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Suitability Assessment of Wastewater of Three Tobacco Industries for Irrigation and Germination of Some Vegetable Seeds

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Abstract:

To assess the suitability classes of wastewater of three tobacco industries for irrigation purposes and their effects on germination and seedlings growth of three vegetables a lab experiment was conducted. The investigation was undertaken in the Agricultural Chemistry Laboratory, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. Several variables such as pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cu^{2+}, Mn^{2+}, Fe^{3+}, PO_4^{3-}, $HC0_3^{-}$, SO_4^{2-}, Cl^{-}, electrical conductivity, sodium adsorption ratio, kelly's ratio, permeability index and hardness were computed. The wastewaters were found acidic and could be suitable for agricultural and aquatic uses. In respect of Ca^{2+}, Fe^{3+}, Mn^{2+}, Cu^{2+}, Cl^{-} and PO_4^{2-} and other cations and anions content all the water samples under investigation was acceptable for continuous irrigation purposes and would not affect the soils. Based on sodium adsorption ratio, hardness, permeability index and kelly's ratio, all water samples were suitable for irrigation purposes. In respect of K^{+} content the water samples were suitable as irrigation water for potassium demanding crops. Water samples under investigation were not suitable for irrigation in respect of sulphate ion. But if the concentration of sulphate ion can be reduced by any way then it will be suitable for sulfur demanding crop. In respect of magnesium all samples were not safely be used for irrigation. Twenty-five ml of collected wastewater showed higher performance in relation to germination rate, shoot length and root length in cucumber, radish and yard long bean.

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Introduction

Water is one of the most valuable natural resources on earth. In the global water resources, about 97.5% is salt water mainly in oceans, and only 2.5% is available as freshwater. Out of 2.5%, about 2.2% is available as surface water and 0.6% as groundwater (Mishra and Dubey, 2015). Agriculture is the greatest users of water accounting for 80% of all consumption. Water quality for irrigation is an utmost important criterion for successful crop production as it contains different ions in varying concentrations. If low quality of water is used for irrigation, toxic elements may accumulate in the soils and deteriorates soil properties. Increasing population, food insecurity, growing economics and poor water management are putting unprecedented pressure on the world's freshwater resources (UNDP, 2016). Climate change, the evolution of new water borne pathogens and the development and use of new chemicals for industrial, agricultural, household, medical and personal use have raised concern as they have the potential to alter both the availability and the quality of water (Karanth, 1994). Water quality is just as an important factor for irrigated agriculture as its quantity. Agricultural production must be maximized to meet a long-term demand for global food as well as fiber and raw materials for other industries. Irrigated agriculture along with nutrient management and agronomic practices play a vital role to enhance production (Sarker *et al*., 2009). Wastewater refers to water whose quality might pose a threat to sustainable agriculture and/or human health, but which can be used safely for irrigation provided certain precautions are taken. It describes water that has been polluted as a result of mixing with waste or agricultural drainage (Cornish *et al.,* 1999). In many countries water is becoming an increasingly scarce resource. Due to increasing population and industrial as well as urban expansion, the production of wastewater and its reuse has grown rapidly. Rough estimates indicate that at least 20 million hectares of land in 50 countries are irrigated with raw or partially treated wastewater (Hoek *et al*., 2001). In addition to being a valuable resource as a source of water, the major objective of wastewater use is the effective utilization of its rich stock of nutrients for agricultural and other purposes. The use of wastewater in agriculture is gaining tremendous popularity because of the wide range of benefits that accompany it. These benefits include conservation of water, provision of reliable water supply and recycling of nutrients, thereby reducing the need for farmers to invest in chemical fertilizers. On the other hand, wastewater use in crop production is not without some risks. The main risk associated with wastewater irrigation is infection with intestinal helminthes (Mara and Cain Cross, 1989). Also, depending on the source of the wastewater it might contain chemical pollutants and heavy metals that can accumulate in the soil and crops thereby posing a threat to human health.

The use of wastewater for agriculture in and around cities across the world is a current and future reality that cannot be denied. In some countries, such as Mexico and China, it has been practiced for centuries (Shuval *et al*., 1986). Since conventional treatment is very costly, most wastewater is allowed to be dumped, untreated, into water bodies or onto the land. Untreated wastewater use for urban and peri-urban agriculture is often either ignored or actively condemned by the public and by government officials. However, these risks can be greatly reduced by treating the wastewater before using it or by applying some precautions while using it. But there seems to be a lack of information or awareness of the effects of wastewater irrigation on crop production in these areas. A profit function was also fitted to ascertain profits made from vegetable production before and after wastewater using with and without principle following Hussain *et al*. (2001). For this reason, Bangladesh appears to be an appropriate choice for applying a framework for assessing and valuing the effects of wastewater irrigation and/or germination of crops. In the study area, most of the farmers use tobacco industry wastewater for raising seedlings as well as cultivation of different vegetables. Farmers apply tobacco industry wastewater for growing different vegetables without testing of water quality. But there is no organization to assess the extent of water toxicity systematically at field level. Keeping all these facts in mind, this area was selected to evaluate the toxicity levels of tobacco industry wastewater with the following objectives-

1. To assess the chemical constituents of some wastewater samples collected from three tobacco industry of Rangpur.
2. To examine the effects of tobacco industry wastewater on the germination and seedling growth of three vegetables.

Materials and methods

Experimental site

The experiment was conducted during the period from January to February, 2016 in the Laboratory of Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

Collection of water samples and sampling techniques

The wastewater samples were collected from the drainage system of 3 different tobacco industries (Abul khayer tobacco industry Ltd., Akij tobacco industry Ltd., British American tobacco Bangladesh Ltd.) situated in Rangpur City. Samples were collected in two-liter plastic bottles that had been cleaned with hydrochloric acid (1:1) and then rinsed with tap water followed by rinsing with distilled water. Before collecting each sample, bottles were rinsed 3 to 4 times with sample. All the samples collected from three industries were mixed together to make a combined sample for further assessment. All reagents used in chemical analysis were of analytical grade.

Selection and collection of vegetable seeds

The following vegetables were selected and the seeds of these vegetables were collected from the Dinajpur seed market. The purity percentages and germination percentages of these seeds were 95% and 80%, respectively.

Table 1: List of vegetables used for germination test

Sl. No.	Bangla name	English name	Scientific name	Family
1.	Shosha	Cucumber	*Cucimis sativus*	Cucurbitaceae
2.	Mulla	Radish	*Raphanus sativus*	Brassicaceae
3.	Borboti	Yard long bean	*Vigna unguiculata var. sesquipedalis*	Papilionaceae

Analytical methods of water analysis

pH

The pH of wastewater samples was determined by the pH meters (WTW-pH-522 Model) according to Ghosh *et al*. (1983).

Electrical conductivity (EC)
The EC values of collected samples were measured by the conductivity bridge (Model WTW LF 521) to according to Ghosh *et al.* (1983).

Total dissolved solids (TDS)
Total Dissolved Solids of the water samples were determined by evaporating 100 ml aliquot of filtered water samples in porcelain dish to dryness and weighing the residue according to the procedure mentioned by Chopra and Kanwar (1991). Special care was taken so that the samples do not get completely dried.

Calcium
For determination of calcium from water samples, Complex metric titration was used. In this titration disodium ethylene di-amine tetra-acetated ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) was used as a chelating agent. The analytical method was carried out to element possible interfacing ions such as Fe, Mn, Cu, Zn, Ni and PO_4 adding respective masking agents in the presence of calcon indicator ($C_{20}H_{13}N_2NaO_5S$) at pH 12. The masking agents are sodium hydroxide (NaOH), Potassium Ferro-cyanide [K_4 Fe $(CN)_6$. $3H_2O$], hydroxylamine-hydrochloride ($NH_2OH.HCl$) and triethanolamine ($C_6H_{15}NO_3$).

Magnesium
Magnesium was analyzed by Complexometric titration method. Here disodium ethylene diamine tetra-acetated ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) was used as a chelating agent. Some masking agents are used in this titration. These are used to eliminate some interfering ions. The masking agents are Eriochrome Black T indicator ($C_{20}H_{12}N_3NaO_7S$), Calcium tungstate ($CaWO_4$), Potassium Ferro cyanide [K_4 Fe $(CN)_6$. $3H_2O$], hydroxylamine-hydrochloride ($NH_2OH.HCl$) and triethanolamine ($C_6H_{15}NO_3$).

Sodium and potassium
Sodium and Potassium were determined with the help of a flame emission spectrophotometer (Gallenkamp Cat. No. 23/FH-500) by using sodium and potassium filters respectively. The sample was aspirated into a gas flame and excitation was carried out in a reproducible condition and carefully controlled. The air pressure was 10 psi. Interference filters were used in desired spectral line.

Bicarbonate
Bicarbonate of water samples were determined by acidimetric method of titration using phenolphthalein indicator ($C_{20}H_{14}O_4$) for carbonate. The bicarbonate was estimated titrimetrically. (Chopra and Kanwar, 1980) and (Ghosh *et al.*, 1983).

$$NaHCO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$$

Chloride
Chloride of water samples was analyzed by argentometric method of titration using potassium chromate indicator (K_2CrO_4) which worked in a neutral or slightly alkaline solution. The reactions are given below:

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

$$2AgNO_3 + K_2CrO_4 \longrightarrow Ag_2CrO_4 + KNO_3$$

Chloride was determined titrimetrically following the procedure described by Ghosh *et al.* (1983) and Clesceri *et al.* (1989).

Phosphorus

All samples were tested by the colorimetric method to determine phosphorus. In this method stannous chloride is used as a reducing agent (Clesceri *et al*., 1989). This method involves the formation of molybdophosphoric acid. This acid is reduced the intensity complex molybdenum blue by stannous chloride. The color intensity was read at 660 nm wavelength with a spectrophotometer (Coleman Junior Model No. 6A) within 15 minutes after stannous chloride addition. The principle of this method is given below as a reaction:

$$H_3PO_4 + 12\ H_2MoO_4 \longrightarrow H_3P\ (Mo_3O_{10})_4 + 12H_2O$$

Sulphate sulphur

Sulphate was estimated turbidimetrically with the help of spectrophotometer. Turibidimetric reagent ($BaCl_2\ 2H_2O$) was added in a definite volume of sample. Sulphate ion reacted with barium chloride to form barium sulphate. Reading was taken in spectrophotometer (Coleman Junior Model No. 6A) after 30 minutes of $BaCl_2$ addition at 425 nm wavelength following the method of Wolf (1982).

Evaluation of water quality

Use of poor water quality can create four types of problems, namely toxicity, water infiltration, salinity and miscellaneous (Ayers and Westcot, 1985). To assess water quality for irrigation, there are four most popular criteria: TDS or EC, sodium adsorption ratio (SAR), chemical concentration of elements like Na+, Cl^- and/or B^- and residual sodium carbonate (RSC) (Michael, 1992). For current irrigation water quality assessment, the following parameters were considered. The following formulae related to the irrigation water classes rating were used to classify water samples using the chemical data.

a) Sodium Adsorption Ratio (SAR) is expressed as:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

b) Hardness or Total Hardness (H_T):

$$H_T = 2.5 \times Ca^{2++} 4.1 \times Mg^{2+} \text{ (Freeze and Cherry, 1979)}$$

c) Potential index (P.I):

$$P.I = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+}$$

d) Kelly's Ratio $= \frac{Na^+}{Ca^{2+} + Mg^{2+}}$

Treatments under investigation for the study of cucumber, radish and yard long bean seeds germination using wastewater samples

Following wastewater samples were used as treatments:

a. Water or control (T_0)
b. 5 ml wastewater (T_5)
c. 10 ml wastewater (T_{10})
d. 15 ml wastewater (T_{15})
e. 20 ml wastewater (T_{20})
f. 25 ml wastewater (T_{25})
g. 30 ml wastewater (T_{30})

Seed placement for germination

Before placement of seed for germination the seeds of each vegetable were thoroughly mixed and were surface sterilized by dipping the seeds in 1% mercuric chloride solution for 2 minutes and rinsed thoroughly with sterilized water. Twenty-five seeds of each vegetable were placed sequentially according to the marking on filter paper soaked with respective treatments in sterilized petridish. Three batches of petridishes each containing twenty-five seeds were used. The petridishes were irrigated with required amount of respective solution when necessary. Seedlings were allowed to grow up to 7 days after placement of germination.

Data recorded on germination rate

Germination was counted at 24-hours interval and continued up to 5th day (120 hours). A seed was considered germinated as plumule and radicle came out and was larger than 2 mm long.
The rate of germination was calculated using the following formula-

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds placed for germination}} \times 100$$

Data recorded on shoot length and root length

At 5th, 6th and 7th days after placement for germination, five seedlings from each petridish were sampled. Shoot and root length of individual seedling were recorded manually with scale.

Statistical analysis

The data were analyzed by STATA program (Version 2.0) using a computer and means were compared by Tukey.

Results and discussion

pH

The pH values of water samples that were collected from three tobacco industries of Rangpur city varied from 6.75 to 6.84 (Table 2). The mean pH value of all samples is 6.79. The minimum pH value is 6.75, while the maximum value is 6.84. The pH values of 3 samples ranged from 6.90 to 6.95. The acidity or basicity of drinking water is expressed as pH (< 7.0 acidic; > 7.0 basic). Ayers and Westcot (1985) mentioned that normal pH range of irrigation usually varied from 6.0 to 8.5. It indicates that pH of all water samples under test were within the normal range and this water might not be harmful for soils and crops. Similar observations were also reported by Quayum (1995) and Razzaque (1995).

Electrical conductivity

Table 2 shows that the electrical conductivity value of water samples that were collected from the tobacco industries of Rangpur city varied from 966.55 to 972.45 µS cm^{-1}. The mean value of three samples is 970 µS cm^{-1}. The minimum EC value was 966.55 µS cm^{-1} and maximum EC value was 972.45 µS cm^{-1}. On the basis of electrical conductivity, the irrigation waters were classified into four groups such as excellent (<250), good (250-750), permissible (750-2000) and doubtful (2000-3000) (Wilcox, 1955). In this study, all three samples were found in the group of ‘permissible’ considering irrigation purpose.

Total dissolved solids (TDS)
Table 2 reveals that the TDS value of water samples that were collected from the tobacco industries of Rangpur city varied from 111.98 to 113.4.10 mg L^{-1}, while the mean value was 112.76 mg L^{-1}. The minimum TDS value was 111.98 mg L^{-1}, whereas the maximum TDS value was 113.4 mg L^{-1}. Total dissolved solids is considered as one of the important criteria for judging water quality for irrigation, drinking and industrial purposes. On the basis of TDS values, the irrigation water was classified into four groups such as fresh water (0-1,000 mg L^{-1}), brackish water (1,000-10,000 mg L^{-1}), saline water (10,000-100,000 mg L^{-1}) and brine water (>100,00 mg L^{-1}) (Freeze and Cherry, 1979). According to Freeze and Cherry (1979), all the water samples under investigation contained 0-1,000 mg L^{-1} TDS and were classified as 'fresh water' in quality. It implies that, these waters would not affect the osmotic pressure of soil solution and cell sap of the plants when applied as irrigation water to soil.

Total cations
Following cations were investigated in collected water samples during the experiment.

Calcium
Table 3 indicates that the concentration of Ca ion in water samples that were collected from tobacco industries of Rangpur city varied from 177.84 to 184.61 mg L^{-1}. The mean value was 180.03 mg L^{-1}, where the minimum value was 177.84 mg L^{-1} and maximum value was 184.61 mg L^{-1}. According to guidelines based on the suggestions of Duncan *et al.* (2000) the entire water samples contained very high Ca concentration (> 80) and can safely be used for irrigation purpose without any harm of soil.

Potassium
The concentration of potassium ion in water samples that were collected from three tobacco industries of Rangpur city varied from 45.86 to 46.63 mg L^{-1} and the mean value was 46.25 mg L^{-1} (Table 3).
Irrigation water containing 5- 20 mg L^{-1} potassium is recommended as normal for irrigation purposes (Duncan *et al*., 2000). On the basis of potassium content, the entire water samples may affect the soils and crops. But the water samples may be suitable as irrigation water for highly potassium demanding crops or root crops.

Zinc
The concentration of zinc ion in water samples that were collected from the tobacco industries of Rangpur city varied from 0.022 to 0.024 mg L^{-1} and the mean value was 0.023 mg L^{-1} (Table 3).
Duncan *et al*. (2000), recommended that irrigation water containing less than 0.30 mg L^{-1} manganese is acceptable for irrigating crops plants. According to this recommendation, all water samples were suitable for irrigation purpose.

Iron
Table 3 reveals that the collected water samples contained very small amount of iron, which was varied from 0.098 to 0.099 mg L^{-1} and the mean value was 0.099 mg L^{-1}.
According to guidelines based on the suggestions of Duncan *et al*., (2000) irrigation water containing 2.4- 4.0 mg L^{-1} iron was suitable for irrigating crops plants. On the basis of iron

content, the entire water samples contain low iron and thus it can safely be used for irrigation purposes and would not affect the soils.

Magnesium

The concentration of magnesium ion in water samples that were collected from the tobacco industries of Rangpur city varied from 111.97 to 113.69 mg L^{-1} and the mean value was 112.78 mg L^{-1} (Table 3). According to Duncan *et al*. (2000), all water samples contained magnesium ion in a very high limit (>35). Based on this clarification in respect of magnesium content, all wastewater samples were not suitable for irrigation purposes.

Sodium

The concentration of sodium ion in water samples that were collected from the tobacco industries of Rangpur city varied from 6.59 to 8.4 mg L^{-1} and the mean value was 7.53 mg L^{-1} (Table 3). According to Ayers and Westcot (1985) the suitable limit of sodium ion in water for irrigation purposes varies from 0- 40 meq L^{-1}. Based on this recommendation, the collected water samples were suitable for irrigation purposes.

Copper

Table 3 shows that the collected water samples contained very low amount of copper. The range of copper concentration was varied from 0.07 to 0.08 mg L^{-1} and the mean value was 0.08 mgL^{-1}. According to Duncan *et al.* (2000), the acceptable limit of copper in irrigation water is less than 0.20 mg L^{-1}. On the basis of this limit all the water under investigation was acceptable for continuous irrigation.

Manganese

The concentration of manganese ion in water samples that were collected from the tobacco industries of Rangpur city varied from 0.0061 to 0.0066 mg L^{-1} and the mean value was 0.0063 mg L^{-1} (Table 3). Duncan *et al*. (2000) recommended that irrigation water containing less than 0.20 mg L^{-1} manganese is suitable for irrigating crops plants. According to this recommendation, all water samples were acceptable for irrigation purposes.

Total anions

Water samples were analyzed for SO_4^{2-}, HCO_3^-, PO_4^{2-} and Cl^-. The results of all samples are presented below with possible interpretations.

Sulphate

Table 4 shows that the concentration of sulphate ion in water samples that were collected from the tobacco industries of Rangpur city varied from 227.7 to 228.93 mg L^{-1} and the mean value was 228.33 mg L^{-1}. According to Ayers and Westcot (1985), the acceptable limit of SO_4^{2-} for irrigation water is 0-20 mg L^{-1}. On the basis of this limit, all the water samples under investigation were not suitable for irrigation in respect of sulphate ion. But if the concentration of sulphate ion can be reduced by any way then it will be suitable for sulfur demanding crop.

Bicarbonate

The concentration of chloride ion in water samples that were collected from the tobacco industries of Rangpur city varied from 8.94 to 9.44 mg L^{-1} and the mean value was 9.21 mg L^{-1} (Table 4). According to Ayers and Westcot (1985) in respect of HCO_3^- content, all water samples were safe for irrigation purposes because HCO_3^- content was within the recommended limit (0-10 mg L^{-1}).

Chloride

The concentration of chloride ion in water samples that were collected from the tobacco industries of Rangpur city varied from 0.33 to 0.38 mg L^{-1} and the mean value was 0.35 mg L^{-1} (Table 4). According to Ayers and Westcot (1985), the acceptable limit of Cl^- for irrigation water is 0-30 mg L^{-1}. On the basis of this limit, all the water samples under investigation were safe for irrigation purposes.

Phosphate

The concentration of phosphate ion in water samples that were collected from the tobacco industries of Rangpur city varied from 6.75 to 6.84 mg L^{-1} and the mean value was 6.79 mg L^{-1} (Table 4). The status of PO_4^{2-} of all tested wastewater samples were found within the recommended limit as per Ayers and Westcot (1985).

Evaluation of water quality

Sodium adsorption ratio (SAR)

Table 5 shows that the water samples collected from the tobacco industry of Rangpur city contained SAR value ranges from 0.54 to 0.70 mg L^{-1} and the mean value was 0.62 mg L^{-1}. On the basis of SAR, Todd (1980) categorized irrigation waters into 4 groups as shown in Table 5. Considering this classification, the entire water sample was 'excellent' for irrigation. The present investigation expressed that a good proportion of Ca and existed in waters which was 'suitable' for good structure and tilth condition of soil also would improve the soil permeability. The irrigation water with SAR less than 1 might not be harmful for agricultural crops (Todd, 1980). According to Richards (1968) all the water samples collected were rated as 'low' alkalinity hazard (SI) class for irrigation as per SAR.

Hardness (HT)

The water samples collected from tobacco industry of Rangpur city contained HT value ranges from 910.73 to 923.10 mg L^{-1} and the mean value was 914.96 mg L^{-1} (Table 5). About 66% samples (2 samples) were less than the mean value. Sawyer and Mc Carty (1967) classified irrigation water into 4 classes based on hardness as mentioned in Table 5. According to this classification, all water samples were 'very hard' (> 300 mg L^{-1}). Hardness resulted due to presence of appreciable number of divalent cations like Ca and Mg (Todd, 1980).

Permeability index (PI)

Table 5 indicates that the water samples collected from different tobacco industry of Rangpur city contained PI value ranges from 0.031 to 0.038 and the mean value was 0.035. Permeability problem occurs when normal infiltration rate of soil is appreciably reduced and hinders moisture supply to crops which is responsible for two most water quality factors as salinity of water and its sodium content relative to calcium and magnesium. Highly saline water increases the infiltration rate. Relative proportions of other different cations or balance of some cations and anions defined by SAR, SSP, KR, MAR, TH, RSBC etc. also the indicators of permeability problem.

Kelly's ratio

The ranges of Kellys ratio of the collected water samples were varied from 0.022 to 0.029 where the mean value 0.026 (Table 5). Kelly's ratio (KR) represents the alkali hazards of water and is calculated by this equation, where all the concentrations were expressed in meq L^{-1}. Kelly's ratio is used to find whether groundwater is suitable for irrigation or not. Sodium measured against calcium and magnesium was considered by Kelly (1951) for calculating Kelly's ratio. Groundwater having Kelly's ratio more than one is generally considered as unfit for irrigation. According to Kelly's ratio, all of the water samples were suitable for irrigation.

Effects of wastewater on cucumber seeds

Germination rate (%)

Table 12 indicates that, the germination rate of cucumber seeds was significantly influenced by the treatments effect of wastewater at 3 and 4 days after placement but not significantly influenced at 5 days after placement. At 3 days after placement the highest germination rate (93.75 %) of cucumber was found in seeds treated with 25 ml of wastewater (T_5), which was statistically similar with treatment T_4 (20 ml wastewater) but different from others treatments. Conversely, the lowest germination rate (52.54 %) of tomato seed was found in seeds treated with normal water (T_0), which was statistically similar with seed treated with 5 ml of wastewater but different from other treatments. At 4 days after seed placement, the highest germination rate (97.91%) was also found in seeds treated with 25 ml of wastewater (T_5), which was followed by T_4 treatment but statistically different with other treatments. The lowest germination rate (85.17%) at 4 days after seed placement was found in T_1 treatment (seed treated with 5 ml wastewater). More or less similar results were also found in 5 days after seeds placement in case of germination rate of cucumber. The highest germination rate of cucumber seeds treated with 25 ml of wastewater may be due to presence of some growth regulatory or enhancing substances in the waste water.

Shoot length (cm)

Table 13 reveals that the shoot length of cucumber seedlings was significantly influenced by the treatments effect of wastewater at different days after seeds placement. Shoot length of cucumber seedlings was observed at 5, 6 and 7 days after placement. At 5 days after placement the longest shoot length (9.05 cm) was observed in seeds treated with treatment T_5 (25 ml wastewater) which was statistically similar with 8.76 cm shoot produced by treatment T_4 (20 ml wastewater) but different with other treatments. However, at 5 days after placement, the shortest shoot length (6.56 cm) was found in seeds treated with T_1 treatment (5 ml wastewater) which was statistically at par with T_0 and T_3 treatments which produced 6.78 cm and 6.61 cm shoot length, respectively.

At both 6 and 7 days after seeds placement the maximum shoot length (13.73 cm and 14.68 cm, respectively) were observed in T_5 treatment applied with 25 ml wastewater, whereas the minimum shoot length (9.47 cm and 12.2 cm, respectively) were observed in seeds treated with control treatment (no wastewater). At 6 days after seeds placement the maximum shoot length recorded in T_5 treatment was statistically similar with shoot length (12.11 cm) recorded in the treatment with application of T_4 but statistically different with other treatments. At 7 days after placement the longest shoot length produced by T_5 treatment was statistically similar with shoot length (14.52 cm) produced by T_3 treatment and followed by T_1, T_2 and T_4 treatments.

Root length (cm)

Table 14 shows that the effect of tobacco industry wastewater on the root length of cucumber seedlings was significant throughout the growth period observed. Root length of tomato was observed at different days after seeds placement (5, 6 and 7 DAP).

At 5 days after placement, the highest root length (9.31 cm) was observed in the treatment T_5 (25 ml wastewater), whereas the lowest shoot length (6.21 cm) was observed in T_1 treatment (5 ml wastewater). sAt 6 days after placement, the maximum root length (11.96 cm) was observed in the treatment T_5 applied with 15 ml wastewater while, the minimum root length (6.25 cm) was recorded in T_0 treatment which were statistically different with other treatments. At 7 days after placement, the longest root length (13.72 cm) was observed in the treatment T_5 applied with 25 ml of wastewater and the shortest root length (9.82 cm) was recorded in the treatment T_0 with application of control.

Effects of tobacco industry wastewater on radish seeds

Germination rate (%)

Table 15 shows that, the effects of wastewater on germination rate of radish seeds was significant ($P<0.01$) at 3, 4 and 5 days after placement. At 3 days after placement, the maximum germination rate (88.4 %) of radish seeds was recorded in T_5 treatment applied with 25 ml wastewater which was statistically different with other treatments. Conversely, the minimum germination rate (57.89 %) of radish seeds was recorded in Treatment T_0 (no wastewater) which was also statistically different with other treatments. At both 4 and 5 days after seeds placement, the highest germination rate (100 %) was recorded in treatments T_5 and T_4 with application of 25 ml and 20 ml wastewater, respectively which were statistically similar with treatments T_2 (98.33 %) applied with 10 ml wastewater and T_3 (98.55 %) applied with 15 ml wastewater. However, in both cases, the lowest germination rate (91.66 %) was observed in treatment T_0 with application of control which was statistically similar with T_1 (93.24 %) and T_6 (93.65 %) applied with 5 ml and 30 ml wastewater, respectively.

Shoot length (cm)

Shoot length of radish seedlings was significantly influenced by the treatment effects of tobacco industry wastewater throughout the growing period observed (Table 16). The effect of wastewater on the shoot length of radish seedlings was observed at different days after placement.

At 5 days after placement, the highest shoot length (7.65 cm) was observed in the treatment T_5 applied with 25 ml wastewater followed by T_4 (7.13 cm) and T_6 (7.1 cm) treatments with the application of 20 ml and 30 ml wastewater, respectively. Conversely, the lowest shoot length (6.23 cm) was observed in treatment T_0 (no wastewater) which was statistically similar with T_3 treatment (6.42 cm) applied with 15 ml wastewater. At 6 days after seeds placement, the longest shoot length (11.02 cm) was recorded in seeds treated with T_5 treatment (25 ml wastewater) which was statistically similar with shoot length (10.28 cm) produced by T_4 treatment (20 ml wastewater) but statistically different with other treatments. The shortest shoot length (7.5 cm) was recorded in treatment T_0 (no wastewater) which was statistically different with other treatments. At 7 days after seeds placement, the highest shoot length (12.06 cm) was observed in the treatment T_5 applied with 25 ml of wastewater while, the lowest shoot length (10.73 cm) was recorded in the treatment T_0 applied with control.

Root length (cm)
Table 17 indicates that, the effect of tobacco industry waste water on the root length of radish seedlings was significant at different days after seeds placement.
At 5, 6 and 7 days after placement, seeds treated with T_5 treatment (25 ml wastewater) produced the longest root length (8.08, 10.4 and 11.93 cm, respectively), whereas the lowest root length (4.85 cm at 5 DAP, 8.22 cm at 6 DAP and 8.9 cm at 7 DAP) was observed in T_6, T_2 and T_6 treatment, respectively.

Effects of wastewater on yard long bean seeds
Germination rate (%)
Table 18 indicates that, the germination rate of yard long bean seeds was significantly influenced by the treatment effect of waste water (P<0.01) at 3, 4 and 5 days after placement. At 3 days after placement the highest germination rate (46.66 %) was found in seeds treated with 25 ml of wastewater (T_5), which was statistically different from other treatments. Conversely, the lowest germination rate (15.06 %) was found in seeds treated with normal water (T_0), which was followed by seeds treated with 5 ml of wastewater but different from other treatments. At 4 days after seed placement, the highest germination rate (86.66 %) was found in seeds treated with 25 ml of wastewater (T_5), which was statistically different from other treatments. The lowest germination rate (46.66 %) at 4 days after seed placement was found in T_0 treatment (seed treated with control) which was statistically different with other treatments. At 5 days after seed placement, the highest germination rate (85.0 %) was found in seeds treated with 25 ml of wastewater (T_5), which was statistically similar with T_4, T_3 and T_2 treatments but different from other treatments. The lowest germination rate (73.33 %) at 5 days after seed placement was found in T_0 and T_1 treatments which were statistically similar with T_6 treatment which gives 72.69 % germination rate.

Shoot length (cm)
Table 19 reveals that the shoot length of long yard bean seedlings was significantly influenced by the treatment effect of wastewater at different days after seed placement. Shoot length of long yard bean seedlings was observed at 5, 6 and 7 days after placement. At 5 days after placement the longest shoot length (5.25 cm) was observed in seeds treated with treatment T_4 (20 ml wastewater) and T_5 (25 ml wastewater) which was statistically different with other treatments. However, at 5 days after placement, the shortest shoot length (4.21 cm) was found in seeds treated with T_0 treatment (control). At 6 days after seed placement, the maximum shoot length (12.57 cm) was observed in T_5 treatment applied with 25 ml wastewater which was statistically different with other treatments, whereas the minimum shoot length (9.01 cm) was observed in seeds treated with control treatment. At 7 days after seed placement, the maximum shoot length (15.03 cm) was observed in T_5 treatment applied with 25 ml wastewater which was statistically similar with T_4 and T_3 treatments, whereas the minimum shoot length (12.91 cm) was observed in seeds treated with T_0 treatment which was statistically similar with T_6 treatment.

Root length (cm)
Table 20 shows that the effect of tobacco industry wastewater on the root length of long yard bean seedlings was not significant at 5 days after placement but significant at 6 and 7 days after seed placement. At 5 days after placement, the highest root length (5.26 cm) was observed in the treatment T_5 (25 ml wastewater), whereas the lowest shoot length (3.62 cm) was observed in T_0 treatment (no wastewater). At 6 days after placement, the maximum root

length (9.42 cm) was observed in the treatment T_5 applied with 25 ml wastewater which was statistically similar with T_4 treatment while, the minimum root length (6.69 cm) was recorded in T_0 treatment. At 7 days after placement, the longest root length (13.11 cm) was observed in the treatment T_5 applied with 25 ml of wastewater and the shortest root length (9.36 cm) was recorded in the treatment T_0 with application of control.

Conclusion

Based on the result of the present study, it was found that wastewater samples were suitable for irrigation purpose with some exception as they contained some ions such as K^+, Mg^{2+} and SO_4^{2-} in a toxicity level. Considering the findings of the experiment, it can be concluded that -

- The risks related to K^+, Mg^{2+} and SO_4^{2-} can be reduced by treating the wastewater before using it or by applying some precautions while using it.
- Twenty-five ml of collected wastewater showed higher performance in relation to germination rate, shoot length and root length in cucumber, radish and yard long bean.

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Table 2. Water quality parameters of the collected wastewater samples

Sample No.	pH	Electrical conductivity (µS cm^{-1})	Total dissolved solid (mg L^{-1})
1.	6.78	971	112.9
2.	6.84	972.45	111.98
3.	6.75	966.55	113.4
Minimum	6.75	966.55	111.98
Maximum	6.84	972.45	113.4
Mean	6.79	970	112.76

Table 3. Cationic constituents of the collected wastewater samples

Sample No.	Ca^{2+} (mg L^{-1})	K^{+} (mg L^{-1})	Zn^{2+} (mg L^{-1})	Fe^{3+} (mg L^{-1})	Mg^{2+} (mg L^{-1})	Na^{+} (mg L^{-1})	Cu^{2+} (mg L^{-1})	Mn^{2+} (mg L^{-1})
1.	179.63	46.26	0.023	0.099	112.68	7.6	0.07	0.0062
2.	184.61	45.86	0.022	0.099	111.97	6.59	0.087	0.0066
3.	177.84	46.63	0.024	0.098	113.69	8.4	0.083	0.0061
Minimum	177.84	45.86	0.022	0.098	111.97	6.59	0.07	0.0061
Maximum	184.61	46.63	0.024	0.099	113.69	8.4	0.087	0.0066
Mean	180.03	46.25	0.023	0.099	112.78	7.53	0.08	0.0063

Table 4. Anionic constituents of the collected wastewater samples

Sample No.	SO_4^{2-} (mg L^{-1})	HCO_3^- (mg L^{-1})	PO_4^{2-} (mg L^{-1})	Cl^- (mg L^{-1})
1.	228.36	9.24	6.78	0.34
2.	227.7	8.94	6.84	0.33
3.	228.93	9.44	6.75	0.38
Minimum	227.7	8.94	6.75	0.33
Maximum	228.93	9.44	6.84	0.38
Mean	228.33	9.21	6.79	0.35

Table 5: Evaluation of water quality of collected wastewater samples

Sample No.	SAR (mg L^{-1})	PI	H_T (mg L^{-1})	Kelly's ratio
1.	0.63	0.035	911.06	0.026
2.	0.54	0.031	923.10	0.022
3.	0.70	0.038	910.73	0.029
Minimum	0.54	0.031	910.73	0.022
Maximum	0.70	0.038	923.10	0.029
Mean	0.62	0.035	914.96	0.026

SAR= Sodium adsorption ratio; PI= Potential index; H_T = Hardness

Table 6. Irrigation water classification on the basis of electrical conductivity (Wilcox, 1955)

Water class	Electrical conductivity (μS cm^{-1})
Excellent	< 250
Good	250-750
Permissible	750-2000
Doubtful	2000-3000

Table 7. Irrigation water classification based on TDS (Freeze and Cherry, 1979)

Water class	Total dissolved solids (mg L^{-1})
Fresh water	0-1,000
Brackish water	1,000-10,000
Saline water	10,000-100,000
Brine water	>100,0000

Table 8. Irrigation water classification based on sodium adsorption ratio

Water class	Sodium adsorption ratio
Excellent	<10
Good	10-18
Fair	18-26
Poor	>26

Table 9. Classification of irrigation water based on hardness (Sawyer and McCarty, 1967)

Water class	Hardness mg L^{-1}, as $CaCO_3$
Soft	0-75
Moderately hard	75-150
Hard	150-300
Vary hard	>300

Table 10: Guidelines for nutrient concentrations in irrigation water

Elements	Symbol	For waters used continuously on all soils
Total Dissolved Solids	TDS	0-2000 mg L^{-1}
Calcium	Ca^{++}	0-20 me L^{-1}
Magnesium	Mg^{++}	0-5 me L^{-1}
Sodium	Na^{+}	0-40 me L^{-1}
Bicarbonate	HCO_3^{-}	0-10 me L^{-1}
Chloride	Cl^{-}	0 – 30 me L^{-1}
Sulphate	SO_4^{--}	0- 20 me L^{-1}
Potassium	K^{+}	0-2 mg L^{-1}
Sodium Adsorption Ratio	SAR	0-15 me L^{-1}

Source: Ayers, R.S. and Westcot, D.W. (1985). Water Quality for Agriculture, FAO irrigation and drainage paper 29 Rev. 1, Reprinted 1989, 1994, M-56 ISBN 92-5-102263-1 Food and Agriculture Organization of the United Nations Rome, 1985 © FAO.

Table 11: Guidelines for nutrient concentrations in irrigation water (mg L^{-1})

Macronutrient	Low	Normal	High	Very High
Phosphorus	<0.01	0.1-0.4	0.4-0.8	>0.8
Potassium	<5	5-20	20-30	>30
Calcium	<20	20-60	60-80	>80
Magnesium	<10	10-25	25-35	>35
Sulfur	<10	10-30	30-60	>60
Micronutrient	Acceptable range	Suggested maximum concentration		
Iron	2.4-4.0	5.0		
Manganese	<0.2	0.2		
Copper	<0.2	0.2		
Zinc	<0.3	2.0		

Guidelines based on the suggestions of Duncan, R.R., R.N. Carrow, and M. Huck. 2000. Understanding Water Quality and Guidelines to Management. USGA Green Section Record. September-October, PP. 14-24.

Table 12. Effects of wastewater on germination rate of cucumber seeds at different days after placement (DAP)

Treatments	Germination rate (%)		
	3 DAP	4 DAP	5 DAP
Water or control (T_0)	52.54 e	91.89 abc	91.89
5 ml waste water (T_1)	60.91 e	85.17 c	89.66
10 ml waste water (T_2)	84.9 bc	94.05 ab	94.05
15 ml waste water (T_3)	79.41 cd	90.39 abc	92.35
20 ml waste water (T_4)	88.62 ab	89.19 bc	89.19
25 ml waste water (T_5)	93.75 a	97.91 a	97.91
30 ml waste water (T_6)	73.89 d	89.4 abc	91.35
Level of significance	**	**	NS
CV (%)	3.27	3.4	3.47

In a column, means followed by the same letter(s) did not differ significantly at $P \leq 5\%$ level by Tukey. **Significant at the 1% probability level. NS Not significant at the 5% probability level.

Table 13. Effects of wastewater on shoot length of cucumber seedlings at different days after placement (DAP)

Treatments	Shoot length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	6.78 c	9.47 c	12.2 c
5 ml waste water (T_1)	6.56 c	10.9 b	14.42 ab
10 ml waste water (T_2)	7.2 bc	10.68 b	14.3 ab
15 ml waste water (T_3)	6.61 c	10.8 b	14.52 a
20 ml waste water (T_4)	8.76 a	12.11 a	14.68 a
25 ml waste water (T_5)	9.05 a	13.73 a	13.6 ab
30 ml waste water (T_6)	7.7 b	10.6 b	13.35 b
Level of significance	**	**	**
CV (%)	3.31	3.12	2.94

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level.

Table 14. Effects of wastewater on root length of cucumber seedlings at different days after placement (DAP)

Treatments	Root length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	6.95 ab	6.25 d	9.82 c
5 ml waste water (T_1)	6.21 b	8.3 cd	11.57 bc
10 ml waste water (T_2)	7.81 ab	9.77 abc	12.1 ab
15 ml waste water (T_3)	6.83 ab	10.38 abc	12.72 ab
20 ml waste water (T_4)	8.56 ab	11.26 ab	12.57 ab
25 ml waste water (T_5)	9.31 a	11.96 a	13.72 a
30 ml waste water (T_6)	8.68 ab	9.3 bc	13.2 ab
Level of significance	*	**	**
CV (%)	14.29	8.46	5.6

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level. **Significant at the 1% probability level. *Significant at the 5% probability level

Table 15. Effects of wastewater on germination rate of radish seeds at different days after placement (DAP)

Treatments	Germination rate (%)		
	3 DAP	4 DAP	5 DAP
Water or control (T_0)	57.89 e	91.66 b	91.66 b
5 ml waste water (T_1)	74.47 bc	93.24 b	93.24 b
10 ml waste water (T_2)	71.66 cd	98.33 a	98.33 a

15 ml waste water (T_3)	68.53 d	98.55 a	99.55 a
20 ml waste water (T_4)	76.33 b	100 a	100 a
25 ml waste water (T_5)	88.4 a	100 a	100 a
30 ml waste water (T_6)	67.80 d	93.65 b	93.65 b
Level of significance	**	**	**
CV (%)	2.2	1.45	1.31

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level.

Table 16. Effects of wastewater on shoot length of radish seedlings at different days after placement (DAP)

Treatments	Shoot length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	6.23 c	7.5 c	10.73 b
5 ml waste water (T_1)	6.6 bc	8.58 b	11.16 ab
10 ml waste water (T_2)	6.51 bc	8.91 b	10.88 b
15 ml waste water (T_3)	6.42 c	9.38 b	11.06 ab
20 ml waste water (T_4)	7.13 ab	10.28 a	11.2 ab
25 ml waste water (T_5)	7.65 a	11.02 a	12.06 a
30 ml waste water (T_6)	7.1 ab	8.71 b	11.68 ab
Level of significance	**	**	*
CV (%)	3.57	3.37	3.6

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level. *Significant at the 5% probability level

Table 17. Effects of wastewater on root length of radish seedlings at different days after placement (DAP)

Treatments	Root length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	5.00 c	7.02 b	9.43 b
5 ml waste water (T_1)	5.40 c	8.64 ab	9.45 b
10 ml waste water (T_2)	6.28 bc	8.22 b	10.94 ab
15 ml waste water (T_3)	5.65 bc	8.53 ab	10.86 ab
20 ml waste water (T_4)	7.08 ab	8.75 ab	11.52 a
25 ml waste water (T_5)	8.08 a	10.4 a	11.93 a
30 ml waste water (T_6)	4.85 c	8.95 ab	8.9 c
Level of significance	**	**	*
CV (%)	9.32	8.96	10.59

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level. *Significant at the 5% probability level.

Table 18. Effects of wastewater on germination rate of yard long bean seeds at different days after placement (DAP)

Treatments	Germination rate (%)		
	3 DAP	4 DAP	5 DAP
Water or control (T_0)	15.06 d	46.66 e	73.33 b
5 ml waste water (T_1)	18.56 cd	68.8 c	73.33 b
10 ml waste water (T_2)	32.77 bc	55.75 d	83.95 a
15 ml waste water (T_3)	22.22 c	58.85 d	83.8 a
20 ml waste water (T_4)	36.52 b	74.48 b	83.33 a
25 ml waste water (T_5)	46.66 a	86.66 a	85.0 a
30 ml waste water (T_6)	22.69 c	70.31 c	72.69 b
Level of significance	**	**	**
CV (%)	3.59	1.86	2.23

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level.

Table 19. Effects of wastewater on shoot length of long yard bean seedlings at different days after placement (DAP)

Treatments	Shoot length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	4.21 d	9.01 d	12.91 b
5 ml waste water (T_1)	4.48 cd	9.28 cd	13.48 ab
10 ml waste water (T_2)	4.67 bc	10.55 bc	13.66 ab
15 ml waste water (T_3)	4.58 bcd	11.27 b	14.76 a
20 ml waste water (T_4)	5.25 a	10.58 b	14.81 a
25 ml waste water (T_5)	5.25 a	12.57 a	15.03 a
30 ml waste water (T_6)	4.96 ab	10.06 bcd	13.02 b
Level of significance	**	**	**
CV (%)	3.31	4.42	4.18

In a column, means followed by the same letter(s) did not differ significantly at P ≤ 5% level by Tukey. **Significant at the 1% probability level.

Table 20. Effects of wastewater on root length of long yard bean seedlings at different days after placement (DAP)

Treatments	Root length (cm)		
	5 DAP	6 DAP	7 DAP
Water or control (T_0)	3.62	6.69 b	9.36 b
5 ml waste water (T_1)	3.82	8.32 ab	11.44 ab
10 ml waste water (T_2)	4.95	8.36 ab	10.44 ab
15 ml waste water (T_3)	4.15	8.06 ab	10.33 ab
20 ml waste water (T_4)	4.6	9.21 a	11.11 ab
25 ml waste water (T_5)	5.26	9.42 a	13.11 a
30 ml waste water (T_6)	4.36	7.36 ab	11.00 ab
Level of significance	NS	*	*
CV (%)	16.19	13.58	9.92

In a column, means followed by the same letter(s) did not differ significantly at $P \leq 5\%$ level by Tukey. *Significant at the 5% probability level. NS Not significant at the 5% probability level.

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