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Sewage water and sludge utilization for increasing the growth and yield of green chilli (*Capsicum annuum* L.)

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Abstract
A field experiment was conducted at college of agriculture Shivamogga for effective utilization of sewage water and sludge generated from sewage treatment plant of college Campus. The experiment was conducted in a factorial RCBD consisting of two factors *viz.*, irrigation source and manurial source each factor having three levels replicated thrice. Irrigation level consists of normal water (I_1), treated sewage water (I_2) and untreated sewage water (I_3). Whereas manurial source consists of FYM 25 t ha^{-1} (M_1), Sewage sludge @ 25 t ha^{-1} (M_2) and FYM @12.5 t ha^{-1}+Sewage sludge @ 12.5 t ha^{-1} (M_3) resulting in nine treatment combination. The growth parameters of chilli plants *viz.*, plant height, number of branches, dry matter, leaf area index, leaf area duration, crop growth rate and relative growth rate was enhanced by irrigation with sewage water irrigation and sludge application. Irrigation with untreated sewage water resulted significantly higher green chilli yield (15.36 t ha^{-1}) as compared to irrigation with normal water (11.11 t ha^{-1}) similarly application of sewage sludge @ 25 t ha^{-1} recorded maximum green chilli yield (14.98 t ha^{-1}). Ascorbic acid content green chilli fruits was found significantly higher in irrigation with untreated sewage water (114.88 mg 100 gm^{-1}) and application of sewage sludge @ 25 t ha^{-1} (126.81mg 100gm^{-1}).

Keywords: untreated sewage water, sewage sludge, green chilli yield, ascorbic acid

Introduction
The global population is increasing and concentrating in urban centers which leads to overcrowding of population in the urban area in the coming decades resulting in huge sewage waste generation due to domestic use and industrial operations (Kaur *et al.*, 2012) [20]. According to central pollution control board (CPCB), New Delhi, about 38354 million liter per day (MLD) wastewater generated from cities and towns is the main cause of freshwater pollution in India. A nearly less than half of this quantity only about 11786 MLD is treated by the sewage treatment plants and rest of the sewage is discharged without treatment. At the same time there is scarcity for irrigation water for agriculture due to decline in ground water table and also because of erratic distribution of rainfall. Hence there is a need for utilization of sewage water for crop production to meet out the deficit supply and also safe recycling of sewage water (Akponikpe *et al.*, 2011) [22]. Similarly, the sewage sludge generated during the treatment of sewage effluent is dried in the sludge beds and can be used for manuring the agricultural crops. Sewage water and sludge contains major and micronutrients apart from these they also contains harmful chemical substances such as heavy metals and other inert materials limited their usage as land application for crop production. Waste minimization and recycling or reuse policies have been introduced so as to reduce the amount of waste generated and alternative waste management strategies are being exploited, to reduce the environmental footprints of waste management and also reverting back the nutrients present in them to the agricultural lands for enhancing the productivity of crops with careful monitoring and management (Poornesh *et al.*, 2004; Mantovi *et al.*, 2005) [23, 26]. Green chillies supplied to markets for fresh consumption are grown near the peri urban areas so there is a greater scope for utilization of sewage water and sludge as a source of irrigation water and manure. Chilli crop gives good response to application of sewage water and sludge among the vegetables

(Iqbal *et al*., 2016) [25]. Unscientific usage of sewage water and sludge in chilli crop will have adverse effect on soil properties besides causing severe health hazards to consumer. Hence, systematic study on usage of sewage water and sludge is very much needed.

Materials and methods

The field experiment was conducted during summer 2018 at College of agriculture Shivamogga near the sewage treatment plant of campus to investigate the effect of sewage water and sludge on growth and yield of green chilli and soil properties. The experimental site was situated in Southern Transitional Zone of Karnataka at 14°0'N to 14º1' N latitude and 75°40' E to 75 º 42’ E longitudes and the soil texture was sandy loam in nature. Soil of the experimental site was slightly acidic (6.01) in nature with low available N -210 kg ha^{-1} (Subbbaiah and Asija, 1956) [27], available P -20.12 kg ha^{-1} (Jackson, 1973) [8] and available K -270 kg ha^{-1}(Jackson, 1973) [8]. The experiment was carried out in completely randomized block design with factorial concept consisting of two factors, irrigation source and manurial source replicated thrice. Each factors tried at three level resulted in nine treatment combinations, irrigation source consists untreated sewage water (I_1), treated sewage water (I_2) and normal water (I_3).Untreated sewage water and treated sewage water used for experiment were collected from sewage treatment plant of College of Agriculture Shivamogga and normal water (best available water in the campus for irrigation) was collected from surface tank which was located near the experimental site. The manure source consists of three levels FYM @ 25 t ha^{-1}(M_1), Sewage sludge @ 25 t ha^{-1} (M_2) and FYM @12.5 t ha^{-1} + Sewage sludge @ 12.5 t ha^{-1}(M_3). The sewage water in the sewage treatment plant treated through sequence batch reactor process.

Treatment combinations

T_1 (I_1M_1) - Irrigation with normal water + FYM @ 25 t ha^{-1}
T_2 (I_1M_2) - Irrigation with normal water + Sewage sludge @ 25 t ha^{-1}
T_3 (I_1M_3) - Irrigation with normal water + FYM @ 12.5 t ha^{-1} + Sewage sludge @ 12.5 t ha^{-1}
T_4 (I_2M_1) - Irrigation with treated Sewage water + FYM @ 25 t ha^{-1}
T_5 (I_2M_2) - Irrigation with treated sewage water + Sewage sludge @ 25 t ha^{-1}
T_6 (I_2M_3) - Irrigation with treated sewage water + FYM @ 12.5t ha^{-1} FYM + Sewage sludge @ 12.5 t ha^{-1}
T_7 (I_3M_1) - Irrigation with untreated sewage water + FYM @ 25 t ha^{-1}
T_8 (I_3M_2) - Irrigation with untreated sewage water + Sewage sludge @ 25 t ha^{-1}
T_9 (I_3M_3) - Irrigation with untreated sewage water + FYM @ 12.5 t ha^{-1} FYM + Sewage sludge @ 12.5 t ha^{-1}.

The irrigation water and manure source analyzed for their Physico chemical characteristics, heavy metal content in the sewage water and sludge was analyzed by inductively coupled plasma emission spectroscopy (Tandon 1993). Microbial count in sewage water and sludge obtained by serial plate dilution technique. Growth parameters such as Plant height was measured from base of the plant to the tip of the main shoot. Total number of branches per plant were counted in tagged plants. Dry weight of plants (drying at 65°C at a constant weight) at different crop growth stages and total dry matter was expressed in gram. Leaf area index (LAI) was worked out by using the formula as suggested by (Sestak *et al.*, 1971) [16]. Leaf Area Duration (LAD**)** for various growth periods was worked out by adopting the formula of (Power *et al*., 1967) [12] and expressed in days. Relative growth rate (RGR**)** was calculated by using the following formula given by Fisher (1921) [4]. Crop Growth Rate (CGR) is the rate of total dry matter (TDM) produced per unit time per unit area and expressed in g m^{-2} day^{-1}. It was worked out by using the formula given by Watson (1952) [28]. Yield parameter such as fruit index is a product of length and diameter of ten randomly selected fruits and average was worked out. Fruit quality parameter ascorbic acid content was measured by 2-6, dichlorophenol indophenol sodium salt method (Sadasivam and Manikam, 1992) [15]. All the growth and yield parametres is subjected to stastiscal analysis (Fisher, 1921) [4].

Results and discussion

Physico chemical characteristics of sewage water and sludge: Sewage water and sludge obtained from sewage treatment plant of college agriculture Shivamogga was of good quality (Table 1) rich in major and micro plant nutrients and all the heavy metals like cobalt, arsenical, lead and nickel and microbial count present in sewage water and sludge was well within the regulatory limits that can be safely utilized for agriculture use without any hazardous effect on soil and the crop. The untreated sewage water contains relatively higher amount nutrients as compared to sewage water (Table 1). The decrease in nutrient content in sewage water after treatment may be attributed to biological nutrient removal process *viz.*, nitrification, denitrification and enhanced biological phosphorus removal (EBPR) when sewage water was treated through sequence batch reactor process (Aparna and Sudipta, 2015) [2]. However the treated sewage water exhibited good quality as compared to untreated sewage water with respect to chemical and biological properties *viz.*, pH, EC, BOD, COD, TSS, heavy metals and microbial population (Table 1) and it is also evident that sewage sludge is a good source of plant nutrients as compared to FYM since sewage sludge contains relatively higher amounts of essential nutrients than the FYM.

Table 1: Characterization of irrigation source and manure.

Properties	Unit	NW	UTSW	TSW	Unit	SS	FYM
pH		7.22	7.86	7.45		6.8	7.1
EC (dS m^{-1})	dS m^{-1}	0.52	1.33	0.91	dS m^{-1}	0.9	0.32
TDS	(mg/l)	100.01	760.40	447.71	-	-	-
BOD	(mg/l)	18.35	45.80	30.21	-	-	-
COD	(mg/l)	23.45	66.23	42.23	-	-	-
Nitrogen	ppm	6.26	13.30	9.3	%	2.5	0.45
Phosphorus	ppm	10.02	16.60	23.0	%	1.2	0.057
Potassium	ppm	9.66	19.50	19.2	%	1.9	0.38
Calcium	meq ltr $^{-1}$	3.46	3.80	3.21	%	3.9	1.8
Magnesium	meq ltr $^{-1}$	2.98	3.60	3.53	%	0.6	0.4

Heavy metals concentration							
Cobalt	mg ltr^{-1}	ND	0.004	0.001	mg kg^{-1}	0.14	ND
Lead	mg ltr^{-1}	ND	ND	ND	mg kg^{-1}	0.67	ND
Arsenic	mg ltr^{-1}	ND	0.004	0.002	mg kg^{-1}	0.32	ND
Nickel	mg ltr^{-1}	ND	0.004	0.004	mg kg^{-1}	2.64	ND
Chromium	mg ltr^{-1}	ND	ND	ND	mg kg^{-1}	5.56	ND
Microbial population							
Sources	**unit**	**Actinomycetes 10^2**	**Fungi 10^3**	**Bacteria 10^5**		***E. coli* 10^5**	***Salmonella* 10^2**
I_1- Normal water	cfu /ml of water	4	8	12		0	0
I_2- Treated sewage water	cfu /ml of water	10	15	17		0	0
I_3- Untreated sewage water	cfu /ml of water	12	37	29		5	0
FYM	cfu gm^{-1} of manure	6	19	22		0	0
Sewage sludge	cfu gm^{-1} of manure	15	39	32		7	0

Growth parameters: Findings of the present study clearly evidenced the differential response with respect to effect different sources of irrigation water and manure source on growth parameters of chilli. Irrigation with untreated sewage water treatments recorded significantly higher plant height (38.44, 53.06 and 60.59 cm), more number of branches per plant (11.23, 19.86, and 23.46) at 60, 90 and 120 DAT respectively as compared to irrigation with normal water (Table 2) Similarly application of sewage sludge @ 25 t ha^{-1} recorded higher plant height at 60 (40.31 cm) 90 (53.93 cm) and 120 DAT (63.96 cm) as compared to application of 25 t ha^{-1} FYM (Table 2).Total number of branches $plant^{-1}$ increased to the extent of 71.68, 40 and 45.09 per cent at 60, 90 and 120 DAT in the manure level M_2 sewage sludge @ 25 t ha^{-1} was compared to M_1 level (Table 2). This may be attributed to higher nitrogen content present in untreated sewage water which promoted excessive vegetative growth by inducing cell enlargement and cell division. The findings are in accordance with the results obtained by Khankhane and Yadav *et al.* (2003) [30]. Irrigation with untreated sewage water resulted in higher leaf area index of 60(0.181) 90(0.353) and 120 DAT (0.173) as compared to normal water irrigation (Table 3). Green chilli crop irrigated with untreated sewage water produced maximum LAD (3.27, 8.02and 7.90 days at 30-60, 60-90 and 90-120 days respectively) which was significantly superior to irrigation with normal water (2.82, 6.23 and 5.85 days at 30-60, 60-90 and 90-120 days respectively). Significantly highest LAD was produced in manure level M_2 (3.66, 8.74 and 8.05 days at 30-60, 60-90 and 90-120 days respectively) which was significantly superior to other manure levels M_1 and M_3 (Table 3). The abundant supply of nitrogen may have increased protoplasmic constituents and accelerated the process of cell division and elongation which in turn resulted in luxuriant vegetative growth thereby exposing more leaf area to the sunlight. Singh and Agrawal (2010) [17] also reported that leaf area increased significantly when grown under various sewage sludge amendment.

Significant difference in the total dry matter production was observed in the different sources of irrigation water and manure (Table 3). The higher rate of dry matter production was observed in Irrigation with untreated sewage water (66.09, 111.03 and 91.64 g / plant) at 60, 90 and 120 DAT over normal water irrigation similarly in case of sewage sludge @ 25 t ha^{-1}.

The higher values of dry matter accumulation may be attributed to higher uptake of nutrients and better canopy coverage, which resulted in the better photosynthesis and translocation of these photosynthates in to different plant parts (leaf, stem and fruit) which reflected in higher total dry matter accumulation in chilli plant. The results are in confirmation with findings of Neginahal *et al.* (2009) [11]. Irrigation with untreated sewage water recorded higher crop growth rate 5.33 $g^{-1}m^{-2}$ day^{-1} which was closely followed by treated sewage water irrigation (4.19 g^{-1} $m^{-2}day^{-1}$) as compared to normal water irrigation during 30-60 DAT (Table 3) this might be attributed to continuous supply of nutrients from waste water Prabu *et al.* (2003) [13]. Hiremath *et al.* (2006) [7] reported that sufficient uptake of nitrogen with their availability progressively increases the growth of plants. The RGR was more during earlier days and gradually decreases thereafter. There was no significant change in RGR due to different sources of irrigation water (Table 3). Because of all the above growth parameters the crop growth rate increased significantly in the treatment received sewage sludge @ 25 t ha^{-1}. There no significant interaction between different sources of irrigation water and manure which affects growth parameter.

Table 2: Growth Parameters of green chilli as influenced by different sources of irrigation water and manure.

Treatments	Plant height (cm)				Total branches				Total dry matter (g/plant)			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
Sources of Irrigation water (I)												
I_1 - Normal water	19.9	33.36	44.05	53.57	3.93	7.47	16.21	16.80	11.28	48.06	86.71	78.29
I_2 -Treated sewage water	22.1	35.94	50.94	58.60	4.05	9.85	18.10	21.51	11.88	54.08	100.52	88.12
I_3- Untreated sewage water	22.3	38.44	53.06	60.59	4.12	11.23	19.86	23.46	12.47	66.09	111.03	91.64
S Em ±	1.37	1.16	1.94	1.68	0.11	0.51	0.66	0.73	0.36	2.49	3.48	1.93
CD (P= 0.05)	NS	3.48	5.81	4.95	NS	1.52	1.98	2.19	NS	7.44	10.41	5.76
Sources of Manure (M)												
M_1- FYM @ 25 t ha^{-1}	20.7	31.80	45.29	52.89	3.92	7.24	15.45	17.01	11.17	47.60	81.57	80.05
M_2- Sewage sludge @ 25 t ha^{-1}	22.2	40.31	53.93	63.96	4.22	12.43	21.63	24.68	11.88	67.41	118.57	93.32
M_3- FYM @ 12.5 t ha^{-1} + sewage sludge @ 12.5 t ha^{-1}	21.5	35.62	48.84	55.92	3.96	8.88	17.08	20.07	12.47	53.21	98.50	84.67
S Em ±	1.37	1.16	1.94	1.68	0.11	0.51	0.66	0.73	0.36	2.49	3.48	1.93
CD (P= 0.05)	NS	3.48	5.81	4.95	NS	1.52	1.98	2.19	NS	7.44	10.41	5.76
Interaction (I×M)												
S Em ±	2.37	2.01	3.37	2.87	0.20	0.84	1.15	1.27	0.63	2.49	6.03	3.34
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Leaf area index, Crop growth rate and Relative growth rate of chilli as influenced by different sources of irrigation water and manure.

Treatments	LAI				CGR			RGR		
	30 DAT	60 DAT	90 DAT	120 DAT	30-60 DAT	60-90 DAT	90- 120 DAT	30-60 DAT	60-90 DAT	90 - 120 DAT
Sources of Irrigation water (I)										
I_1 - Normal water	0.033	0.155	0.261	0.128	3.65	3.84	0.23	0.0208	0.0084	0.0012
I_2 -Treated sewage water	0.035	0.166	0.323	0.151	4.19	4.62	0.32	0.0219	0.0088	0.0015
I_3-Untreated sewage water	0.037	0.181	0.353	0.173	5.33	4.47	0.10	0.0229	0.0076	0.0005
S Em ±	0.001	0.005	0.012	0.013	0.25	0.5	0.13	0.0009	0.0001	0.0005
CD (P= 0.05)	NS	0.017	0.036	NS	0.77	NS	NS	NS	NS	NS
Sources of Manure (M)										
M_1- FYM @ 25 t ha^{-1}	0.035	0.128	0.246	0.150	3.62	3.37	0.45	0.0208	0.0078	0.0021
M_2- Sewage sludge @ 25 t ha^{-1}	0.036	0.207	0.374	0.162	5.46	5.05	-0.03	0.0233	0.0082	0.0008
M_3- FYM @ 12.5 t ha^{-1} + sewage sludge @ 12.5 t ha^{-1}	0.034	0.166	0.317	0.141	4.16	4.50	0.25	0.2152	0.0088	0.0017
S Em ±	0.001	0.005	0.012	0.013	0.25	0.56	0.13	0.0009	0.0001	0.0004
CD (P= 0.05)	NS	0.017	0.036	NS	0.77	NS	NS	NS	NS	NS
Interaction (I×M)										
S Em ±	0.0023	0.0098	0.063	0.023	0.47	0.97	0.22	0.0015	0.0016	0.0009
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Yield parameters: Green chilli yield is a reflection of number of fruits per plant, fruit index and fruit weight per plant. Untreated sewage water irrigation witnessed significantly higher number of fruits $plant^{-1}$ (79.94) as compared to irrigation with normal water (52.75), however, it was on par with irrigation using treated sewage water (70.77). Increasing the quantity of sewage sludge (M_2) resulted in increased number of fruits $plant^{-1}$ (79.61) which was significantly superior to other manure levels M_1 (56.66) and M_3 (67.19) (Table 4). Fruit length of green chillies did not differ significantly from each other due to different sources of irrigation water and manure and also exist non significant interaction between sources of irrigation and manure. Significantly higher fruit index (28.56 cm^2) was noticed when crop was irrigated with untreated sewage water as compared to irrigation with normal water (23.42 cm^2). Application of sewage sludge @ 25 t ha^{-1} recorded maximum fruit index (29.23 cm^2) followed by FYM @ 12.5 t ha^{-1} + sewage sludge @ 12.5 t ha^{-1} (26.89 cm^2) and the least significant fruit index was recorded in FYM @ 25 t ha^{-1} (22.09 cm^2) (Table 4). Interaction between sources of irrigation and manure found non-significant. Irrigation with untreated sewage water produced 38.2 per cent increase in fresh green chilli yield as compared to chilli crop irrigated using normal water. The magnitude of increase in number of fruits $plant^{-1}$ (52 and 34%), fruit index (21.9 and 15.8 %) due to untreated and treated sewage water irrigation, respectively over normal water irrigation. These results are further supported by findings of Yadav *et al.* (2002) [19] who noticed increased productivity of rice crop due to irrigation with sewage water than that of irrigation with normal water. The lowest yield of chilli was registered with freshwater irrigation 13.31 t ha^{-1} while, irrigation with wastewater recorded a yield of 14.63 t ha^{-1}. Manure level sewage sludge @ 25 t ha^{-1} recorded maximum fresh green chilli yield (14.98 t ha^{-1}) which is significantly superior other two manure levels, M_1 (12.34 t ha^{-1}) and M_3 (13.46 t ha^{-1}). This increase in yield may be due to increase in leaf area and better translocation of photosynthates to sink by sewage water and sludge application. Increased leaf area might have allowed plants to trap more radiant energy required for enhanced photosynthetic activity which in turn might have increased the yield $plant^{-1}$. Similar results are quoted by Iqbal *et al.* (2015) [25]. Interaction effect of irrigation and manure with respect to fresh green chilli yield found non-significant (Table 5).The increased photosynthetic activity in turn would have increased photosynthates assimilation and thereby increased yields (Reddy and Reddy, 1998) [14]. Crop grown on soil treated with sewage sludge produces yield often equal to or higher than those grown on soils treated with recommended fertilizer applications (Epstein, 2003) [3].

Table 4: Yield, yield attributes and Ascorbic acid content of green chilli as influenced by different sources of irrigation water and manure.

Treatments	Number of fruits $plant^{-1}$	Fruit length (cm)	Fruit index (cm^2)	Average fruit weight (g)	Yield $Plant^{-1}$(g)	Yield $plot^{-1}$ (Kg)	Yield (t/ha)	Ascorbic acid mg/100 gm
Sources of Irrigation water (I)								
I_1-Normal water	52.75	7.33	23.42	4.90	429.87	11.25	11.11	89.29
I_2-Treated sewage water	70.77	8.15	27.13	4.86	517.76	14.50	14.32	96.55
I_3-Untreated sewage water	79.94	8.57	28.56	5.12	524.55	15.55	15.36	114.88
S Em ±	4.12	0.24	1.06	0.05	14.75	0.39	0.38	4.91
CD (P= 0.05)	12.34	NS	3.18	0.15	44.10	1.17	1.15	14.67
Sources of Manure (M)								
M_1- FYM @ 25 t ha^{-1}	56.66	8.13	22.99	4.73	457.98	12.50	12.34	68.45
M_2- Sewage sludge @ 25 t ha^{-1}	79.61	8.33	29.23	5.18	525.74	15.17	14.98	126.81
M_3- FYM @ 12.5 t ha^{-1} + Sewage sludge @ 12.5 t ha^{-1}	67.19	9.23	26.89	4.96	488.46	13.63	13.46	105.47
S Em ±	4.12	0.24	1.06	0.05	14.75	0.39	0.38	4.91
CD (P= 0.05)	12.34	NS	3.18	0.15	44.10	1.17	1.15	14.67
Interaction (I×M)								
S Em ±	7.14	0.30	1.84	0.09	25.55	0.68	0.67	8.504
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Ascorbic acid content: Irrigation with untreated sewage water resulted in significantly higher ascorbic acid content (118 mg 100 g^{-1}) as compared to irrigation with normal water (107 mg 100 g^{-1}) however, it was statistically at par with treated water irrigation (112.28 mg 100 g^{-1}). Sewage sludge applied @ 25 t ha^{-1} recorded higher ascorbic acid content (126.81 mg 100 g^{-1}) over the FYM @ 25 t ha^{-1} the next best improvement in quality of fresh green chilli fruits was seen in sewage sludge @ 25 t ha^{-1} followed by combined application of FYM @ 12.5 t ha^{-1} and sewage sludge @ 12.5 t ha^{-1} (105 mg 100 g^{-1}) (Table 4). Thus the observed increase in ascorbic acid content was not surprising because potassium in untreated sewage water which is present in higher amount as compared freshwater could have played an important role in transport of essential ingredients for ascorbic acid content synthesis and also due to close relationship between carbohydrate metabolism and formation of ascorbic acid (Hartz *et al.*, 1999; Majumdar *et al.*, 2000; Ananti *et al.*, 2004) [6, 10, 1]. Similarly Sinha *et al.* (2007) [29] have also reported higher production of ascorbic acid in fenugreek plants grown in soil amended with sludge to nullify the adverse effect of heavy metals since ascorbic acid, a natural antioxidant, may have scavenged free radicals generated by heavy metals.

Conclusion

From the conduct of this experiment we can conclude that the sewage water and sludge used in this experiment is of good quality and can be safely utilized for agriculture purpose since it contains appreciable amount of nutrients it will be an alternative potential source for supplementing plant nutrients. The growth of chilli plants favourably get increased with application of sewage water and sludge which in turn increases the yield of green chilli plants and also quality aspects of green chilli.

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