.69µg/g) than the other water samples (Fig. 4).

The total chlorophyll in bajra plant was maximum (175.54 µg/g) in WWS-2, followed by WWS-1 (174.56µg/g) and WWS-3 (146.18µg/g).
In the control sample total chlorophyll content was low (110.92µg/g) than other samples (Fig. 4).
The total chlorophyll in barley leaves was maximum (109.08µg/g) in WWS-2 followed by WWS-1 (164.17µg/g) and WWS-3 (154.83µg/g).
The total chlorophyll in control water (TW) was less (105.98µg/g) than other samples (Fig. 4).
It was found that carotenoid contents in jowar leaves were highest in TW sample followed by WWS-2 (2.46), WWS-3 (2.29) and WWS-1(2.1).
In bajra leaves carotenoid content was high in WWS-2 (2.72) followed by TW (2.30), WWS-1 (1.98) and WWS-3 (1.2). In barley leaves carotenoid content was maximum in TW (3.76) followed by WWS-3 (3.59), WWS-2 (2.49) and WWS-1 (1.51) these readings are graphically represented (Fig. 4).

4. Discussion:

The present work evaluates the industrial effluents effects on forage crops. The irrigation system dependence on wastewater effluents is essential now-a-days and as an alternative in drought condition because fresh water shortage. In this way, heavy metals started to accumulate in the soil and as well as in our food chain. We need to evaluate the accumulated metals and their effects on crops. Similar kinds of work were conducted on three leafy vegetables by Ali et. al., 2019, they are Coriander (*Coriandrum sativum*), Purslane (*Portulaca oleracea*) and Lettuce (*Lectuca sativa*), Munir et. al., 2007 conduct on Barley (*Hordeum vulgare*) and Uzma *et. al.* in 2016 conducts an experiment on vegetables. Effects of domestic sewage water on the desert shrub *Calotropis procera* were evaluated by Abdellah *et. al.* in 2019. Investigate the short-term effect of different dilutions of wastewater on soil chemical properties, chemical fractions of zinc (Zn) and copper (Cu), and to assess the chemical buildup of heavy metal on two bean species were evaluated by Saffari and Saffari (2013). Wastewatertreatment had found a significant effect on the growth of leafy plants (Aghtape et. al., 2011; Munir et. al., 2007). Assessment of changes in physical and biochemical characteristics of soil and metal partitioning in *Beta vulgaris* was revealed by Singh and Agrawal (2012). Vegetative growth parameters such as height, number of leaves, and rate of germination of seed were measured to know the impact of Wastewatertreatment (Faiz *et. al.*, 2010; Ali et. al., 2019). Oil and Natural Gas Corporation (ONGC) is leading national oil company, refines crude oil and natural gas etc. and huge quantity of water is used in refining process and water used in the process come out as wastewater with major pollutants like high COD, hydrocarbons, suspended particles, oil and grease and with other contaminant. ONGC has setup the wastewater treatment system which includes physical, chemical and biological methods. To analyze water quality of treated wastewater of ONGC, use this in raising the vegetable crops and check its effects (Gadhia et. al. 2014). Water quality assessment showed that results of temperature, total solids, total dissolved solids, total hardness, total alkalinity, nitrate and phosphate were higher in treated waste water.

In 2004, Vigneswaran reported that the water with 1000–2000 mg/L total dissolved solids, 200 mg/L total suspended solids, (5.5–8.5) pH, (150 mg/L) chemical oxygen demand, (250 mg/L) chloride and (5mg/L) oil and grease was suitable for the cultivation of vegetables crops in China. Bansal and Kapoor in 2000, pointed out that the usage of wastewater supplied nutrients to different crops and also improved soil physical properties and its fertility. Alderfasi and Ali Abdullah (2009) reported the increase in the growth of wheat plants irrigated with treated wastewater. The literature survey suggest that the use of wastewater to irrigate the crop is not only significant to the farmers apart from this it reduces the applications of chemical fertilizers to the crop. Therefore, the great possibilities for growing highly profitable forage crops using treated wastewater in off season is significance to the farmers.

5. Conclusion:

On the basis of overall observations of all the three forage crops while subjecting to different industrial effluents, it can be suggested that effluents released from various industries are prospective source of nutrients and therefore, they may be beneficial alternative resource to fresh water for irrigation purposes in off season. However the extent of growth success depends on the plant species. From the present investigations it is concluded that the quality of most of the wastewater samples were almost within the tolerance limits of irrigation water standards prescribed by the Bureau of Indian standards for industrial effluents on land for irrigation thus they are suitable for irrigation purpose. This study indicates that the irrigation of forage crops under treated wastewater can save the most valuable agricultural resource which is water under climate change conditions. In a study it was found that the fodder crop Sudax a variety of *Sorghum vulgare* produced from treated sewage effluent and fed to ruminants as hay or as fresh green material (forage) to sheep and goats, did not cause health problems to the animals. Thus there are great possibilities for growing highly profitable forage crops using treated wastewater in off season.

Declarations

Conflict of Interest: The authors declare that they have no conflict of interest.

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Tables

Parameters	UNIT	DW	TW	WWS-1	WWS-2	WWS-3	BIS
Temp	0_C	25	25	28	28	28	**40**
Colour	NA	*	*	*	Pale yellow	Milky	*****
Odour	NA	*	*	Foul	Foul	*	*****
pH	NA	6.08	6.90	7.50	8.1	7.75	**5.5 – 9**
EC	mS	0.25	1.0	0.86	1.75	1.16	**NA**
Alkalinity	mg/L	NA	390	420	620	500	**NA**
Chlorides	mg/L	NA	469	367.26	52.60	52.60	**600**
Hardness	mg/L	5	281	187	420	196	**300**
TDS	mg/L	400	500	1050	1800	1550	**2100**
TSS	mg/L	20	102	134	650	700	**200**
Tdo	mg/L	20.8	31.3	24	8	17.2	**NA**
$TDCO_2$	mg/L	NA	0.05	NIL	0.025	NIL	**NA**
COD	mg/L	0.0	142	174.4	126.4	195.2	**250**
BOD	mg/L	NA	11	56	63	79	100

Table 1 - Physicochemical parameters of wastewater samples.
Note: BIS,- Bureau of Indian Standards; DW- distilled water; TW-tap water; WWS- wastewater sample; NA, not applicable; * Absent

Sl. No.	Unit	Parameters	Value
1.	-	pH	8.06
2.	mS/cm	EC	0.27
3.	mg/Kg	OC	1.52
4.	mg/Kg	N	0.35
5.	mg/Kg	P_2O_5	15
6.	mg/Kg	K_2O	611
7.	mg/Kg	S	8.15
8.	mg/Kg	Zn	0.18
9.	mg/Kg	B	0.20
10.	mg/Kg	Fe	5.72
11.	mg/Kg	Mn	1.53
12.	mg/Kg	Cu	0.40
13.	%	Clay	32.69
14.	**%**	Silt	57
15.	**%**	Sand	9.61

Table 2 - Physico-chemical parameter of soil samples.

Sl. No.	Sample type	Days of observation	No. of test seeds	JOWAR											
				(WWS-1)				(WWS-2)				(WWS-3)			
				MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) PG	MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) PG	MRL (cm)	MSL (cm)	PG	VI= (MRL + MSL) PG
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	4.25	2.82	100	707	10.19	6.44	96	1596	8.79	5.74	96	1394.88
4.	50%	5	25	4.36	3.83	92	753	8.89	5.94	92	1364.36	9.68	5.20	96	1428.48
5.	100%	5	25	5.73	3.35	88	799	8.60	5.14	84	1154.16	10.60	7.50	92	1665.2
				BAJRA											
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	4.1	2.2	96	604.8	9.5	6.1	100	1497.6	6.8	4.7	92	1058
4.	50%	5	25	7.4	5.1	92	1150	7.5	4.2	96	1123.2	11.2	8.1	92	1775.6
5.	100%	5	25	8.6	3.8	92	1140.8	8.2	4.8	92	1196	9.9	5.1	88	1320
				Barley											
1.	DW	5	25	4.46	2.72	88	631.84	4.46	2.72	88	631.84	4.46	2.72	88	631.84
2.	TW	5	25	3.54	2.38	100	592	3.54	2.38	100	592	3.54	2.38	100	592
3.	25%	5	25	6.9	4.2	96	1065.6	8.2	6.3	96	1392	8.2	6.3	92	1334
4.	50%	5	25	8.3	6.9	92	1398.4	10.2	5.9	96	1545.6	10.2	5.9	96	1545
5.	100%	5	25	11.2	5.9	84	1436.4	9.3	6.5	88	1390.4	9.3	6.5	92	1453.6

Table 3 - Vigour index of jowar, bajra and barley plants grown in different concentrations of wastewater

JOWAR													
Water Sample types	Height of plants (15^{th} day)	No. of leaves in plants			Avg. leaf length (cm)			Avg. leaf width (cm)			Avg. leaf SA (cm^2)		
		6^{th} day	10^{th} day	15^{th} day	6^{th} day	10^{th} day	15^{th} day	6^{th} day	10^{th} day	15^{th} day	6^{th} day	10^{th} day	15^{th} day
TW	0.19 m	3	4	8	9.03	12	16	0.9	1.1	1.5	5	6	7.5
WWS-1	0.21 m	2	3	4	5.46	7.4	10.2	0.7	0.8	1.0	3.5	4	5
WWS-2	0.21 m	3	4	5	5.66	6.5	9.8	0.83	0.9	1.1	3.5	4	4.5
WWS-3	0.23 m	3	4	6	6.36	11.2	13.6	0.83	0.96	1.3	4	4.5	6
BAJRA													
TW	0.195m	2	3	5	5	6.8	9.5	0.5	0.8	1.1	4	4.5	6
WWS-1	0.195 m	2	3	5	4.2	6.6	9	0.4	0.6	0.9	4	4.5	6.5
WWS-2	0.2 m	2	3	4	3.8	5.9	7.6	0.4	0.5	0.8	3	4	5.5
WWS-3	0.19 m	3	4	4	4.8	7.1	9.2	0.5	0.7	1.0	4.5	5	6.5
BARLEY													
TW	0.2 m	3	5	7	7.2	8.5	10.2	0.4	0.4	0.5	5	6	7.5
WWS-1	0.215 m	3	4	6	6.9	8.1	9.1	0.3	0.4	0.5	3.5	4	5
WWS-2	0.24 m	4	5	6	7.5	8.6	9.5	0.83	0.9	1.1	3.5	4	4.5
WWS-3	0.23 m	3	4	6	6.36	11.2	13.6	0.83	0.96	1.3	4.5	4.9	6.2

Table 4 - Plant height and surface area of leaf in jowar, bajra and barley plants grown in different concentrations of wastewater

Figures

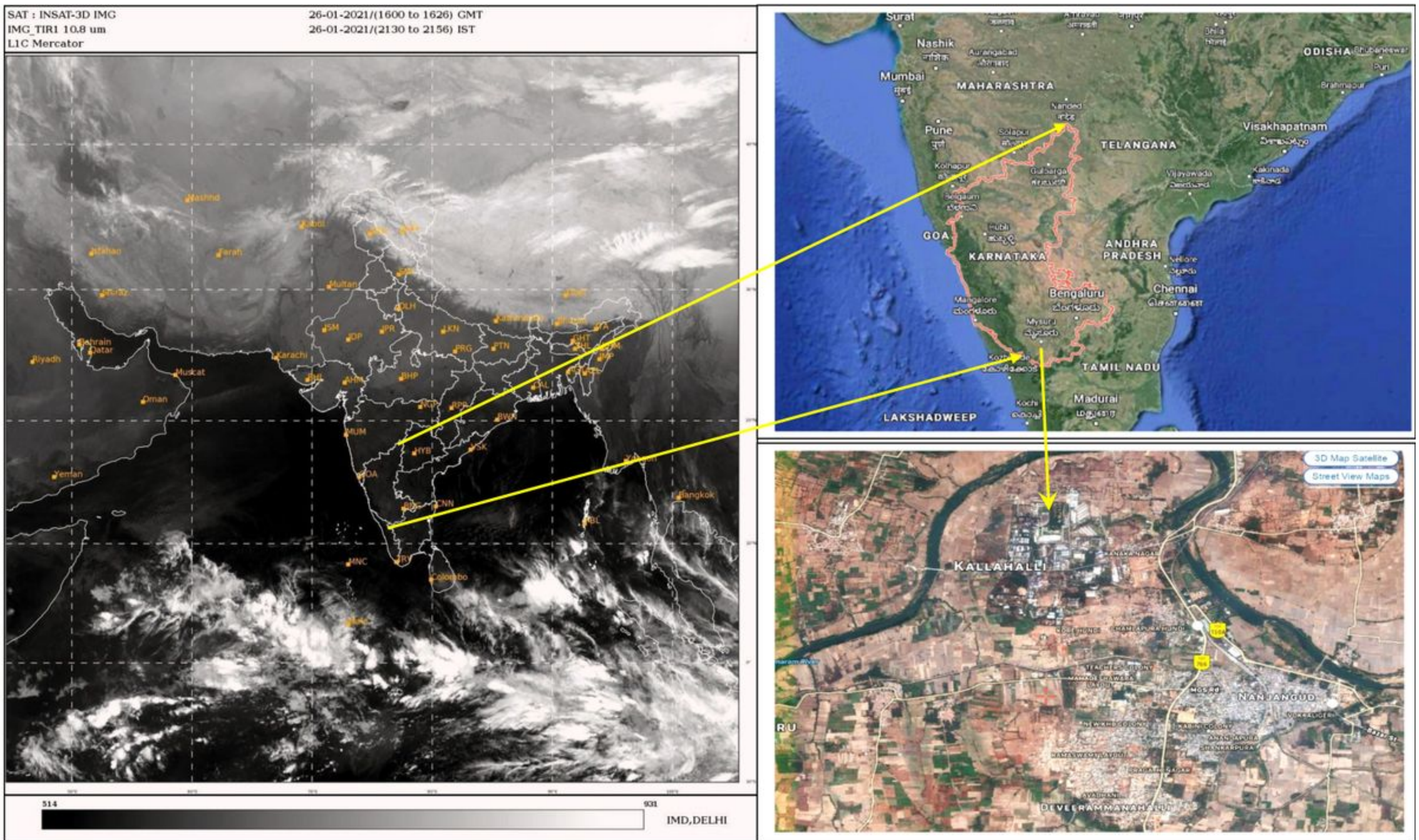

Fig.1 – Satellite Photograph of Nanjanagud (study location), Mysore District, Karnataka, India

Figure 1

Satellite Photograph of Nanjanagud (study location), Mysore District, Karnataka, India. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

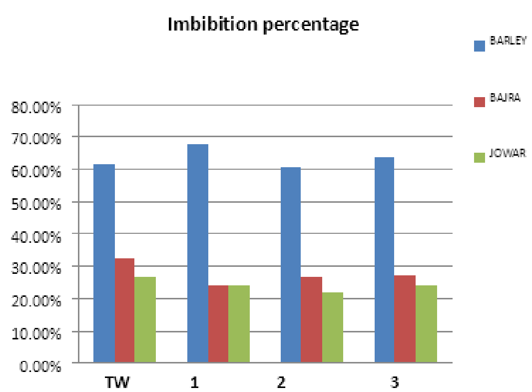

Figure 2

Graph showed imbibitions percentage in three crop varieties.

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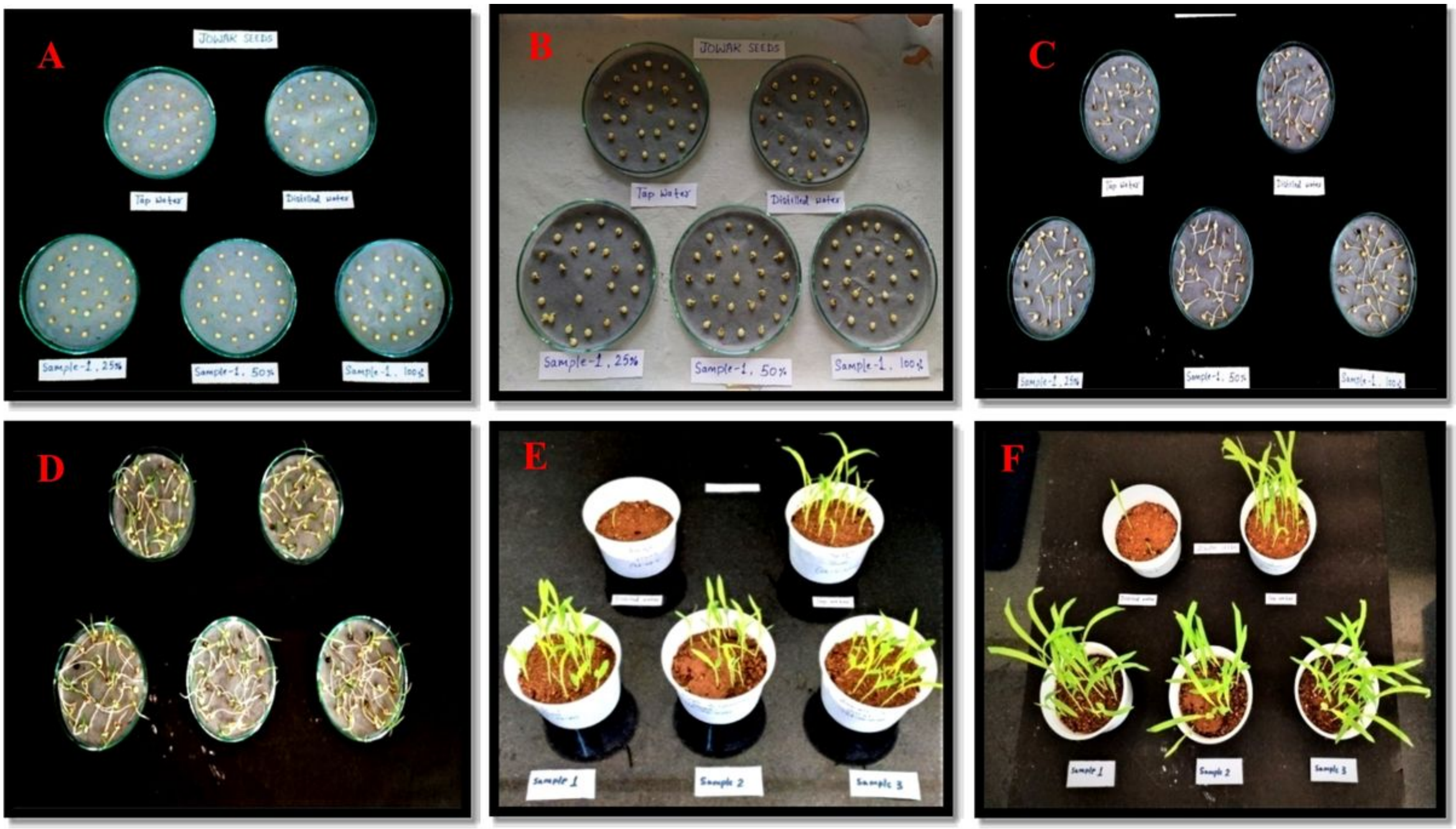

Figure 3

Jowar seeds subjected without and with soil medium for testing seed viability, vigor index and plant height at different time intervals. A., B. and C. Jowar seeds on first day, second day and third days in different concentrations of wastewater treated for seed viability test. D. Jowar seeds on day 5 with shoot and root emerged to estimate vigor index. E. and F. Jowar plant growth with different water samples on 5 to 10 days interval after sowing to estimate plant height and number and length of the leaves.

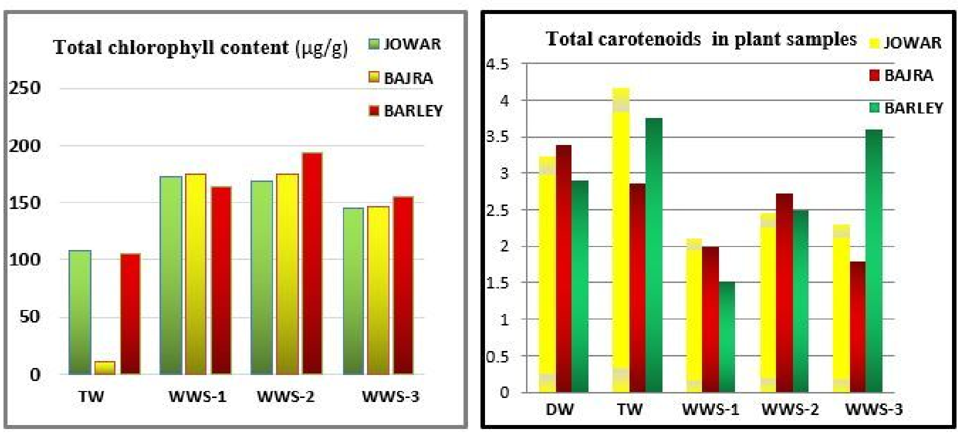

Figure 4

The effect of industrial wastewater treatment in pot cultures revealed significant range of pigment chlorophyll a, b, total chlorophyll and carotenoid contents.