Effect of gasifier effluent on agricultural production and soil

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Gasifier generates wastewater during cooling and cleaning of producer gas. This wastewater contains harmful chemicals which adversely affect the natural stream if disposed off without treatment. In the present work the effect of gasifier effluent on agricultural soil and vegetable production was studied. Experiments were conducted on seasonal vegetables like radish, spinach and tomato plant. Each plant was irrigated with gasifier wastewater and treated wastewater to study the effects of these waters and compared with control plants which were irrigated by tap water. After irrigation with gasifier wastewater and treated wastewater, different physico-chemical analyses of soil and growth parameters of plant were done. It was found that gasifier wastewater is not suitable for agricultural fields. It inhibits or delay growth of plants. But after suitable treatment, it can be useful for agricultural fields.

Keywords: Agricultural field, gasifier effluent, growth parameter, physico-chemical analysis.

WITH increasing population growth, the gap between supply and demand of fresh water is widening. Therefore the need for reuse of wastewater of industries for irrigation is increasing. The reuse of gasifier wastewater for agricultural irrigation reduces the amount of water that needs to be extracted from water resources. It is thus important to think about the existing urban wastewater disposal infrastructure, wastewater agriculture practices, quality of water used, health implications and level of institutional awareness of wastewater-related issues[1,2]. In agriculture practices, the irrigation water quality has an effect on the soil characteristics, crop production and management of water[3]. Wastewater of industries can be considered both as a resource and a problem because industrial wastewater can contain nutrients or harmful chemicals depending on the type of industries. Nutrients of wastewater can impose positive effects on agricultural production whereas toxic elements can impose hazardous impact on human health and long-term effects on soil properties. While problematic for the nation, wastewater has some useful aspects which may be utilized for beneficial purposes. Instead of disposal of wastewater into environment, it is widely used in both developed and developing countries for agricultural irrigation and other purposes after treatment[4–7]. Gasifier wastewater is rich in organic matter which is helpful for vegetable and crop production without using fertilizers, but tar and phenolic compounds are harmful for agriculture. Tar can be considered as a mixture of several acidic, basic and neutral compounds. The acidic components include acids and phenols, basic components include nitrogen containing compounds and neutral components include polyaromatic compounds (PAHs)[8,9]. Discharge of phenolic wastewater of gasifier imparts carbolic odour to the water body and has detrimental effects on human beings and agricultural land. This water can be used for irrigation after treatment.

The present study deals with the use of gasifier wastewater with and without treatment for irrigation and its short-term effects on vegetable production.

The wastewater of gasifier-based power plant was treated with an integrated system containing coconut coir, sand and activated carbon. The first two biomaterials work as filter and the third one as an adsorbent. Water used for this study was tap water (as control), gasifier wastewater and treated wastewater. The effect of gasifier effluent on soil and vegetable growth was studied by a pot experiment in which three vegetable crops namely tomato, spinach and radish were taken and their growth parameters observed. Plants were irrigated with 200 ml of gasifier wastewater, treated wastewater and tap water on alternate days. Effect of treated wastewater, gasifier wastewater with control was observed on the growth parameter of plants like number of leaves, height of plants, number of branches, number of flowers, and number of fruits at 15-day interval after sowing/plantation. Biomass yield was also calculated. After harvesting, soil samples were taken 10–20 cm depth from the top layer and its physico-chemical analysis was done to assess the effect of gasifier wastewater and treated wastewater on soil.

Collected soil sample was dried and grounded to pass through 2 mm sieve and stored in plastic bags. The soil pH was determined by pH meter in saturated paste (1 : 1

Table 1. Physico-chemical properties of soil use for cultivation

pH	7.05
Electrical conductivity (mS cm^{-1})	0.67
Elements present in soil	
Organic carbon (%)	0.41–0.45
Phosphate (kg h^{-1})	18.16
Nitrogen (kg h^{-1})	285.88
Potassium (kg h^{-1})	185.92

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Table 2. Physico-chemical parameters of water used for irrigation

Parameters	Gasifier water	Treated wastewater	Tap water
pH	5.9	6.4	7.08
EC (μmhos/cm)	1189	734	678
Total organic carbon (g/l)	10.2	3.5	0.6
Total nitrogen (mg/l)	0.34	0.32	0.0
Potassium (mg/l)	29.9	27.4	1.35
Phosphorus (mg/l)	3.68	3.12	0.078
Phenol (mg/l)	132	0.84	0.001
Chemical oxygen demand (mg/l)	4038	234	8
Oil and grease (mg/l)	897	9.8	0.84

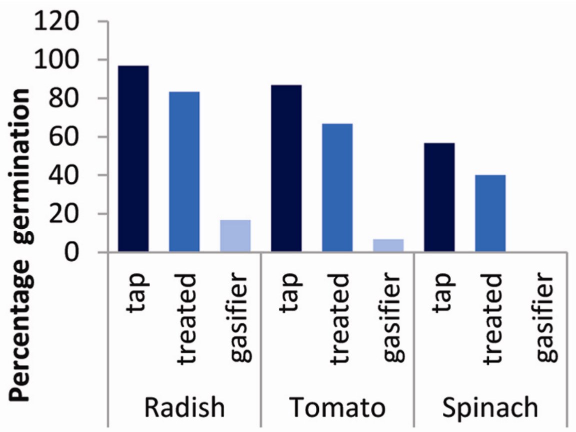

Figure 1. Germination in different vegetables.

suspension)[10]. In the same suspension electrical conductivity was also measured using conductivity meter. Soil organic carbon was estimated with TOC analyser. Available phosphorus was determined by Olsen's method[11] and available nitrogen by Kjeldal method. Potassium was estimated by flame photometer after extraction in ammonium acetate solution. Similarly water sample was analysed. Total organic carbon was determined by TOC analyser, chemical oxygen demand by open reflux method and phenol by spectro-photometric method. Microbial biomass carbon was determined by fumigation method.

For measurement of fresh weight, the plants were harvested freshly, washed with distilled water and blotted on blotting paper to remove excess water. The fresh weight was recorded from the root and shoot by using digital single pan balance and values expressed as g/plant. Subsequently, plant parts such as root and shoot were kept for drying in a hot air oven ($68 \pm 5°C$) until constant weight was achieved (~70–80 h). The average dry weight was monitored and expressed as g/plant.

Soil sample collected from the agricultural field of Central Institute of Agricultural Engineering, Bhopal was analysed for physico-chemical properties (Table 1) to check the suitability of soil for the growth of the plant. The pH of soil sample was measured as 7.05 which indicates its neutral behaviour and conductivity was 0.67 mS/cm. Percentage of organic carbon was found to be 0.41% to 0.45%. Phosphorus content was measured as 18.16 kg h^{-1}. Nitrogen content was 285.88 kg h^{-1} and potassium was 185.92 kg h^{-1}. The NPK level clearly indicates the suitability of soil for irrigation.

The wastewater generated from gasifier-based power plant of 20 kW was used to study the effect of this wastewater on agricultural crops. Seasonable vegetables were grown and irrigated with gasifier wastewater, treated wastewater and tap water separately. Physicochemical properties of all the three types of water are given in Table 2. The pH of tap water is slightly alkaline whereas gasifier wastewater is acidic; after treatment pH of wastewater increases due to removal of phenolic compound. Gasifier wastewater is rich in organic carbon and NPK, which is suitable for irrigation purpose without fertilizer. But high concentration of phenolic compound and high level of chemical oxygen demand indicates the pollution level of gasifier wastewater which prevents its use for irrigation purpose without treatment. Phenol and chemical oxygen demand are 132 times and 16 times more respectively, than the permissible limit of irrigated water[12]. After treatment with integrated treatment system, harmful products of wastewater were removed and their value reached up to tolerance limit. This treated water now becomes as safe as tap water.

The effect of gasifier wastewater and treated wastewater was studied on radish, tomato and spinach. It showed that untreated water had harshly affected germination. Most affected seeds were spinach followed by tomato and radish. Different vegetable seeds show germination at different time intervals. Radish seeds show germination after 48 h, tomato seeds show germination after 72 h and spinach seeds after 96 h. The best germination result was seen in radish, which is clear from Figure 1. Radish seeds showed 96.67% germination with tap water, 83.33% with treated wastewater and 16.67% with gasifier wastewater. Tomato seeds showed 86.67% germination with tap water, 66.67% with treated wastewater and 16.67% with gasifier wastewater whereas spinach seeds showed 56.67% with tap water, 40% with treated wastewater and 0% with gasifier wastewater. This shows that gasifier wastewater is not suitable for germination of seeds. This

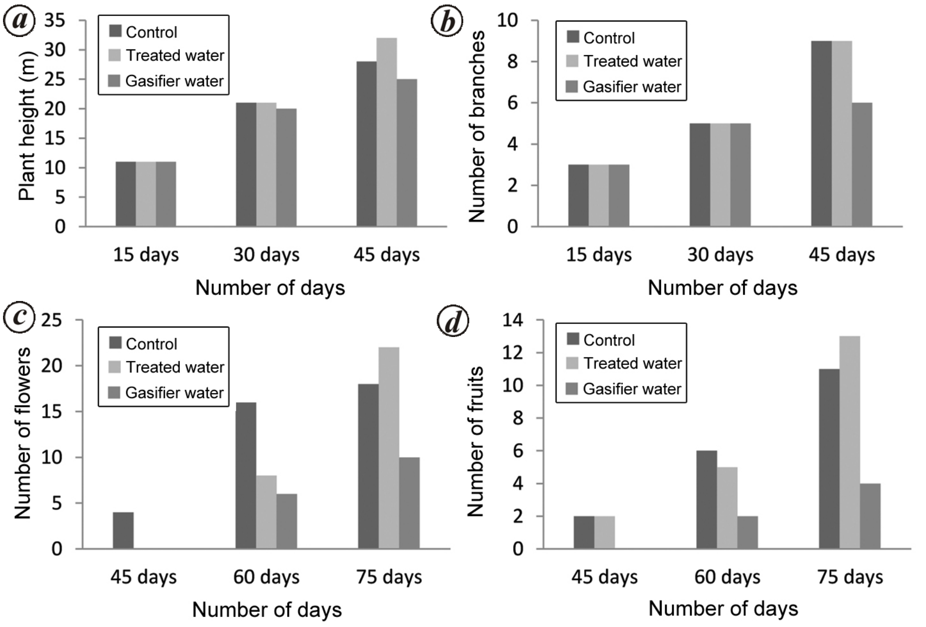

Figure 2. ***a***, Plant height; ***b***, number of branches; ***c***, number of flowers; ***d***, number of fruits in tomato plant at different time intervals.

is due to the presence of phenolic compounds in gasifier wastewater which suppresses the germination of seeds. This result is in line with El Hadrami *et al.*[13] who worked on the effect of olive mill wastewater (OMWs) on different crops and concluded that phenols in OMWs are the main compounds that suppress germination.

The effect of gasifier wastewater on plant growth parameters was monitored after establishing the plant using ground water for irrigation. Later the plants were irrigated with gasifier wastewater and treated wastewater. Different growth parameters were observed in different vegetables at different time intervals.

In the case of tomato plant, plant height, number of branches, number of flowers and number of fruits were observed at different time intervals (Figure 2). Differentiated behaviour was observed after 45 days where treated wastewater irrigated plant height observed was 114% and gasifier wastewater irrigated plant height was 89% as compared to control. Similarly in the case of number of branches, it is clear from Figure 2 *b* that treated wastewater irrigated plants had the same number of branches as control plant but gasifier wastewater irrigated plants had only 66.67% branches when compared to control and this difference remained constant after 45 days.

Fruiting and flowering in tomato plant start after 45 days where numbers of flowers in treated irrigated plant were 50% and in gasifier wastewater irrigated plant were 37.5%. This measured to 122% and 55% respectively, after 60 days but reduced after 75 days because of conversion of flower into fruits. Maximum numbers of fruits were grown in treated wastewater irrigated plants which were 118.18% as compared to control and only 36.36% in gasifier wastewater irrigated plants. This indicates that there are harmful chemicals present in gasifier wastewater which affect the fruiting of plants.

The effect of gasifier wastewater was studied in spinach plant in terms of plant height, number of leaves and breadth of leaves (Figure 3). Measurable changes in spinach plant were observed when compared to tomato and radish plant. As irrigation started with gasifier wastewater, plant height decreased 11.4% after 15 days and 37.5% after 30 days. Plant height of treated wastewater irrigated plant also decreased to less than 12.5% when compared to control. Breadth of leaves and number of branches were also 69.2% less in gasifier irrigated plant when compared to control. Plant irrigated with treated wastewater also showed inhibited growth compared to control in which breadth of leaf was 7.7% less and the number of branches was 13.3% less when compared to control after 30 days.

Effect of gasifier wastewater on radish plant was measured only in terms of number of leaves and root size (Figure 4). There were no measurable changes observed in number of leaves in radish plant. At different time intervals they were same in all types of irrigated water. Size of roots also followed the same trend. Initially there were minor differences among size of roots but after 45 days size of roots of treated water irrigated plants and gasifier wastewater irrigated plants were comparable with control plants.

The effect of wastewater on physico-chemical properties of soil was analysed after harvesting of plants (Table 3). pH of soil sample of gasifier and treated wastewater irrigated plant was measured. It was found that pH of all

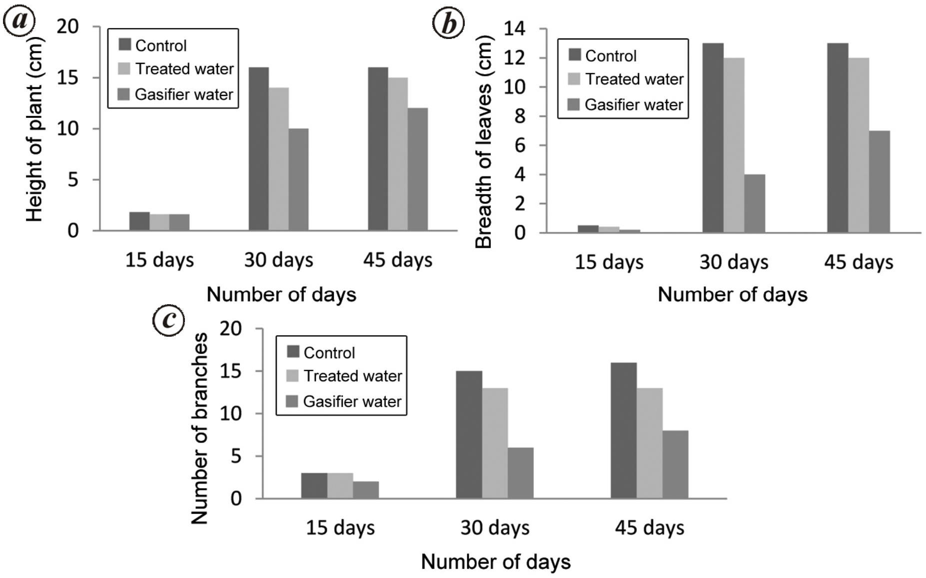

Figure 3. ***a***, Height of plant; ***b***, breadth of leaves; ***c***, numbers of branches in spinach plant in different durations of times.

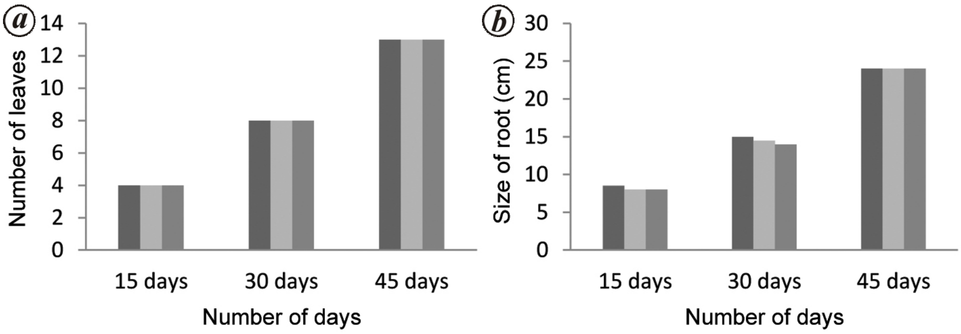

Figure 4. ***a***, Numbers of leaves; ***b***, size of root in radish plant at different durations of times.

soil samples was nearly the same as the original soil sample and showed slightly less pH than original soil. Although gasifier wastewater was acidic, a measurable change in pH was not seen in soil samples. It shows that the effect of wastewater on soil pH is not short-term, but perhaps a long-term effect. Electrical conductivity of soil irrigated with gasifier wastewater was measured high due to presence of soluble salt. Percentage of organic carbon was also measured high in gasifier wastewater irrigated plant due to presence of high organic matter present in it, but available phosphorus, available nitrogen and sodium, and potassium ions are less. This is due to presence of toxic element in wastewater due to which availability of these elements become less for plants, whereas availability of these elements in treated wastewater irrigated soil is sufficient as control soil. This may be due to removal of toxic elements. Microbial biomass carbon shows microbial activity in soil which is sufficient in control and treated wastewater irrigated soil but very less in gasifier wastewater irrigated soil, which again shows the toxic elements present in gasifier wastewater which inhibit the growth of microbes in soil.

Effect of wastewater on bio-mass yield was analysed in terms of fresh and dry weight of root and shoot of vegetable plant.

Fresh root and shoot weight of spinach plant, irrigated with treated wastewater was measured as 79.4% and 89.9% whereas in gasifier wastewater irrigated plant these weights were 56.4% and 64% respectively, compared to control. Similarly, dry weight of root and shoot of treated wastewater irrigated plant was measured as 95.8% and 91.2% whereas dry weight of root and shoot of gasifier wastewater irrigated plant was measured as 62.5% and 53.8% respectively, when compared to control. This shows that gasifier wastewater suppresses the growth of plants due to presence of phenolic compounds.

Fresh shoot weight of tomato plant irrigated with treated wastewater and gasifier wastewater was 101.7% and 83.8% respectively, when compared to control, whereas fresh root weight of treated water irrigated plant

Table 3. Physico-chemical properties of soil before and after harvesting

		Tomato			Spinach			Radish		
	Soil sample	Control	Gasifier waste-water	Treated waste-water	Control	Gasifier waste-water	Treated waste-water	Control	Gasifier waste-water	Treated waste-water
pH	7.29	7.32	7.27	7.33	7.28	7.24	7.31	7.25	7.21	7.26
EC (mS cm^{-1})	0.73	0.74	0.81	0.72	0.71	0.79	0.70	0.72	0.85	0.69
Organic carbon (%)	2.21	2.17	2.64	2.08	2.18	2.59	2.15	2.15	2.81	2.16
Available nitrogen (kg h^{-1})	326.85	352.00	311.24	339.46	356.10	326.84	342.18	339.40	332.76	336.52
Available phoshorus (kg h^{-1})	27.80	37.58	35.24	34.17	36.93	33.62	29.51	37.18	39.78	35.67
Available potassium (kg h^{-1})	383.68	346.20	334.08	347.28	348.00	357.56	349.76	363.20	359.84	361.72
Microbial biomass carbon (μg g^{-1})	457.00	476.47	222.82	465.48	481.93	297.32	472.26	471.32	248.70	466.94

and gasifier water irrigated plant was 96.3% and 39%. Dry weight of root and shoot of treated water irrigated plant was 97.4% and 93.2% and gasifier water irrigated plant was 50% and 58.9% respectively.

This indicates that gasifier wastewater inhibits the growth of plant, and compared to the shoot it mostly affects the growth of the root. This may be due to presence of phenolic compounds in gasifier wastewater. This result correlates with the work of Ouzounidou *et al.*[14] who worked on the effect of olive mill wastewater triggered changes in physiology and nutritional quality of tomato and concluded that root growth is more sensitive to polyphenols and fatty acids present in OMWs.

Fresh root weight of radish in treated wastewater irrigated plant and gasifier wastewater irrigated plant was measured as 98.2% and 97.7% respectively, whereas fresh shoot weight in treated wastewater irrigated plant and gasifier wastewater irrigated plant was 99.4% and 98.9% respectively, when compared to control plant. Similarly dry weight of radish root in treated wastewater irrigated plant and gasifier wastewater irrigated plant was 98.9% and 98.3% respectively, and dry weight of radish shoot in treated wastewater irrigated plant and gasifier wastewater irrigated plant was 97.7% and 89.8% respectively, when compared to control plant. This indicates that plant growth in radish is less sensitive towards phenolic compounds.

Biomass-based power plant is a useful source of power generation in remote areas. It also prevents current smoke problems by using crop residues in power plants. Power generation creates wastewater problem through cooling and cleaning and cannot be used in agricultural fields without treatment. The present study indicates that gasifier wastewater is not suitable for agricultural fields due to presence of phenolic compounds and other toxic elements which could not be identified during this research. These toxic elements inhibited the growth of leafy and fruity plants and also delayed fruiting but were suitable for rooty vegetables. After treatment gasifier wastewater becomes suitable as control water.

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Received 8 January 2016; revised accepted 20 April 2017

doi: 10.18520/cs/v113/i06/1148-1152