International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

---

# Suitability Assessment of Effluent of Mineral Water Bottling Factory for Crop Irrigation

Alemu Shiferaw Debela[a]*, Hameed Sulaiman[b]

[a]*Biology Department, Wachemo University, Hossana P.O. Box 667, Ethiopia*
[b]*Biology Department, Sultan Qaboos University, Alkhod 123 and P.O. Box 36, Sultanate of Oman*
[a]*Email: alemushiferaw@gmail.com*, [b]*Email: hameed@squ.edu.om*

**Abstract**

Agricultural production in Ethiopia is mostly dependent on rain water and this kind of production system is severely affected by climatic irregularities. Thus, it is increasingly becoming obvious that reuse of wastewater especially, industrial effluent is one promising solution. Conversely, without detailed investigation, based on knowledge of the possible harmful effects on plants and soils, prolonged use of such waters will be challenging. In light of this, the aim of the present study was to evaluate the suitability of effluent of Ambo Mineral Water Bottling Factory (untreated) at different concentrations (0, 25, 50, 75, and 100%) for crop cultivation. Accordingly an experiment was conducted to evaluate the effect of effluent on growth and yield of *Phaseolus vulgaris* (Haricot beans). The methodology of the study was: Lab analysis of wastewater samples, soil and pot experiment with replications. Each treatment had nine replications, of which four are non-destructive sampling and five are for destructive sampling. Measurements of different growth parameters such as shoot length, root length, number of leaves, numbers of branches and plant fresh and dry weight have been done each 15 days after sowing. Comparison of seed yield and number of pods was also done after end of maturity. The result indicated that most of physico-chemical characteristics of the industrial effluent, except $HCO_3^-$, $K^+$, Ni and $F^-$, met the irrigation quality requirements for crop production and it was found to be a reach source of useful plant nutrients like N, P, K, Ca and Mg. The effluent irrigation had significant ($P<0.05$) effect on soil parameters viz. PH, EC, $Na^+$, $Ca^{2+}$, $Mg^{2+}$, $K^+$, $Fe^{2+}$, $Cl^-$, B, Cu and TKN. However, non-significant ($p>0.05$) effect was observed for heavy metals (Zn, Cd, Cr and Mn) translocation in soil and plant parts. The ANOVA also showed effluent treatments gave significantly higher values ($P<0.05$) of growth parameters and yield than tap water irrigation. Accordingly, it was concluded that the effluent can be used as a liquid fertilizer for irrigating crop cultivation.

***Keywords:*** *Phaseolus vulgaris;* Effluent; Irrigation; Growth parameters; Yield.

---

* Corresponding author.

## 1. Introduction

Agriculture is the major cornerstone for the economic development of Ethiopia. Agricultural production that depends on rain is mostly aimed at self-provision and this kind of production system is severely affected by climatic irregularities. To alleviate the recurrent drought problems, the appropriate management and utilization of water resource is paramount importance. An effective method to reduce vulnerability of climatic irregularities is to use irrigation for the agricultural production [33].

A reliable water supply suitable for irrigation, coupled with the necessary input, can boost agricultural production and ensure food self-sufficiency. Also, irrigation is the most common means of ensuring sustainable agriculture and coping with periods of inadequate rainfall and drought. Sufficient supplies of clean unused water can no longer be taken for granted due to population growth, increasing urbanization and water demands.

Ethiopia gets plenty of annual rainfall on the aggregate but; the required amount is not available at the right time for effective crop production. Therefore, sustainable solution for such problems necessitates an integrated management of available water resources [21]. And the reuse of waste water, especially Industrial effluent, in agriculture should be an integral component of the strategy. However, without proper management, based on knowledge of the possible harmful effects to plants and soils, prolonged use of such water will be challenging [9, 12]. Therefore, it will be beneficial to study possible impacts of the effluent before recommending for irrigation [1].

Ambo Mineral Water has been bottling and selling since 1930 and is considered the market leader in Ethiopia. Even though the industry releases huge amount of wastewater each day and there is demand for irrigation, the water has not yet been used and the quality of the wastewater has not yet been determined whether it really fits for irrigation purposes. As a result, information is required on quality to evaluate the suitability of the effluent for irrigation. And this study, therefore, was designed to characterize the physicochemical properties of industrial wastewater and evaluate its suitability for crop irrigation.

## 2. Materials and Methods

### *2.1 Study Area*

The mineral water factory where the effluent comes from is located in Ambo town, which is a town in central Ethiopia located, at a distance of about 114km West of Addis Ababa. This town has a latitude and longitude of 8°59′N 37°51′E/ 8.983°N 37.85°E and an elevation of 2101 meters above sea level. The area has a mean annual rainfall of 900-1000mm and temperature varies from 23-28$^0$c.

### *2.2 Effluent sample collection*

The effluent samples (untreated) were collected in clean glass containers of 1L volume, in a way that no bubbles were formed in the containers, directly from the outlet of the Ambo mineral water product factory. The effluents were stored at 4$^0$C during storage period to avoid any change in its characteristics. The physicochemical properties of the effluent such as : color, odor, temperature, pH, EC, TDS, TSS, DO, BOD, COD, Turbidity, total alkalinity, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, nitrate, chloride, fluoride, nitrogen, phosphorus, iron, manganese, lead, aluminum, nickel, copper, chromium and cadmium were analyzed by standard methods of water analysis [23].

### *2.3 Plant Materials*

Seeds of the Haricot bean (*Phaseolus vulgaris*) (Awash-1) cultivar was procured from the Awash Melkasa Agricultural Research Centre, Ethiopia. The reason why this crop type was selected for experiment is that the crop is widely consumed by the community; it is a leading export crop among other pulses grown in Ethiopia, produced mainly in low lands and mid altitude areas and very essentially it is short season crop which can be harvested within three months.

### *2.4 Experimental Setup and Growth Conditions*

The present investigation was conducted under protected conditions, in Addis Ababa, Ethiopia. The climatic conditions were averaged as follows: 13.6 h photoperiod, 65-73.5% relative humidity and 25°C / 10°C day/ night temperatures, respectively.

Fresh effluent was diluted with different concentration of: 25, 50, 75, and 100% (by volume) with tap water for experimental studies. The collected wastewaters were stored in dark at room conditions for future uses. Uniform sized, 90 healthy seeds were selected and thoroughly washed with tap water. Plenty of top Soil (15cm) was collected mixed carefully, air dried and then sieved. Thereafter, 2.5 kg of the soil was weighed and put into pots of 25 cm diameter and then, seeds were placed (two seed per pot of which one was removed after germination) in different pots, filled with soil. The pots were irrigated with equal quantity of different combinations of effluent. Each treatment had nine replications of which four were for destructive sampling (for measurement of time dependent variation of growth parameters) and the other five non-destructive sampling (for yield comparison), i.e. there were 5 blocks 9 pots/block = 45 pots.

A control set, irrigated with tap water was also maintained for comparison. The pots were covered at the top with transparent plastic sheet, which was maintained at 1.50m above the plant, to avoid rain water from diluting the contents. Pots were arranged in random spatial order (to randomize light/watering variation) and trays were rotated to limit effects of light/watering variation and with no fertilizer and other inputs except water of different concentration. And watering was done twice a day before germination and in two days interval after germination throughout the experimental period (75 days).

### *2.5 Growth Measurements*

Measurement of different growth parameters of experimental plants was done every fifteenth day i.e., 15, 30, 45 and 60th days after sowing, to evaluate time dependent variation on plant growth parameters including: shoot length, root length, number of branches, and number of leaves. In total, 20 plants (those planted for destructive sampling) were removed before end of maturity. Then, after maturity (75 days), the other 25 seedlings (Five replicates for each Treatment) were harvested to evaluate the effect of wastewater on number of pods and yield of the crop. Lastly, the plants were washed with tap water weighed for wet weight and oven dried at 70°C for 48hr following procedure used by [19] for constant mass and the dry weight of shoots and roots was then determined. Data obtained were analyzed for variance ANOVA by using SPSS statistical software.

### *2.6 Soil sampling and analysis*

Soil samples of different irrigation treatments and control soils were analyzed for different physico-chemical parameters viz. Moisture of soil, pH, EC, OC, $Ca^{2+}$, $Mg^{2+}$,$Na^{+}$ ,$K^{+}$ ,TKN, $PO_4^{3}$ , $Cl^{-}$, $SO_4^{2-}$, $Fe^{2+}$ ,Cu, Cr, Cd, Mn and Zn using standard methods of soil analysis.

### *2.7 Heavy metal analysis*

The concentration of heavy metals in water, soil and plant parts were analyzed using Atomic absorption spectrophotometer (AAS), model 210 VGP. Effluent samples (10ml of all combination); 1gm of air dried soil and 0.5gm of powdered plant samples were prepared for analysis. Effluent samples passed through 0.45μm Whatman filter paper were acidified with 1ml of $HNO_3$ and analyzed by AAS.

Plant samples were oven dried at $60^0$c for 72hrs grounded and sieved by 1mm mesh and mixed with conc. $HNO_3$ (69%) and digested for 5hrs. Then digested samples were diluted with 50ml of double distilled and deionized water and put in refrigerator. Cooled mixture were filtered through 0.45 μm Whatman filter paper and analyzed by AAS. Similarly, soil samples were oven dried at $107^0$c for 24hrs then grinded and sieved by75 μm and mixed with 5ml of $HClO_4$ in 50ml beaker, placed in sand bath and heated by fumes of $HClO_4$ for 45 min and then 45ml of HClO was used to leach the mixture and analysis was made by AAS.

## 3. Results and Discussions

### *3.1 Water Quality Test Results*

As shown in Table.1 below, the result of analysis of the irrigation water (untreated effluent) reveals that only Ni has exceeded the threshold level of trace elements for crop production. All the other selected and tested elements are below the maximum permissible limits. And the concentrations level of iron (0.6 mg/L), manganese (0.11 mg/L), lead (0.19mg/L) and Aluminum (0.6 mg/L) are also lower than the limits set in guidelines.

The analyses showed that the pH of mineral water industrial effluent was (8.01±0.2) which is slightly alkaline in nature. This could be due to the higher concentration of bicarbonate in the effluent [6]. The values recorded for basic water suitability indexes: EC (2.13dSmol-1), TDS (804mg/L), and total salinity of the samples were found to be within the limits set in the guidelines. Calculated values of SAR (2.54±0.3) also found to be with in the moderate range for surface irrigation.

The effluent showed low BOD, and contained more essential plant nutrients like N (3.2mg/L), P (0.99mg/L) K (28.2mg/L) and Ca (77.8mg/l). The lower levels of BOD (32.3±0.5 mg/L) and COD (86±2.21 mg/L) in the effluent is an indicator of low level of organic carbon.

**Table 1:** Chemical characteristics of effluent water samples as compared to recommended standards

| Parameters measured | Values (Mean ± std. error of mean) | FAO standards (2004) |
|---|---|---|
| color | Almost Clear | - |
| odor | No detectable odor | - |
| PH | 8.01±0.2 | 6.5-8 |
| Temperature ($^0$C) | 28.8±0.11 | - |
| Turbidity (N.T.U) | 4.6±0.03 | - |
| Eclectic conductivity dSmol$^{-1}$ | 2.13±0.05 | 0.7 - 3.0 dS/m |
| Total Suspended solids (mg/L) | 39±0.2 | 50 mg/L |
| Total Dissolved solids (mg/L) | 804±0.15 | 450 - 2000 |
| Salinity, mg/L | 0.09±0.03 | <3 ds/m |
| DO mg/L | 8.96±0.6 | - |
| BOD mg/L | 32.3±0.5 | - |
| COD mg/L | 86±2.21 | - |
| Hydroxide Alkalinity (OH) | nil | - |
| Carbonate alkalinity (as $CaCO_3$) (mg/L) | nil | - |
| Total alkalinity, mg/L | 654.8±1.30 | - |
| $CO_3^{2-}$ | 22± 1.1 | - |
| Bicarbonate ($HCO_3$), mg/L | 654.8±1.30 | 600 mg/L |
| Fluoride ($F^-$) mg/L | 1.45±0.4 | 1.0 mg/L |
| Chloride ($Cl^-$) mg/L | 54.1± 0.11 | 120-300 mg/L |
| Magnesium($Mg^{+2}$), mg/L | 32.10±0.23 | 60 mg/L |
| Calcium ($Ca^{2+}$), mg/L | 77.8± 1.03 | 400 mg/L |
| Sodium($Na^+$), mg/L | 105.85±1.66 | 900 mg/L |
| Potassium as ($K^+$) mg/L | 28.2± 0.12 | 0-2 mg/L |
| Lead (Pb) mg/L | 0.19±0.02 | 5 mg/L |
| Cadmium (Cd) mg/L | nil | 0.01mg/L |
| Copper (Cu) mg/L | 0.02±0.00 | 0.2mg/L |
| Nickel (Ni), mg/L | 0.22±0.03 | 0.20 mg/L |
| Chromium (Cr) mg/L | nil | 0.1mg/L |
| Iron (Total), as $Fe^{2+}$ mg/L | 0.09±0.002 | 5 mg/L |
| Manganese (Mn), mg/L | 0.11±0.004 | 0.20 mg/L |
| Aluminum (mg/L) | 0.6±0.00 | 5.0 mg/L |
| Boron (B) mg/L | nil | <0.75 |
| Sulphate ($SO_4^{2-}$), mg/L | 10±0.21 | 1000 mg/L |
| Total phosphorus (P), mg/L | 0.99±0.01 | 0-2 mg/L |
| Nitrate ($NO_3$-N), mg/L | 3.2±0.33 | 5 - 30 |
| Total Nitrogen (as N), mg/L | 1.2±0.1 | 5 – 30 mg/L |
| SAR | 2.54±0.3 | 3 - 9 |

The results data from Table 1 indicated that, the concentration of most of the anions and cations in the effluent sample were below the maximum threshold levels for irrigation. Only $HCO_3$-, F- and $K^+$ exceeded the limits. Higher values of 654.8mg/L and 28.2mg/L were recorded for $HCO_3$- and $K^+$ while the maximum recommended limits were 600mg/L and 2.0mg/L, respectively. And slightly higher value of $F^-$ (1.45mg/L) was recorded while the limit for irrigation water was only 1mg/L.

### *3.2 Germination rates*

[28] Explained the germination of seed ensures the reproduction and crop productivity. Bottling industry had no negative effect on seed germination of *phaseolus vulgaris* and there is negative correlation (r = -0.878) between germination and effluent concentration.

Polluted water does not inhibit seedling germination and growth at low concentration [27]. However, several researchers reported heavily polluted wastewaters will affect both germination and growth of seedlings [29].The present investigation revealed that the effluent of mineral water bottling factory, both diluted and undiluted, has no effect on germination of *phaseolus vulgaris.*

### *3.3 Effect on Soil parameters*

Moisture of soil, pH, EC, OC, $Ca^{2+}$ , $Mg^{2+}$ ,$Na^{+}$ ,$K^{+}$ ,TKN, $PO_4^{3}$ , $Cl^{-}$, $SO_4^{2-}$, $Fe^{2}$ ,Cu, Cr, Cd, Mn and Zn **.** ANOVA showed Effluent irrigation significantly ($p<0.05$) changed soil parameters PH, EC, $Na^{+}$, $Ca^{2+}$, $Mg^{2}$, $K^{+}$, $Fe^{2+}$, Cu and TKN. However, the effluent irrigation had insignificant ($p>0.05$) effect on metals (Zn, Cd, Cr and Mn) and anions ($PO_4^{3-}$, $SO_4^{2-}$) concentration in soil. The findings are not in agreement with that of [15] who reported significant change in metal concentration in soil and *phaseolus vulgaris* irrigated with paper mill effluent.

**Table 2:** Influence of different irrigation treatments on soil characteristics

| Soil parameters | Control | T1 | T2 | T3 | T4 | *r- value* | P |
|---|---|---|---|---|---|---|---|
| Moisture of soil (%) | 48.34 | 59.41 | 58.47 | 56.36 | 54.80 | 0.357 | 0.096 |
| pH | 6.9 | 7.11 | 7.32 | 7.43 | 7.78 | 0.986 | 0.000* |
| EC (dS m-1) | 1.91 | 1.97 | 2.06 | 2.14 | 2.19 | 0.986 | 0.000* |
| OC (mg Kg -1) | 0.452 | 0.453 | 0.449 | 0.451 | 0.454 | 0.409 | 0.065 |
| $Ca^{2+}$ ( mg Kg -1) | 16.21 | 17.27 | 20.02 | 24.31 | 23.14 | 0.934 | 0.000* |
| $Mg^{2+}$(mg Kg -1) | 2.43 | 2.47 | 3.53 | 3.59 | 4.24 | 0.957 | 0.000* |
| $Na^{+}$ ( mg Kg -1) | 10.98 | 11.23 | 14.31 | 18.99 | 21.64 | 0.970 | 0.000* |
| $K^{+}$( mg Kg -1) | 112.34 | 115.12 | 119.03 | 124.71 | 118.01 | 0.713 | 0.003* |
| TKN (mg Kg -1) | 21.11 | 21.33 | 20.23 | 22.47 | 24.62 | 0.763 | 0.001* |
| $PO_4^{3-}$ ( mg Kg -1) | 39.86 | 43.05 | 41.34 | 40.12 | 38.92 | -0.478 | 0.072* |
| $SO_4^{2-}$ ( mg Kg -1) | 66.29 | 67.56 | 71.42 | 65.47 | 69.61 | 0.295 | 0.286 |
| $Fe^{2+}$ (mg Kg -1) | 2.91 | 3.11 | 3.02 | 2.94 | 3.47 | 0.664 | 0.007* |
| B mgKg-1 | 0.009 | 0.008 | 0.008 | 0.009 | 0.008 | -0.16 | 0.57 |
| Cu ( mg Kg -1) | 0.77 | 0.89 | 0.91 | 0.93 | 0.95 | 0.894 | 0.000* |
| Cr ( mg Kg -1) | 0.011 | 0.012 | 0.012 | 0.011 | 0.012 | -0.152 | 0.294 |
| Cd ( mg Kg -1) | 0.08 | 0.14 | 0.13 | 0.11 | 0.09 | -0.062 | 0.826 |
| Mn ( mg Kg -1) | 0.39 | 0.41 | 0.46 | 0.40 | 0.43 | 0.399 | 0.141 |
| Zn ( mg Kg -1) | 0.072 | 0.07 | 0.09 | 0.053 | 0.07 | -0.253 | 0.363 |

*stands for significant change $p<0.05$

### *3.4 Influence of effluent concentrations on plant growth parameters*

**Root Length**: The data of root length of haricot beans as influenced by different concentrations of wastewater are presented in Figure1. The result revealed that the root length of Haricot bean was positively affected by different combinations of wastewater at all growth stages. The highest root length of 16.3, 27, 39, 43.5 and 47.6 were recorded in T3treatment and the lowest recordings of (11, 21.5, 29, 35 and 39.8) were obtained in control groups on days 15, 30, 45, 60, and 75, respectively. Values of root length recorded in T1 were almost comparable with that of Control and this could be due to the higher dilution 25:75 in T1.

The data at harvest (Figure.1) revealed that the effluent had positive effect on development of roots and larger root length values were recorded in all the effluent treatments over control. The minimum mean root length value (39.8cm) was noted in control (tap) irrigated crops. The maximum mean plant root length (46cm) in haricots was recorded in T3 (75%) followed by T4 (43.4cm), T2 (42.2cm) and T1 (42cm). And F- test (F-cal=10.31> F-tab =2.87) indicated that there is significant difference between mean root lengths of treatments. The effects of this effluent differ from that of distillery effluent [20] in that the root lengths were considerably increased with only 5% effluent concentration.

In addition, the correlation coefficient ($r = 0.879$) between effluent concentration growth of roots of haricot beans in this study indicated, a positive correlation which is significant at level of 0.05. But, LSD indicated the significant values of 0.098 and 0.073 for the mean difference between control and Treatments T1 and T2 respectively, which is not significant at level of 0.05 while, T3 and T4 are significantly higher than control with significant values of 0.000 and 0.010, respectively, i.e. the maximum mean difference was observed between T3 and control.

**Shoot length**: Plant shoot length increased significantly in all the treatments over control. From Figure.1 it can be seen that, the effect of different combinations of wastewater on shoot length of Haricot bean seedlings was not pronounced in the first two measurements 15 and 30 DAS, i.e. at initial stages of growth, but at later stages, T3 treatments excelled other treatments and control. Interactions between effluent concentration (treatments) and plant growth showed that effluent with 75% concentration (T3), gave taller plants with shoot length of 16.9 cm, 24 cm, 62 cm, 88cm and 94.8 cm at different stages of growth.

The mean shoot length of haricot bean as influenced by effluent concentration in comparison to control at harvest was shown in Figure.1. The maximum mean shoot length (94.8 cm) was recorded in T3 treatment followed by T2 (91 cm), T4 (87.8 cm), T1 (76.4 cm) and the minimum (72 cm) was recorded in control irrigated with tap water. Result of F-test ($F_{cal} = 3.426 > F_{tab} = 2.87$) showed that there was significant difference between mean shoot lengths of treatments. The maximum mean difference of 22.8±7.46 was observed between T3 and control which was statistically significant. The statistical analysis revealed that the concentration of wastewater was found to be significant for plant shoot length.

A positive correlation between seedling shoot length and effluent concentration correlation coefficient ($r = 0.923$) being significant at 0.05 level of significance, suggested beneficial effects of wastewater on stem growth. This might be due to the availability of nitrogen, which plays an important role and stimulates the growth of stem and other essential nutrients like Ca, Mg and P in the wastewater [13].

**Number of Leaves**: The data on the number of leaves in (Figure.1) reveals that T3 treatments were on par with T4 treatments at earlier stages of growth, but later they surpassed in giving large number of leaves over the others. Even though, the difference became magnified at later stages of growth, the data in Figure.1 clearly indicated that the 75% (T3) irrigation was better in giving larger number of leaves at all stages of growth. The values recorded at 15, 30, and 45, 60 and 75 DAS are 11, 14, 38, 65, and 71 respectively. The data on the number of leaves in T1, T2, T4 and that of the control is not consistent at different growth stages, but still the recordings in effluent treatments were better than control except at 45 and 75 DAS, which could be due to a combination of other factors.

The data on number of leaves of haricot beans with different irrigation treatments at harvest are presented in (Figure.1) below. The wastewater application enhanced the number of leaves of haricot beans and maximum mean number of leaves recorded in T3 (71plant-1) grown in 75% effluent water while, the minimum (50 plant-1) was recorded in T1 and this might be related to the number of branches of those plants.

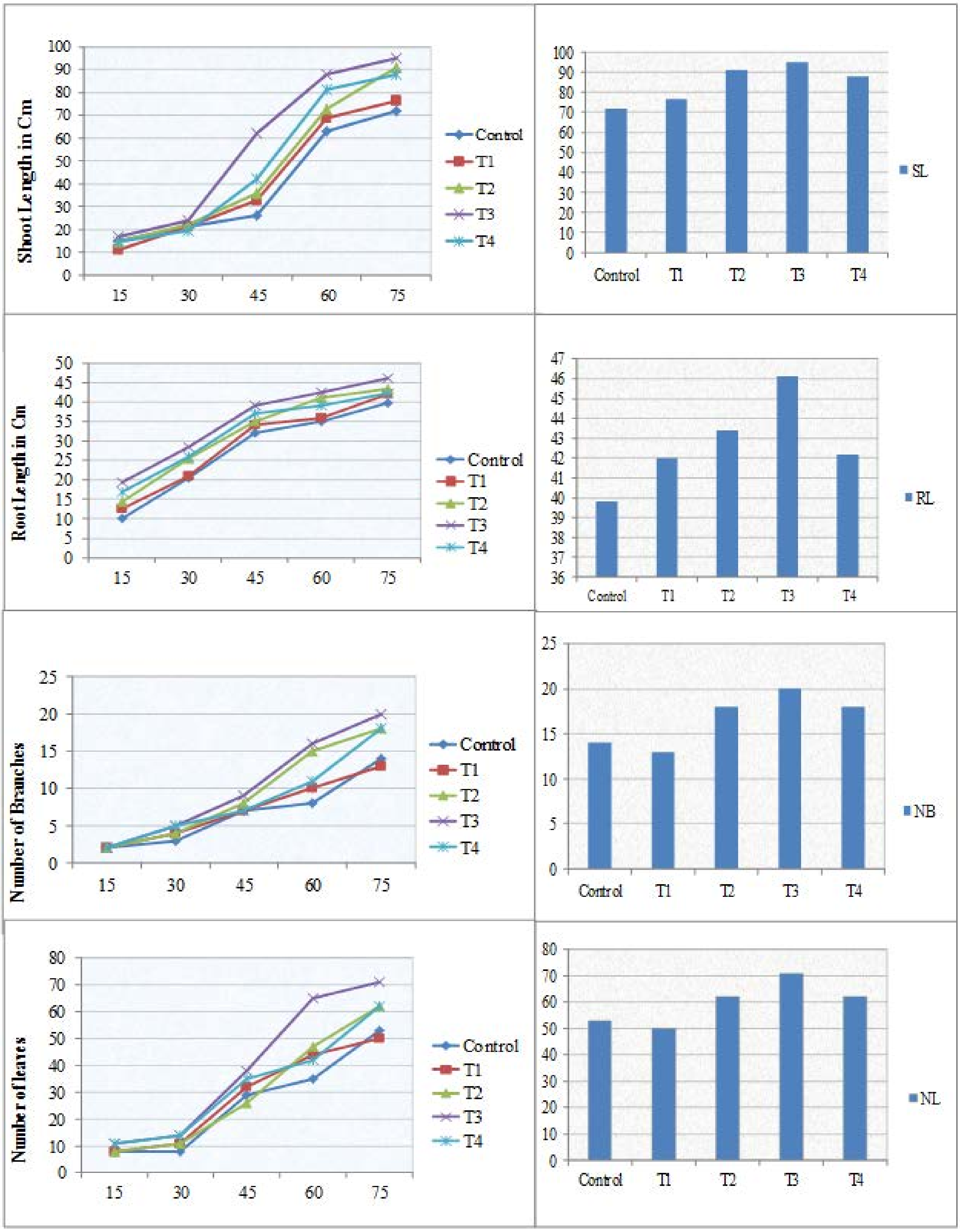
F-cal = 6.638 indicated there was significant difference in number of leaves between treatments. Comparison between control and effluent treatments show that the mean number of leaves recorded in T1, T2 and T4 did not differ significantly from that of the control, while that of T3 plants showed significant difference at 0.05 level, as it was evident from LSD value 0.001. Treatments with different concentration indicated that the number of leaves recorded in T3 treatments were significantly higher than the rest and control.

This could be due to the availability of nitrogen in the effluent which plays a role and stimulate the growth of leaves [13] or increased concentration of other essential nutrient which increases leaf number and leaf area by increasing cell size and number [8]. In addition, the larger number of leaves recorded in T3 than T4 could be explained as - T3 might be a better combination for maximum growth of leaves. However, Leaf-tip burns in few plant of T4 irrigation might be attributed to residual chlorine [26].

**Number of Branches**: Number of branches of haricot beans varied due to different irrigation treatments. Plants of different irrigation treatments did not differ from one another at early vegetative stage but gradually (after 45 DAS) T3 irrigated plants gave a larger number of branches compared to control and other treatments (Figure 1). Number of branches increased gradually in increasing the effluent concentrations up to 75%, but T4 irrigated plants gave slightly lower number of branches compared to T3 irrigated plants and the recordings were 2, 5, 7, 11 and 18 for T4 and 2, 5, 9, 16, and 20 for T3 at days 15, 30, 45, 60, 75 respectively.

Analysis of variance (F-cal = 6.769 > F-tab= 2.87) indicated the difference in number of branches between treatments at harvest (Figure.1) was significant.

The correlation coefficient r = 0.80 also indicated the number of branches of haricot beans was significantly correlated with effluent concentration. The mean numbers of branches observed in T2 (18), T4 (18) and T3 (20) treatments were significantly higher than that of the control (14). The mean value recorded in T1 (13) treatment was lower than that of the control (14) which could be attributed to a combination of various factors other than irrigation water.




NB- Number of branches          NL- Number of leaves SL- Shoot length          RL- Root length

**Figure 1:** Growth characteristics of haricot bean plants irrigated with different treatments of wastewater for 75 days

### *3.5 Influence of different combinations of effluent on plant biomass at various growth stages*

**Plant fresh biomass**: Data in Figure.2 illustrate the measured fresh biomass of haricot bean plants as affected by the applied concentrations of wastewater. Stem, root and total fresh weight significantly increased by wastewater application and the highest values were recorded in effluent irrigated plants than the tap irrigated plants at various growth stages. Measurements of shoot fresh weight at different growth stages (15, 30, 45, 60, 75 days) showed the maximum recordings of (1.85, 3.81, 12.43, 22.86 and 29.72g/plant) and minimum recordings of (1.58, 2.55, 7.65, 16.3, and 23.52g/plant) for T3 and control respectively. Similarly, maximum (1.15, 1.77, 5.31, 8.96, 12.48 g/plant) and minimum (0.55, 1.39, 2.78, 6.56, 9.89 g/plant) values of root fresh weight were recorded at various growth stages in T3 and control respectively.

Statistical analysis of F-test for shoots (F-cal= 30.742) and root (F-cal=24.112) fresh weight variation revealed that the difference in shoot and root fresh biomass between different irrigation treatments was significant. The correlation coefficient $r = 0.81$ for shoot and $r = 0.802$ for root indicated that there was a positive correlation between effluent concentration and biomass yield. The result data on effect of wastewater on plant fresh weight at harvest in Figure.2 also indicated that, application of 75% effluent concentration had the best effect on shoot fresh weight (29.72 g. plant-1) and root fresh weight (12.48 g plant-1). The minimum values of 23.52g/plant and 9.89g/plant for shoot and root fresh biomass were observed in control. The differences in total fresh biomass between various treatments (F-cal= 30.886) were found to be significant for the haricot beans (Figure.2). A significantly higher mean biomass (42.2g/plant) was recorded with the T3 (75%) effluent irrigation followed by T4, T2, T1 and control (tap) with recordings of 38.42g, 37.2g, 34.2g, and 33.41g, respectively.

The highest wet biomass production (42.2g) in seedlings of T3 treatments as compared to those in the other treatments was due to the beneficial effect of wastewater which provided macro-nutrients and micro-nutrient, essential for growth and productivity of the seedlings. This indicated a positive effect of industrial effluent on haricot bean growth and biomass production.

Application of wastewater produced a strong nutrient effect influencing growth and productivity of the seedlings. Greater biomass in the seedlings of effluent treatment than in the tap water irrigated crops (control) could be due to increased concentration of the available $PO_4$- -P and K in the effluent [7].

**Plant dry biomass**: Crops treated with wastewater of different concentration gave better dry biomass yield than the control at all stages of growth (Figure.2). The values recorded at different growth stages (15, 30, 45, 60, 75 DAS) for both shoot (0.19, 0.30, 1.39, 2.91, 4.21g/plant) and root (0.06, 0.15, 0.61, 1.45, 2.21 g/plant) dry weight of control indicated they were inferior in giving dry weights. Whereas, T3 plants gave maximum shoot (0.20, 0.41, 2.22, 4.08, and 5.32g/plant) and root (0.07, 0.10, 1.17, 1.98, and 2.76 g/plant) dry biomass at different growth stages.

Furthermore, application of wastewater for irrigation had significant effect on plant dry weight. F-test indicated (F-cal = 28.311) that total dry weight was greater the tabulated value of 2.87 from which we can deduce there was significant difference between mean weights of treatments. The statistical analysis for correlation between effluent concentration and plant dry biomass yield r = 0.805 for plant dry weight indicated that, plant dry biomass responded positively to the increment in the applied concentration with the maximum response recorded with the concentration of 75% after which the response started to decline.

There were no significant differences ($p = 0.517 > 0.05$) under both concentrations of 0% (control) and 25% (T1) applications regarding dry weight. The same previous trend was observed regarding dry weights of the shoots and roots. LSD for separate mean indicated and significant values for root 0.718 and shoot 0.421 dry weights.

However, ANOVA indicated there was significant difference between treatments in root (F-cal=23.919) and shoot (F-cal=30.534) dry weight, whereas, all applied treatments gave positive effect on both parameters compared to control treatment. This positive effect increased as the applied concentration increased until 75% after which the effect decline. The effect might be due to desired level of nutrient in diluted condition [18].

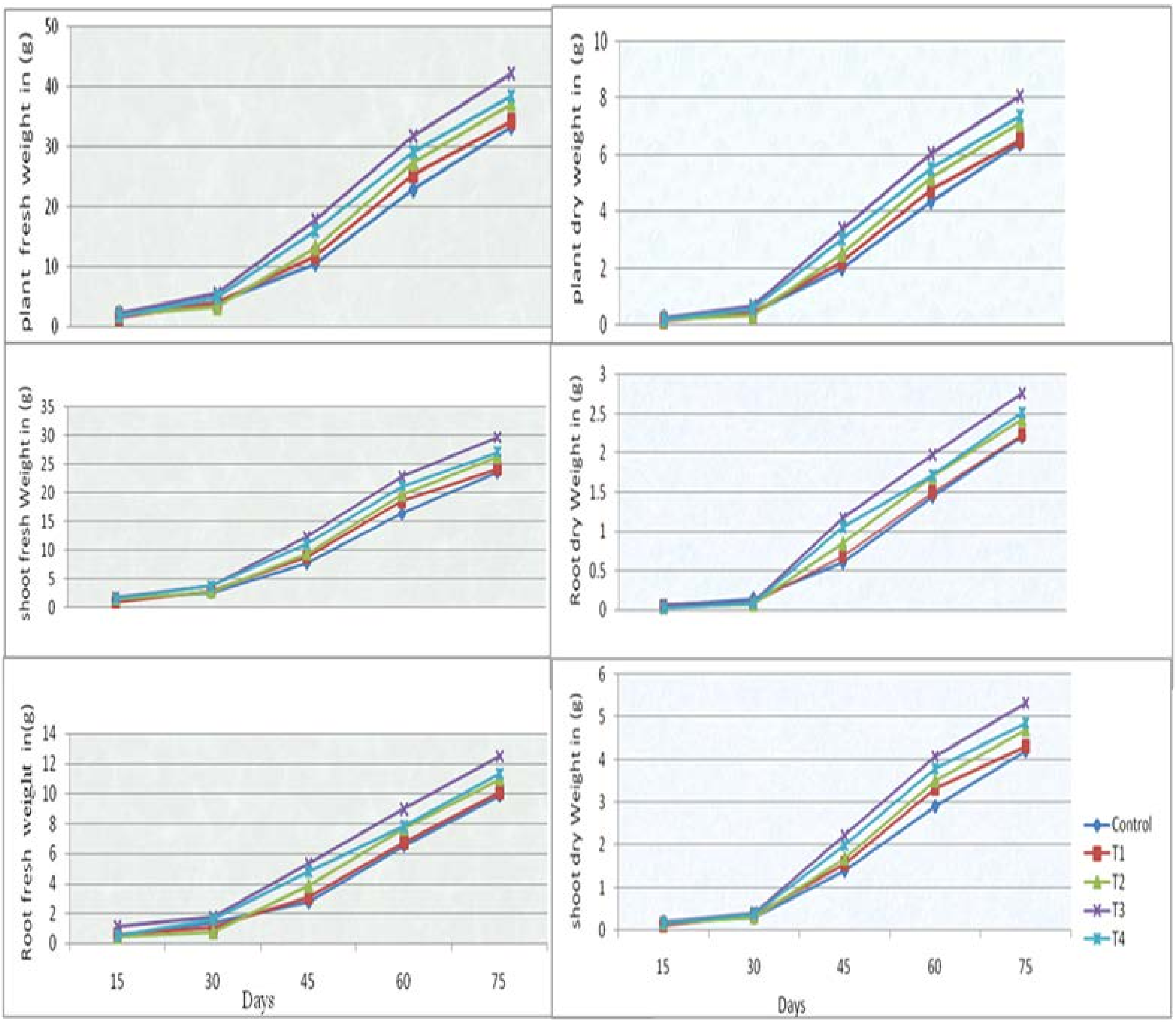



**Figure 2:** Fresh and Dry weights of haricot bean plants irrigated by different combinations of waste water at different growth stages for 75 days (g/plant)

### *3.6 Influence of effluent on yield and yield contributing characters at harvest*

Increase in Effluent concentration positively affected yield and number of pods of the plant. This is not in agreement with the findings of [20] who reported the effluent of fertilizer factory was toxic to *phaseolus vulgaris* at high concentration, but was beneficial at 2.5% concentration.

**Number of Pods**: The data on number of pods and number of seeds per plant with different concentrations of wastewater are presented in (Figure.3). Number of pods per plant as shown in Figure.3 was increased as the applied concentration increased until 75% (T3) after which the number of pods started to decrease however it was still higher than control. The maximum and minimum mean number of pods 16 and 9 pods/plant was recorded in T3 and T1 respectively.

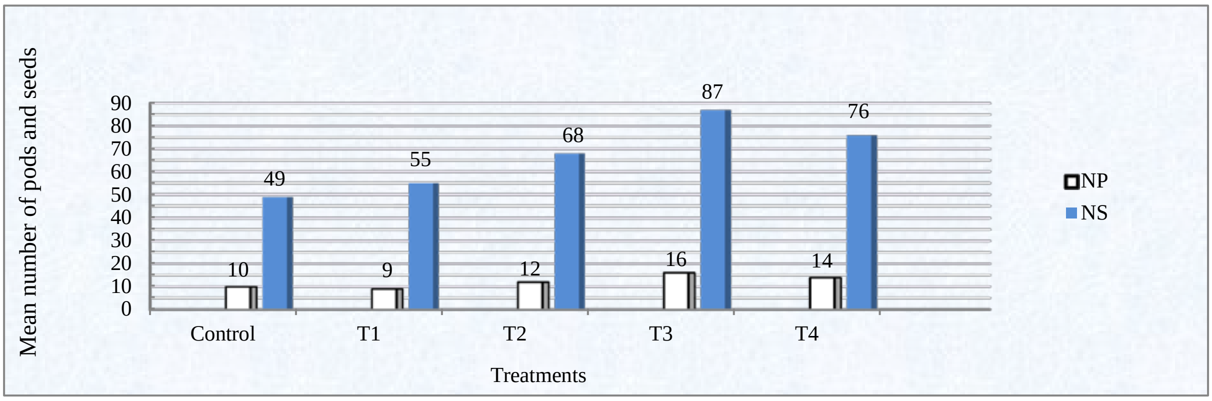



**Figure 3:** Influence of different composition of waste water on yield and number of pods of haricot bean at harvest

The statistical analysis (F-test) indicated F-cal (53.571) >F-tab (2.87) implies there was significantly higher difference between mean number of pods of haricot beans in treatments. The positive correlation ($r = 0.808$) between effluent concentration and number of pods indicated that the wastewater had beneficial effect on pod yield of haricot bean seedlings.

**Seed yield**: Seed yield showed significant differences due to different irrigation treatments, the highest mean seed yield (87 seed/plant) was noticed with T3 (75%) irrigation, followed by T4 (76 seeds/plant), T2 (68 seeds/plant), and T1 (55 seeds/plant). While the minimum (49seeds/plant) was recorded in control groups irrigated with tap water. The correlation coefficient ($r = 0.882$) indicated there was a positive correlation between effluent concentration and seed yield. Effluent had positive effect on the growth and yield of the haricot bean plants. This may be attributed to the presence of several essential plant nutrients like N, P, K, Ca and Mg present in the industrial wastewater [16, 11, 14]. Similar observation, increased height, growth and yield of pulse crops, irrigated with distillery spent wash effluent were reported by [4].

### *3.7 Interpretation of effluent for irrigation suitability*

Most important water quality parameters (EC, TDS, Cl, SAR, Potential salinity(PS), Residual sodium carbonate

(RSC) and Permeability Index (PI) of the irrigation water are analyzed and computed for interpretation of irrigation suitability. The EC of 2.13dSmol-1and and TDS of 804 ±0.15 are within the prescribed standard for safe irrigation.

SAR calculated by the formula of [30] *SAR*= Na+/ (Ca2++Mg2+)/2 was found to be 2.57 which can be classified as excellent for irrigation [22].

The potential salinity calculated by (PS= $Cl^-$ + $SO_4$/2) of [31] was found to be 1.65 which is less than the 3meq/l indicates the water is suitable for irrigation in almost all soil.

The formula of [31] for PI=100× [([Na] + [HCO3]1/2) / [Na] + [Ca] + [Mg] was also used for computation of PI the value obtained PI= 48.8% will classify the water to suitable for irrigation [25].

Residual sodium carbonate which explain potential impact of carbonates and bicarbonates [32] RSC= ($CO_3$+$HCO_3$)-($Ca^{2+}$+$Mg^{2+}$) calculated by formula of [24] is found to be 4.91 which is >2.5meq/l may result in the buildup of sodium in the long run. The higher RSC could be due to the carbonate concentration in the water [32].

**4. Limitations of the study**

This study is limited to the pot scale growth evaluation of the crop under green house or controlled environment. We believe field scale assessment might well explore the situation. Further, we only considered the effect of the wastewater on the Haricot bean (*phaseolus vulgaris*).

**5. Conclusions**

The results of present study revealed that most of the physicochemical characteristics of industrial effluent were below the maximum threshold level. The effluent was found to be reach source of essential plant nutrients like N, P, K, Mg and Ca. Haricot beans irrigated with mineral water industrial effluent gave a better biomass and seed yield over the control groups irrigated with tap water.

It was concluded that, irrigation of haricot beans (*phaseolus vulgaris*) with the Mineral water bottling factory effluent could fulfill the fertilizer requirements of crop and can increase crop yield and may lead to an economic advantage over regular water irrigation.

**6. Recommendations**

Based on the findings of the study, we would like to recommend the community to use the effluent for cultivation of *phaseolus vulgaris* and take the advantages; preferably the optimal combination (75% waste water + 25% tap water) is advised for better crop yield.

The authors would also like to recommend further studies, especially field scale researches and studies on other edible crops, that can adapt the climatic conditions of the specific area, are suggested.

## References

[1] P. Thamizhiniyan, P.V. Sivakumar, M. Lenin, and M. Sivaraman. "Sugar mill effluent toxicity in crop plants," Journal of Phytology, vol .1, no.2, pp. 68–74, 2009.

[2] M. Bhati and G. Singh. "Growth and mineral accumulation in Eucalyptus camaldulensis seedlings irrigated with mixed industrial effluents," Biores. Technol , vol. 88, no.3, pp. 221-228, 2003.

[3] T.A. Bauder, R. M. Waskom and J. G. Davis. "Irrigation water quality criteria, Colorado State University." US Department of Agriculture, 2007.

[4] S. Chandraju, H.C. Basavaraju, and C.C. Kumar. "Investigation of impact of irrigation of distillery spentwash on the nutrients of pulses," Asian Journal of Chemistry, vol. 20, no.8, p. 6342, 2008.

[5] S. Divyapriya, D. Divakaran, and K. P. Deepthi. "Biochemical effect of industrial effluent on germinating seeds of Cicer arietinum,"International Journal of Pharmacy and Pharmaceutical Sciences, vol.6, no. 2, pp. 538-542, 2014.

[6] FAO, Wastewater treatment and use in agriculture 2004.FAO irrigation and drainage paper 47

(http://www.fao.org/../do crep/T0551E/T0551E00.htm)

[7] S. Gholami and S. Srikantaswamy ."Analysis of agricultural impact on the Cauvery river water around KRS dam," World Appl Sci J, vol. 6, no.8, pp. 1157-1169, 2009.

[8] F. P. Gardner, R. B. Pearce, and R. L. "Mitchell, Physiology of crop plants," lowa State Univ. USA. Int. Rice Res. Notes. 27, pp.11-12, 1985.

[9] P. K. Goel and S. M.Kulkarni. "Effects of Sugar Factory Waste on Germination of Gram Seed (Ciceraeritinum L," International Journal of Environment and Pollution, vol. 1, no.1, pp.35-53, 1994

[10] Z. Huma, N. Shahida, R. Abdur, U. Asad and K. Inayat. "Effects of domestic and industrial waste water on," Current Opinion in Agriculture, Vol. 1, no.1, pp. 27–30, 2012.

[11] V. Kannan, R. Ramesh., and C. Sasikumar. "Study on ground water characteristics and the effects of discharged effluents from textile units at Karur District," Journal of environmental biology/Academy of Environmental Biology, India, vol. 26, no.2, pp. 269-272, 2005.

[12] P.Kalaiselvi, S.Shenbagavalli, S.Mahimairaja, and P.Srimathi. "Impact of post biomethanated distillery spent wash on seed germination and seedling growth of dry land crops," Madras Agric. J, vol. 96, pp. 331- 334, 2009.

[13] N.A. Khan, L. Gupta, S. Javid, S. Singh, M. Khan, and A. Inam. "Effects of sewage waste water on

morphophysiology and yield of Spinacia and Trigonella," Indian journal of plant physiology, vol. 8, no.1, pp. 74-78, 2003.

[14] F.M. Kiziloglu, M. Turan, U. Sahin, Y. Kuslu, and A. Dursun. "Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (Brassica olerecea L. var. botrytis) and red cabbage (Brassica olerecea L. var. rubra) grown on calcareous soil in Turkey," Agricultural water management, vol. 95, no.6, pp. 716-724, 2008.

[15] V. Kumar, and A.K. Chopra. "Ferti-irrigation Effect of Paper Mill Effluent on Agronomical Practices of Phaseolus vulgaris (L.) In two Seasons," Communications in Soil Science and Plant Analysis, Vol. 45, no.16, pp. 2151-2170, 2014.

[16] B.Niroula."Comparative effects of industrial effluents and sub-metropolitan sewage of Biratnagar on germination and seedling growth of rice and black gram," Our Nature, vol.1, no.1, pp. 10-14, 2003.

[17] S. Ramana, A.K. Biswas, S. Kundu, J.K. Saha, and R.B.R. Yadava. "Effect of distillery effluent on seed germination in some vegetable crops," Bioresource Technology, vol. 82, no.3, pp. 273-275, 2002.

[18] A. Rita, P.K. Jha, P. K., and N. Belbase. "Effect of distillery effluent on some agricultural crops, a case of environmental injustice to local farmers in Khajura VDC, Banke," Scientific world, vol.6, no. 6, pp. 68-75, 2008.

[19] O.E. Robert, O.A. Ulamen, and N. Osarodion. "Growth of Dialium guineense Willd Seedlings and Changes in Some Chemical Properties in Soil Amended with Brewery Effluent," Journal of Agronomy, 2007.

[20] R. Sahai, N. Shukla, S. Jabeen, and P. K. Saxena. "Pollution effect of distillery waste on the growth behaviour of Phaseolus radiatus L,"Environmental Pollution Series A, Ecological and Biologica., vol. 37, no .3, pp. 245-253, 1985.

[21] B. Shomar, M. Darwish, and C. Rowell. "What does integrated water resources management from local to global perspective mean? Qatar as a case study, the very rich country with no water," Water resources management, vol. 28, no.10, pp. 2781-2791, 2014.

[22] T. Subramani, L. Elongo, S.R. Damodarasamy."Groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin, Tamil Nadu, India." Environ Geology, vol. 47, no.8, pp.1099-1110, 2005.

[23] APHA, AWWA, WEF. ‘‘Standard Methods for the Examination of Water and Wastewater,’’ 19th Edition, American Public Health Association, American Water Works Association and Water Environment Federation, Washington, DC, 1995.

[24] F. M. Eaton “Significance of carbonate in irrigation waters.” Soil Science, 69, pp. 123–133. 1950.

[25] A. Nagaraju, S. Suresh, K. Killham and K. Hudson-Edwards. “Hydrogeochemistry of waters of manga mpeta barite mining area Cuddapah Basin, Andhra Pradesh, India.” Turkish Journal of Engineering and Environmental Sciences. vol. 30, no. 4 pp. 203-19. Nov 14, 2006.

[26] M. Darwish, H. Abdulrahim, A. N Mabrouk, A. Hassan, B. Shomar . “Reclaimed wastewater for agriculture irrigation in Qatar.” Glob. J. Agric. Res. Rev. Vol. 3, no. 1, pp. 106-120, January, 2015.

[27] D .B. Panasker and R.S. Pawar “ Effect of textile mill effluent on growth of Vigna unguiculata and Pisum sativum seedlings,” Indian Journal of Science and Technology, vol. 4, pp. 266 –272, 2011.

[28] S. Rodosevich , J. Holt and C. Ghersa, “Weed Ecology, Implications for Management,” Wiley Publishers, New York, USA. 1997.

[29] G. K. Nagda, A.M. Diwan and V.S. Ghole. “Seed germination bioassays to assess toxicity of molasses fermentation based bulk drug industry effluent,” Electronic Journal of Environmental, Agricultural and Food Chemistry, vol. 5, pp.1598–1603, 2006.

[30] L. A. Richards. “Diagnosis and improvement of saline alkaline soils,” US Department of Agriculture, Handbook 60 (160), 1954.

[31] L. D. Doneen. “Water quality for agriculture,” Department of Irrigation, University of Calfornia, Davis, 48. 1964.

[32] K. Ramesh and L. Elango. "Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India." Environmental monitoring and assessment, vol. 184, no. 6, pp. 3887-3899, 2012.

[33] D. Rahmato. “Water resource development in Ethiopia,” Issues of sustainability and participation. Forum for social studies Addis Ababa, Ethiopia. 1999.