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Assessment of irrigation quality of disposal water of Ashuganj-Polash Agro-Irrigation Project, Brahmanbaria, Bangladesh

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ABSTRACT

The study was conducted at Ashuganj-Polash agro-irrigation project (APAIP), Brahmanbaria, aim to determine the chemical properties of power plant disposal water and to assess its suitability for irrigation. Initial soil samples (before irrigating crop field) and final soil samples (after crop harvesting) were collected. During irrigation ten water samples (six from crop field and four from irrigation canals) were collected for analysis. All soil samples were analyzed in Humboldt soil testing laboratory and water samples in bio-chemistry laboratory of Bangladesh Agricultural University and compared to FAO irrigation standard. Results show that the sodium absorption ratio (SAR) (0.53 to 0.88), residual sodium bi-carbonate (0.8 to 1.3meq L^{-1}), Kelly's ratio (0.31 to 0.6) and total hardness (85 to 150) found in normal range and largely suitable for irrigation. Soluble sodium percentage values found in satisfactory (20.26 to 41.1) level and magnesium absorption (57.1 to 76.4) found unsuitable for irrigation. Statistically similar value of pH, EC, total nitrogen, organic carbon, calcium, magnesium and phosphorus in initial and final soil sample were observed. But potassium and sulfur value reduced in final soil sample from initial soil. The water samples fall within the permissible limit and found suitable for crop production.

Keywords: Power plant disposal water, water quality, irrigation, chemical properties

INTRODUCTION

Irrigation water quality refers to its suitability for use in crop production. A good water quality has the potential to allow maximum yield under good soil and water management practices. However, with poor quality water, problems of saline soil and contamination of soil with potentially toxic substances such as trace elements, biocides, etc. impaired cropping and reduced yields can be expected to develop unless special management practices are adopted to maintain or restore maximum production capability under a given set of conditions. The evaluation of water quality is related to soil problems, which are interrelated to salinity, toxicity, water infiltration rate and other miscellaneous problems. Irrigation water quality is determined by its potential to cause problems, which will reduce yields unless special management practices are adopted to maintain or restore maximum production capability under given conditions (Finkel, 1982).

Quality of irrigation water is defined by analyzing physical, chemical and biological characteristics of water. Conceptually, water quality determines the suitability of water for specific use, to be precise, how well the water meets the desires of users (Ayers and Wescot, 1985). Suitability of water for use is judged on the potential severity of problems that can be expected to develop during long-term use.

Water quality standard may be defined as a qualitative statement of a desired quality of water for definite purpose. Standards and norms have no universal validity. Standards are developed to prevent or control environmental problems or adverse effect on the product or health. But, many environmental problems may only become apparent long after an activity or environmental stress had occurred. Standard may differ in space and/or time; one approach is to relate them to the bearing capacity of the receiving environment on which an environmental stress is exerted. Standard for different parameters are not necessarily of equal weight. In establishing standards, the benefits of a good environmental quality have to be weighed against the socio-economic cost of imposing such standards.

Irrigation is a vital input for optimum crop production, but extremely dangerous if it contains toxic substance(s). Farmers sometimes test soil but they never test water for its quality. It is unknown to most of the farmers that utilization of low quality water for irrigation undoubtedly deteriorates soil productivity, which adversely affects crop production. Besides irrigation, quality of water should be assessed for drinking, domestic use and agro-based industries (Jinwal and Dixit, 2008).

Irrigation from surface water is not feasible for most of the areas of Bangladesh because of limited quantity of water, which can be safely drawn from the rivers or from perennial streams. Therefore, groundwater is believed to be the only

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constant source of water supply remained for the successful cultivation of winter crops. So, if the groundwater is contaminated by arsenic or any ionic composition, crop production may be reduced. Bangladesh has made tremendous progress towards achieving its goal of food grain self-sufficiency. Substantial increase in irrigated area and use of modern rice varieties have led to rapid production growth in Bangladesh in the last decade. Irrigated area is increasing day by day due to extensive use of groundwater. In Bangladesh, the total irrigated area is about 3.83 M ha and 71% of them are irrigated by groundwater (Quasem, 2011 and World Bank, 2011). Irrigated agriculture is dependent on an adequate water supply of useable quality.

Water quality has often been neglected because good quality supplies have been plentiful and readily available in Bangladesh. Now this situation is changing. Irrigated agriculture in Bangladesh has already started showing problems regarding water quality (Barkat *et al.*, 2007). All groundwater contains salts in solution that are derived from the location and past movement of the water. Water while moving through underground geologic formation may have various minerals dissolved in it. The type and concentration of salts depends on the environment, movement and source of the groundwater (Moses *et al.*, 2016). The poor quality of irrigation water affects crop growth directly and also damages physical properties of irrigated soil by accumulating harmful and toxic elements in the soil (Priya and Pragya 2014), which ultimately destroys productivity of agricultural land Moreover, availability of groundwater for irrigation has contributed to increase in crop productivity in Bangladesh (Islam *et al.*, 2013)but power plant discharge water have not contribution to irrigation due to unknown quality attributes.

Ashuganj power station, the second largest power station in Bangladesh located at latitude of 24.05º N and longitude of 91.02º E to generate electricity. It is situated on the bank of the river Meghna and is about 100 km North-East of Dhaka. The power station consists of two different blocks of generating units. One block consists of five stream power plants, while the other one consists of two gas turbine and stream units. The water of the Meghna River is used for cooling of the power plants and subsequently disposed of. The disposed water of the power plant is the main source of irrigation for the Ashuganj-Polash agro-irrigation project, which was established under Bangladesh Agricultural Development Corporation (BADC) in 1990. The power plant disposal water covers 16,194hectares of land for irrigation in dry season (BADC, 2013). Since long time has elapsed, no studies relating to water quality of the disposed of water of the plant for irrigation purpose was done. With the above discussions the study was undertaken with the following objectives

i. to determine the chemical properties of power plant disposal water,
ii. to assess the suitability of disposed water for irrigation,
iii. to determine the physico-chemical properties of disposed water-irrigated soil.

MATERIALS AND METHODS

Study location

The study location was Ashuganj-Polashagro-irrigation project, Brahmanbaria under administrative control of Bangladesh Agriculture Development Corporation (BADC). It is situated at 24.02ºN to 90.00º E with 10 m altitude above mean sea level. Disposal water of Ashuganj power plant is used for irrigation in the project over eleven thousand hectares of land. This study was conducted during December 2013 to May 2014 at the project areas. *Boro* is the major irrigated crop of the project areas and power plant disposal water is the main source of irrigation. Supplemental irrigation is also applied using this water in other *Robi* crops likes wheat, tomato, mustard, broadcast *Aman* etc. During the study period irrigation was applied to *Boro* rice.

Collection and analysis of samples

Initial soil samples were collected before irrigated the field on 31 December, 2013 from six different plots randomly of the study area at 15 cm depth. During irrigation to rice field with disposed water, six water samples from the same field and four samples from irrigation canals were collected for analysis. After harvesting of the crop eight soil samples were collected again. All soil samples were analyzed in Bangladesh Agricultural University Humboldt soil testing laboratory and water samples in bio-chemistry laboratory of Bangladesh Agricultural University. Soil samples were analyzed for pH, EC, Na, K, Ca, S, P, total N (%) and OC (%) to determine their quality. The disposal water samples were analyzed for pH, EC, Na, K, Ca, Fe, Mg, Zn, Cu, and bi-carbonate to determine its quality.

Water quality parameters

Sodium Adsorption Ratio: SAR was calculated by the equation of Richards (1954) as given by

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

Where,

SAR = Sodium Adsorption Ratio,
Na^+ = sodium ion concentration, $meqL^{-1}$,
Ca^{++} = calcium ion concentration, $meqL^{-1}$,
Mg^{++} = magnesium ion concentration, $meqL^{-1}$

Soluble Sodium Percentage: Soluble sodium percentage was calculated by the following equation (Todd, 1980):

$$SSP = \frac{Na^+ + K^+}{Ca^{++} + Mg^{++} + Na^+ + K^+} \times 100$$

Where,

SSP = Soluble Sodium Percentage,
Na^+ = sodium ion concentration, $meqL^{-1}$,
K^+ = potassium ion concentration, $meqL^{-1}$,
Ca^{++} = calcium ion concentration, $meqL^{-1}$,
Mg^{++} = magnesium ion concentration, $meqL^{-1}$

Residual Sodium Bi-carbonate: It was calculated according to Gupta and Gupta (1987) by using the following equation:

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{++} + Mg^{++} + Na^+} \times 100$$

Where,

PI = Permeability Index,
Na^+ = sodium ion concentration, $meqL^{-1}$
Ca^{++} = calcium ion concentration, $meqL^{-1}$,
Mg^{++} = magnesium ion concentration, $meqL^{-1}$,
HCO_3^- = bi-carbonate ion concentration, $meqL^{-1}$,

In general, water is good if it belongs to class I (PI>75, safe) or II (PI=27-75, marginally safe) in Doneen's chart (Fig. 1).

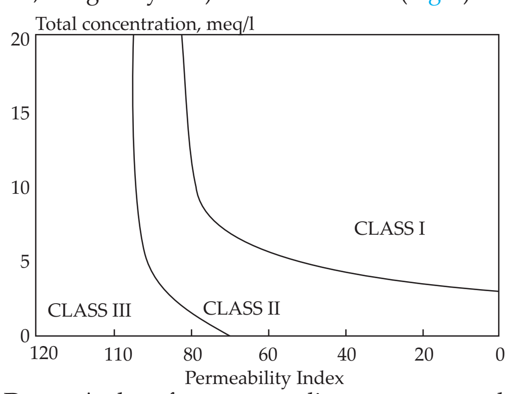

Fig. 1: Doneen's chart for water quality measurement base on permeability index.

Total Hardness: Total Hardness was calculated by the following equation (Raghunath, 1987):

$$TH = (Ca^{++} + Mg^{++}) \times 50$$

Where,

TH = Total Hardness,
Ca^{++} = calcium ion concentration, $meqL^{-1}$,
Mg^{++} = magnesium ion concentration, $meqL^{-1}$

Magnesium Adsorption Ratio: MAR was calculated by (Szobocles and Darab, 1968):

$$MAR = \frac{Mg^{++}}{Ca^{++} + Mg^{++}} \times 100$$

Where,

MAR = Magnesium Adsorption Ratio,
Ca^{++} = calcium ion concentration, $meqL^{-1}$
Mg^{++} = magnesium ion concentration, $meqL^{-1}$

Kelly's Ratio: The kelly's ratio was calculated by the equation (Kelly, 1963) expressed as,

$$KR = \frac{Na^{+}}{Ca^{++} + Mg^{++}}$$

Where,

KR = Kelly's Ratio,
Na^+ = sodium ion concentration, $meqL^{-1}$
Ca^{++} = calcium ion concentration, $meqL^{-1}$,
Mg^{++} = magnesium ion concentration, $meqL^{-1}$

Suitability of irrigation water

The suitability of water for irrigation was classified based on the following parameters and grading:

pH: The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.4 (Ayars and Wescot, 1985). Water is classified as acidic (<5.5), slightly acidic (5.6-6.4), practically neutral (6.5-7.5), slightly alkaline (7.6-8.0), alkaline based (>8.1) on pH values (Michael, 1978).

Electrical Conductivity: The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). Based on EC, the water was classified for suitability of irrigation following Gupta (1979) and is classified as excellent (<250 $\mu S\ cm^{-1}$), good (250-750 $\mu S\ cm^{-1}$), permissible (750-2000 $\mu S\ cm^{-1}$), doubtful (2000-3000 $\mu S\ cm^{-1}$) and unsuitable (>3000 $\mu S\ cm^{-1}$).

Sodium Adsorption Ratio: The sodium absorption ratio gives a clear idea about the adsorption of sodium by soil. It is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop. Based on values of sodium adsorption ratio, the water was classified as normal (<10), low sodic hazard (10-20), medium sodic hazard (20-30), high sodic hazard (30-40), very high sodic hazard (>50) for suitability for irrigation following Gupta (1979).

Soluble Sodium Percentage: SSP is important factor to study sodium hazard and used to adjudging the quality of water for agriculture purpose. High percentage of soluble sodium for irrigation may stunt the plant and reduces soil permeability. Wilcox (1955) classified suitability of irrigation water based on SSP values following excellent (<20), good (20-40), permissible (40-60), doubtful (60-80) and unsuitable (>80).

Residual Sodium Bi-carbonate: The concentration of bicarbonate and carbonate influences the stability of water for irrigation. High RSBC causes high pH. Fertility of land may be degraded with irrigation water containing high RSBC. Based on Residual Sodium Bi-carbonate (RSBC), the water was classified for suitability of irrigation (Gupta and Gupta, 1987) as satisfactory (<5), marginal (5-10) and unsatisfactory (>10.

Total Hardness: Water has classified for hardness according to the ranges recommended by the United States Geological Survey (USGS) and it is soft (0-50), slightly hard (51-100), moderately hard (100-200) and very hard (201-500) (Raghunath, 1987).

RESULTS AND DISCUSSIONS

Assessment of chemical composition of Power Plant Disposal Water

The chemical compositions of collected power plant disposal water samples were analyzed and shown in Table 1. Result shows that the total sodium, potassium, calcium and magnesium concentration varied from 0.443 to 0.716, 0.060 to 0.156, 0.30 to 0.80, and 0.70 to 1.20 $meqL^{-1}$, respectively (Table 1). The concentrations of most of the captions were within the FAO recommended limits for irrigation use (Ayars and Wescot, 1985). The FAO recommended range of sodium, potassium, calcium and magnesium are 0-40, 2.00, 0-20 and 0-5 $meqL^{-1}$, respectively in irrigation use. Bi-carbonate concentration varied from 1.30 to 1.80 $meqL^{-1}$ (Table 1). The anion concentration was very small in respect of the recommended maximum limit for irrigation water. The recommended maximum value of bi-carbonate in irrigation water is **10**meqL^{-1}(Ayers and Wescot, 1985).

The pH of the power plant disposal water samples in the study area was found to vary from 5.78 to 6.54 (Table 1), indicates slightly acidic to practically neutral water. Recommended range of pH for irrigation water varies from 6.5 to 8.5 (Ayers and Wescot, 1985). The pH values were well within the normal range of irrigation quality. Although the pH is not directly related to soil, plant and animal health, but had been applied widely and successfully over many years to ensure the wholesomeness of water. On the basis of pH value, all water samples were suitable for irrigation. The electrical conductivity of the water samples varied from 133.60 to 171.70 µScm^{-1} (Table 1). All the samples showed that EC is in excellent class according to electrical conductivity hazard classification made by Gupta (1979).

Table 1: Major chemical properties of power plant disposal water

Treatment	Max	Min	Mean	SD	Recommended limit (FAO standard)
pH	6.54	5.78	6.28	0.27	6-8.5
EC (µS cm^{-1})	171.7	133.6	144.92	111	<3000
K (meq L^{-1})	0.16	0.05	0.09	0.04	0-2
Na (meq L^{-1})	0.72	0.44	0.53	0.11	0-40
Ca (meq L^{-1})	0.80	0.3	0.54	0.15	0-20
Mg (meq L^{-1})	1.20	0.7	0.96	0.14	0-5
HCO_3(meq L^{-1})	1.80	1.3	1.54	0.16	1-10
CO_3(meq L^{-1})	0	0	0.00	0.00	0-0.1
Total-N (ppm)	4.3	1.4	2.95	1.05	0-10
P (ppm)	0.71	0.04	0.13	0.20	-
S (ppm)	5.33	2.41	3.49	0.96	-

Assessment of water quality for irrigation

Sodium absorption ratio: The mean value of SAR present in power plant disposal waterwas 0.62 with standard deviation of 0.13, which indicates low alkali hazards and normal quality of water.

Soluble sodium percentage: Soluble sodium percentage of disposal water valuesranges between 20.26 to 41.49 (Table 2)

Table 2: Water quality parameters of power plant disposal water

Indicator	Max	Min	Mean	SD	Recomme-nded limit	Remarks
SAR	0.88	0.53	0.62	0.13	<10	Normal
SSP	41.49	20.26	28.53	5.68	20-40	Permissible
RSBC (meqL^{-1})	1.3	0.8	1.00	0.16	<5	Satisfactory
KR	0.6	0.31	0.36	0.09	<1	Suitable
TH	150	85	131.5	24.50	<500	Normal
MAR	76.9	57.1	64.29	6.57	50	Unsuitable
PI	111.6	75.8	88.07	9.56	-	Class III

indicating low alkali hazards and in a permissible limit to irrigation.

Residual sodium bi-carbonate : All analyzed sample had RSBC within the recommended limit. The highest RSBC was observed 1.3 meq L^{-1} where the lowest was found 0.8 meq L^{-1}. Power plant disposal water showed satisfactory for irrigation.

Total hardness : Total hardness of water samples were varied from 85 to 150 meqL^{-1}, which were classified as normal in range. Hardness resulted due to abundant presence of divalent cations such as Ca and Mg in disposal waters (Todd, 1980). The higher value of hardness indicates the presence of higher amounts of Ca and Mg and vice-versa for the lower value of hardness (Karanath, 1994).

Permeability Index: According to Doneen Chart, the permeability index of all the water samples was found to be good. PI values ranging from 78.5 to 111.6belong to class I, which is safe.It may be expected that the water will not create any permeability problem.

Magnesium Adsorption Ratio

The magnesium adsorption ratio, MAR, of the water samples varied from 58.80 to 76.90. Gupta and Gupta (1987) mentioned that high MAR affects soil unfavorably; harmful effects on soils appear when MAR exceeds 50. The results reported herein had a harmful effect on soils as MAR of all of the water samples exceeded 50.

Kelly's Ratio

The Kelly's ratio, KR, for the water samples varied from 0.31 to 0.60 (Table 2). Kelly (1963) suggested that this ratio should not exceed unity for irrigation water. In the present study all the samples had KR less than 1.0. So Kelly's ratio showed full satisfaction in using for irrigation.

Effect of irrigation with power plant disposal water in soil chemical properties

Chemical composition of initial soil and soil after boro rice cultivation with power plant disposal water were analyzed and shown in Table 3. Result shows that almost same pH value was found after irrigation with power plant disposal water. Electric conductivity reduced in final soil (235 µS cm^{-1}) from initial condition (295 µS cm^{-1}). This is result of applying irrigation to the crop with less saline water. Statistically similar value of Na concentration in soil was found in initial (97 meq L^{-1}) and final soil (78 meq L^{-1}). Potassium (K) content decreased in final soil (60 ppm) from initial soil (39.6 ppm). Almost similar total nitrogen content and organic carbon (C) content was observed in initial and final soil samples. Phosphorous (P) content was slightly increased where sulfur (S) content significantly decreased from 64 ppm in initial soil to 21 ppm in final soil. No significant change occurred in Calcium (Ca) and magnesium (Mg) content of initial and final soil (Table 3). The chemical property of a soil is location specific and comparison with Adham *et al.* (2006) findings showed similar values of chemical properties as found in current study. Besides, the values of chemical composition of soil are within the range of data observed by SRDI (1990) and Sadat (2000) reported for different soil types in Bangladesh.

Table 3: Chemical properties of initial soil and after *Boro* rice cultivation with power plant disposal water during Boro, 2013-14 at Ashugonj agro-irrigation project.

Sample type	pH	EC (µS cm $^{-1}$)	Na (meq L $^{-1}$)	K (ppm)	Total N (%)	OC (%)	P (ppm)	S (ppm)	Ca (ppm)	Mg (ppm)
Initial soil	5.87	295	97	60	0.13	1.32	3.6	64	1.1	1.4
Final soil	5.99	235	78	39.6	0.12	1.25	4	21	1	1.3
$LSD_{0.05}$	0.4	93	29.8	15.4	0.48	0.65	0.48	23	0.16	0.2

CONCLUSION

The quality of Ashugonj power plant disposal waste water was assessed for its irrigational purposes. Result shows the mean value of SAR in power plant disposal water was 0.62 with standard deviation of 0.13. Residual sodium bi-carbonate (0.8 to 1.3 meq L $^{-1}$), Kelly's ratio (0.31 to 0.6) and total hardness (85 to 150) obtained for all the samples were in normal limit. Soluble sodium percentage values found in satisfactory (20.26 to 41.1) level. Magnesium absorption ratio (57.1 to 76.4) found unsuitable (desired range <50) for irrigation. Statistically similar value of pH, EC, total nitrogen, organic carbon, calcium, magnesium and phosphorus in initial and final soil sample were found. But potassium and sulfur value reduced in final soil sample from initial soil. Thus all the analysis indicates that power plant disposal water neither causes toxicity nor have an adverse effect on soil properties.

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