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Research Article

SUITABILITY OF IRRIGATION WATER QUALITY OF CANALS IN NCR DELHI

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ABSTRACT

Within the acceptable range of pH in water quality, deficiency and excess of various levels of critical pollutants such as, Total Dissolved Salts (TDS), Electrical Conductivity, Sodium Adsorption Ratio (SAR) and Boron determined the suitability of water for irrigation, in four major canals of Delhi. Canal waters were deficient in minimum SAR levels of 0.046 to 2.33. Average Boron levels of 0.639 to 0.807 mg/l were good enough for irrigation to sensitive group of crops, 0.639 mg/l to 0.807 mg/l levels were excellent for irrigation to semi tolerant group of crops and 1.22 to 1.966 mg/l of Boron levels were good for irrigation to tolerant group of crops. Excellent to good irrigation water was indicated by clean to slight pollution in biological water quality of Gang Canal and Western Yamuna Canal and medium to high salinity hazards supported moderate to heavy pollution in biological water quality of Agra Canal and Hindon Canal.

Key Words: Irrigation water, SAR, Boron, Sensitive, Tolerant.

INTRODUCTION

Irrigation is one of the important uses of surface waters used for agricultural purposes in India. In order to maintain the water quality for irrigation, pollution levels in surface waters have been detected by monitoring physico-chemical parameters for critical pollutants such as; pH, Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Boron in Class 'E' of Primary Water Quality Criteria(CPCB,1978-79). Similarly, for assessment of the wholesomeness of water quality, Biological Water Quality Criteria (BWQC) has been developed using saprobic and diversity score of benthic macro-invertebrates(CPCB,1999). The Water (Prevention and Control of Pollution) Act, 1974 is aimed to support the water quality of designated best-uses of water bodies (CPCB, 1978-79). For all practical purposes, pure water is considered as one which has low dissolved solids required only for drinking purposes while for other uses like agriculture and industry, the quality of water can be quite flexible and water polluted up to certain extent in general sense can be regarded as pure (Joshi, Kumar and Agrawal,2009). Suitability of surface waters for irrigation to various sensitive and tolerant group of crops has not been studied so far in India. However, soil scientists use various categories to describe irrigation water effects on crop production and soil quality such as; salinity hazard –total soluble salt content, sodium hazard – relative proportion of sodium (Na^+) to calcium (Ca^-) and magnesium (Mg^{2-}) ions, pH, alkalinity in terms of carbonate and bicarbonate, specific ions such as; chloride (Cl), sulphate (SO_4^2), boron(B), and nitrate nitrogen (NO_3-N). Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants (Bauder, Waskom and Devis,2010). In order to make an organized use of the river waters, extensive canal network is used to transport to remote places for irrigation. A significant quantity of river water is drawn into canals to meet the requirement of growing urbanization and industrialization in India. As a result, the water quality of canals has become a subject of concern in recent past. The present study deals with the assessment of suitability of critical pollutants of canal waters with respect to water quality criteria/standards of irrigation water, and their relative affinity to biological water quality of four major irrigation canals namely, Western Yamuna Canal, Gang Canal, Hindon Canal and Agra Canal in NCR of Delhi.

MATERIALS AND METHODS

Water quality of Western Yamuna Canal, Gang Canal, Hindon Canal and Agra Canal was assessed for suitability to irrigation in terms of critical pollutants such as pH, Electrical Conductivity, Sodium Adsorption Ratio (SAR) and Boron identified for Class E of primary water quality criteria. Total Dissolved Solids (TDS) and Chlorides were also analyzed to assess the sodium and salinity hazards of irrigation water. The study area selected for the present study is shown in Table 1. Annual average of physico-chemical and biological water quality data for year 2001-2005 was utilized for Western Yamuna Canal and Agra Canal. Water quality data of Hindon Canal was utilized for year 2006-2008. Ionic balance was calculated by converting the mg/l value to milliequivalent/l. Samples were also analyzed for sodium, potassium, calcium, and magnesium and chlorides. Benthic macro-invertebrates were collected for bio-monitoring of water quality of Western Yamuna Canal and Gang Canal through artificial substratum located at raw water intake (CPCB,1998-99). High sedimentation areas of Hindon Canal and Agra canal were sampled by direct netting and sieving the sediments for collection of benthic macro-invertebrates. Primary Water Quality Criteria(Table 2) and Biological Water Quality Criteria (Table 3) was used for water quality assessment for irrigation water. Average taxonomic composition of benthic macro-invertebrates was calculated from bio monitoring data of raw water sources in Delhi (Table 4). Classes of TDS, Electrical conductivity and, SAR, Boron and Chlorides were used in the study (Rowe and Abdel- Magid,1995, Sakthivel, 2007).

RESULTS AND DISCUSSION

pH

The normal pH range for irrigation water is 6.5 to 8.4. Average pH in water quality of canals remained between 7.42- 7.7. and maximum did not exceed the pH of 8 (Figure 2). pH in water quality of Western Yamuna Canal, Gang Canal and Agra Canal was more than 6.5 and less than 8.5. whereas, Hindon canal water often showed pH as low as 5.62 during August,2007. Abnormally low pHs may cause corrosion in irrigation

Electrical Conductivity (EC)

The most influential water quality guidelines developed on crop productivity is the water salinity hazard as measured by electrical conductivity . The primary effect of high electrical conductivity on crop productivity is the inability of plant to compete with ions in the soil solution for water (physico-chemical drought). Higher the electrical conductivity, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire " pure" water, usable plant water in the soil solution decreases dramatically as EC increases. Maximum limits of 2,500 µmhos/cm has been adopted for Class 'E' water in the Primary Water Quality Criteria. However, electrical conductivity levels have been suggested as per guidelines for evaluation of irrigation water quality as ; <250µmhos/cm for excellent and 250 to 750µmhos/cm for good water quality(Rowe and Abdel- Magid,1995). The average electrical conductivity level of 197.6 to 611.5 µmhos/cm in canals was within the permissible range of 2000 µmhos/cm for irrigation (Figure 3). Electrical Condictivity of 138 to 520µmhos/cm in water quality of Western Yamuna Canal and 116 to 429 µmhos/cm in Gang Canal, was found to be excellent to good for irrigation whereas, medium water quality limit of 750 to 2,250 µmhos/cm for irrigation water was indicated in Hindon Canal and Agra Canal water between 117 to1090 µmhos/cm and 296 to 734µmhos/cm respectively.

Total Dissolved Solids (TDS)

Water salinity is usually measured by TDS (Total Dissolved Solids). In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both soil structure and crop yield. According to the concept of designated best uses, TDS level of 2,100 mg/l are required for 'E' Class water as per the water quality standards used for irrigation waters in India (Rowe and Abdel-Magid,1995). TDS levels in Gang Canal ranged from 63 -230 mg/l and in Western Yamuna Canal between 90-197 mg/l. These levels were suitable for excellent (175mg/l) and good water quality(175-

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525mg/l) and within the permissible limits of irrigation water (Sakthivel, 2007). Such waters are also considered to have low to moderate salinity hazards. The TDS levels in water quality of Agra Canal (188 -724 mg/l) and Hindon Canal (162-800 mg/l), were within permissible limits of 525-1400 mg/l for irrigation water and were also prone to medium and high salinity hazards. Average and maximum levels of TDS in Gang Canal and Western Yamuna Canal, contributed excellent water quality (175 mg/l) for irrigation whereas, minimum TDS levels of 63 to 188 mg/l in all the canal waters indicated excellent to good water quality for irrigation (Figure 4).

SAR

SAR is an important parameter for the determination of suitability of irrigation water because it is responsible for the sodium hazard. Sodium Adsorption Ratio (SAR) gives the concentration of sodium, relative to the concentrations of calcium and magnesium and is a guide to judge the sodium hazards of irrigation water. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio . Sodium replacing adsorbed calcium and magnesium is an hazard as it causes damage to the soil structure and soil becomes compact and impervious. The waters were classified in relation to irrigation based in the ranges of SAR values. Maximum limits of SAR of 26 has been recommended for water bodies used for irrigation purposes in Class 'E' of Primary Water Quality Criteria. However, continuous use of irrigation water having low SAR levels of 1 to10 may cause sodium hazard on sodium sensitive crops (Sakthivel, 2007). SAR levels in all the canal waters were low ranging from 0.046 to 2.33 (Figure 5). Use of such waters on sodium sensitive crops such as avocados has been suggested to be cautioned. Water having medium SAR levels of 10 to 18 require amendmends (such as Gypsum) and leaching to avoid sodium hazard. Water generally are unsuitable for continuous use with high SAR values ranging from 18 to 26 whereas, irrigation water having >26 SAR indicate very high sodium hazard. These levels have been defined as, excellent, good, medium, bad and very bad as per Indian guideline for evaluation of irrigation water quality (IS2296, 1992). In some studies, water with SAR ranging from 0 to 3 is considered good and with greater than 9 is considered unsuitable for irrigation purpose. SAR was found to be 0.397 to 1.49 for Ganga river categorized as water of excellent category. It can be used for irrigation on almost all soil types with little danger of the development of harmful levels of exchangeable sodium (IS2296, 1992). Excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability(Mass,1987). SAR levels of 0.39 to 60.9 have been reported in River Mahanadi basin in year 2003, 0.51 to 55 in River Brahmani in year 2002 and maximum of 0.56 to 122.7 in River Baitarani in year 2001 in Orissa state (OSPCB,2007). Hence the assessment of sodium concentration is necessary while considering the suitability for irrigation

Boron

Another element that is essential in low amounts but toxic at higher concentration, is boron level in irrigation waters. In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 ppm. Boron in excess of 2 mg/l in irrigation water, becomes toxic for most of the field crops, affecting the metabolic activities of the plant as per Primary Water Quality Criteria (CPCB,1978-79). Various boron levels have been prescribed for sensitive, semi tolerant and tolerant group of crops for rivers of Colorado (Bauder, Waskom and Devis,2010). Accordingly in canal water, average levels of boron ranging from 0.639 to 0.807 mg/l were considered good for sensitive group of crops whereas maximum levels of 1.22 to1.966 mg/l of boron were doubtful and unsuitable for irrigation to sensitive crops (Figure 6a). Average boron levels of 0.639 mg/l to 0.807 mg/l were suitable for excellent water quality to semi tolerant group of crops whereas maximum levels of 1.22 to 1.271 mg/l in Agra Canal and Hindon Canal were considered good for irrigation to semi tolerant group of crops(Figure 6b 7 6c). Maximum levels of boron in canals ranging from 1.22 to 1.966 mg/l were good for irrigation to tolerant crops. In Mahanadi river basin, boron level reached to 2.11 mg/l, and in river Baitarani,2.278mg/l. Peach and Onion have been considered to be sensitive to the boron levels of 0.5-0.75mg/l, whereas, wheat, barley, sunflower and dry been were sensitive to Boron levels of 1.0 mg/l. Carrot, potato and cucumber were considered to be moderately

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sensitive to 1.1 to 2.0 mg/l of boron and lettuce, cabbage, corn and oats were found to be moderately tolerant to 2.1 to 4.0mg/l levels. alfalfa, sugar beet and tomato are tolerant to 4.1 to 6.0 mg/l of boron (Mass, 1987).

Thus in Western Yamuna Canal, levels of boron were permissible(0.67 to 1.00mg/l) for irrigation to crops like Wheat, barley, sunflower and dry Been. However, boron exceeded the permissible levels due to seasonal variation during May, July,2003 and also the doubtful levels of 1.0 to 1.25mg/l during July,2003. In case of Gang Canal, boron levels were almost unsuitable(>1.25 mg/l) for sensitive crops but were considered to be moderately sensitive (1.1 to 2.0 mg/l of boron) to carrot, potato and cucumber. Abrupt variations were observed for boron levels in water quality of Hindon Canal, unsuitable during January 2002, within permissible limit during December 2001, excellent to good for irrigation during November 2001. Similarly, boron levels were unsuitable in Agra Canal during March 2003, November 2004 and January 2005 for sensitive group of crops. Boron levels were mostly excellent (<0.67 mg/l) in Gang Canal water whereas, these levels were good and within permissible(1.33 to 2.00 mg/l) levels in Western Yamuna Canal, required for irrigation to semi tolerant group of crops. Boron levels in water quality of Hindon Canal and Agra Canal were excellent (<1,0 mg/l) to good (2.0 to 3.0 mg/l) and suitable for irrigation to moderately tolerant group of crops such as, lettuce, cabbage, corn and oats. Average boron levels of 0.639 to 0.807 mg/l in canal waters were well below the excellent levels required for irrigation to tolerant crops like alfalfa, sugar beet and tomato.

Chlorides

Average chlorides levels of 7.35 to 69.86 ppm in canal waters were found safe for irrigation to all plants. Sensitive and moderately tolerant plant will indicate injury to maximum chloride levels of 188 ppm in Agra Canal. More than 350 ppm of chloride levels can cause severe problems in irrigation water (Figure 7). Studies have suggested that chloride concentration of >5 mol/m^3 show relative susceptibility to foliar injury of almonds, apricot, citrus and plums, 5-10 mol/m^3 to grapes, pepper, potato and tomato, 10-20 mol/m^3 to crops of alfalfa, barley and corn and >20 mol/m^3 levels to cauliflower, cotton and sugar beet (Mass,1987).

Biological water quality

Irrigation water of Gang Canal and Western Yamuna canal indicated mostly clean to slight pollution supported by sensitive group of families of ephemeroptera, plecoptera and trichoptera. Irrigation water of Hindon Canal and Agra Canal were moderately polluted most of the time, supporting the dominance of tolerant families of mollusca and oligochaeta (Figure 1). Thus, level of critical pollutants such as pH, total dissolved solids, electrical conductivity, sodium adsorption ratio and boron were used not only for assessment of irrigation water for their suitability to sensitive, semi tolerant and tolerant group of crops but also indicated their affinity to aquatic life existing in canals in terms of sensitive and tolerant group of benthic macro-invertebrates (Table 4)

Table 1. Study area and water use status

Canals	**Sampling location**	**Source**	**Sampling duration**	**Total Number of Samples**	
				Biological	**Chemical**
WesternYamuna Canal	Bhagirthi Water Works,Delhi	River Yamuna at Tajewala Barrage	2001-2005	34	12
Gang Canal	Haiderpur Water Works, Delhi.	River Ganga at Har ki pouri Hardwar	2001-2005	32	16
Hindon Canal	Ghaziabad	River Hindon at Hindon barrage	2006-2007	24	19
Agra Canal	Badarpur	River Yamuna at Okhla barrage	2001-2005	29	18

Table 2. Primary Water Quality Criteria

S.No.	Water Quality Characteristics	Water Quality Class				
		A	B	C	D	E
1.	Dissolved Oxygen (DO),mg/l, Min.	6.0	5.0	4.0	4.0	-
2.	Biochemical Oxygen Demand (BOD) mg/l, Max.	2.0	3.0	3.0	-	-
3.	Total Coliform Organism MPN/100ml, Max.	50	500	5,000	-	-
4.	pH value	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.5-8.5
5.	Free Ammonia (as N) ,mg/l,Max.	-	-	-	1.2	-
6.	Electrical conductivity, micromhos/cm, Max.	-	-	-	-	2,250
7.	Sodium adsorption Ratio (SAR), Max.	-	-	-	-	26
8.	Boron, mg/l, Max.	-	-	-	-	2

Table 3. Biological Water Quality Criteria (BWQC)

Sl. No	Taxonomic Groups	Range of saprobic score (BMWP)	Range of Diversity Score	Water quality characteristic	Water quality class
1	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera	7 and more	0.2 - 1	Clean	A
2	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera	6 – 7	0.5 - 1	Slight Pollution	B
3	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Diptera Hirudinea, Oligochaeta	3 – 6	0.3 - 0.9	Moderate Pollution	C
4.	Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta	2 – 5	0.4 & Less	Heavy Pollution	D
5	Diptera, Oligochaeta No animals	0 – 2	0 - 0.2	Severe Pollution	E

Table 4. Families of Benthic macro-invertebrates found in irrigation canals

Western Yamuna Canal	**Gang Canal**	**Agra Canal**	**Hindon Canal**
Heptageniidae (E)	Ephemerllidae(E)	Caenidae (E)	Coenagrionidae(OD)
Siphonuridae (E)	Heptageniidae(E)	Baetidae (E)	Protoneuridae (OD)
Caenidae (E)	Siphonuridae(E)	Hydropsychidae(T)	Amphypterygidae (OD)
Baetidae (E)	Caenidae(E)	Protoneuridae (OD)	Libellulidae (OD)
Leptoceridae (T)	Baetidae(E)	Libellulidae (OD)	Gomphidae (OD)
Polycentropodidae(T)	Perlidae(P)	Gomphidae (OD)	Aeshnidae (OD)
Hydropsychidae(T)	Polycentropodidae(T)	Paleamonidae (C)	Asellidae (C)
Protoneuridae (OD)	Htdropsychidae (T)	Lymnaeidae (M)	Viviparidae (M)
Libellulidae (OD)	Limnophilidae(T)	Physidae (M)	Sphaeridae (M)
Gomphidae(OD)	Protoneuridae(OD)	Planorbidae (M)	Hirudenidae (H)
Paleamonidae (C)	Libellulidae(OD)	Pomatiopsidae (M)	Glossiphonidae (H)
Atydae (C)	Gomphidae (OD)	Viviparidae (M)	Salifidae (H)
Planorbidae (M)	Cordullidae (OD)	Sphaeridae(M)	Tubifiscidae (O)
Thiaridae (M)	Paleamonidae (C)	Unionidae(M)	
Sphaeridae (M)	Atydae (C)	Gossiphonidae (H)	
Glossiphonidae (M)	Physidae (M)	Erpobdellidae (H)	
Erpbdellidae (H)	Planorbidae (M)		
Oligochaetes (O)	Bithynidae (M)		
	Viviparidae (M)		
	Thiaridae (M)		
	Glossiphonidae (H)		
	Octochaetidae (O)		
	Tubifiscidae (O)		
	Lumbricidae (O)		

E- Ephemeroptera, P- Plecoptera, T- Trichoptera, OD- Odonata, C- Crustacea, M- Mollusca, H- Hirudinea, O- Oligochaeta

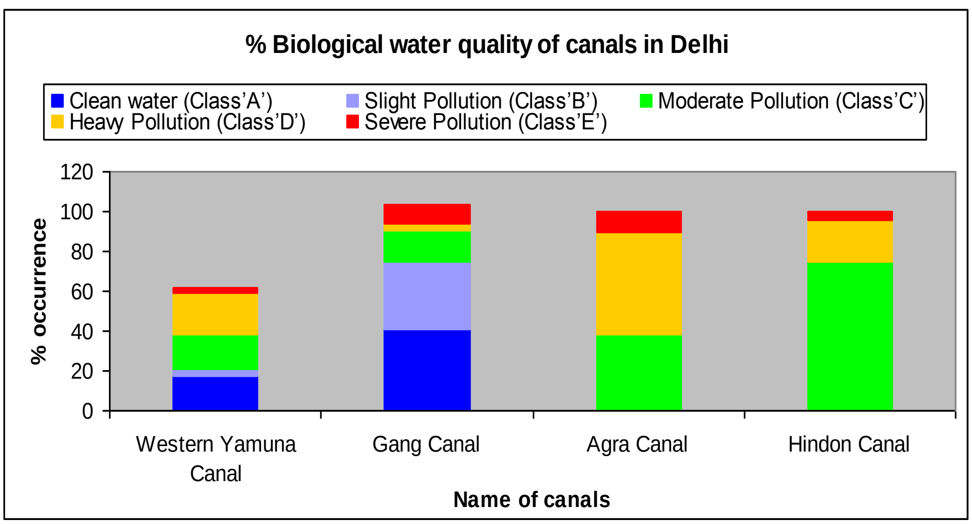

Figure 1. Biological water quality of irrigation canals

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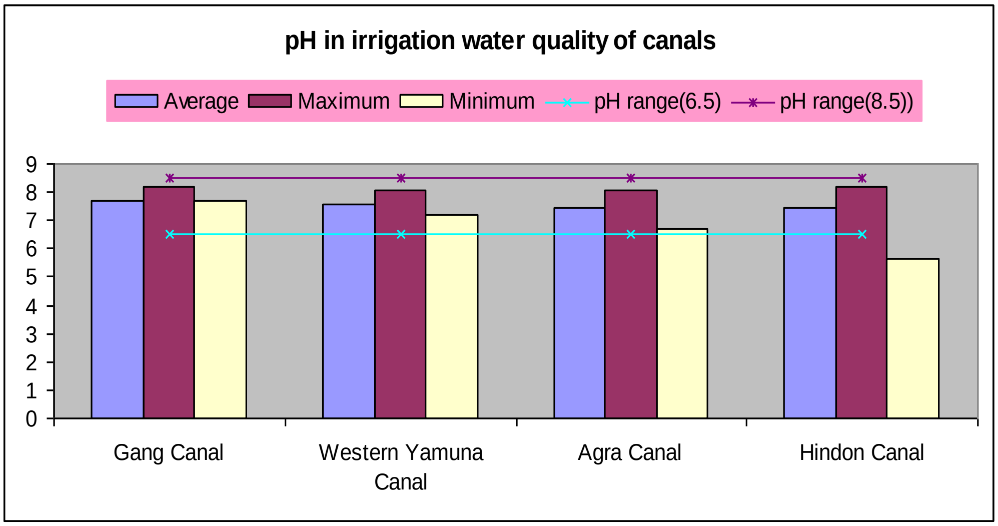

Figure 2. Average pH in water quality of irrigation canals

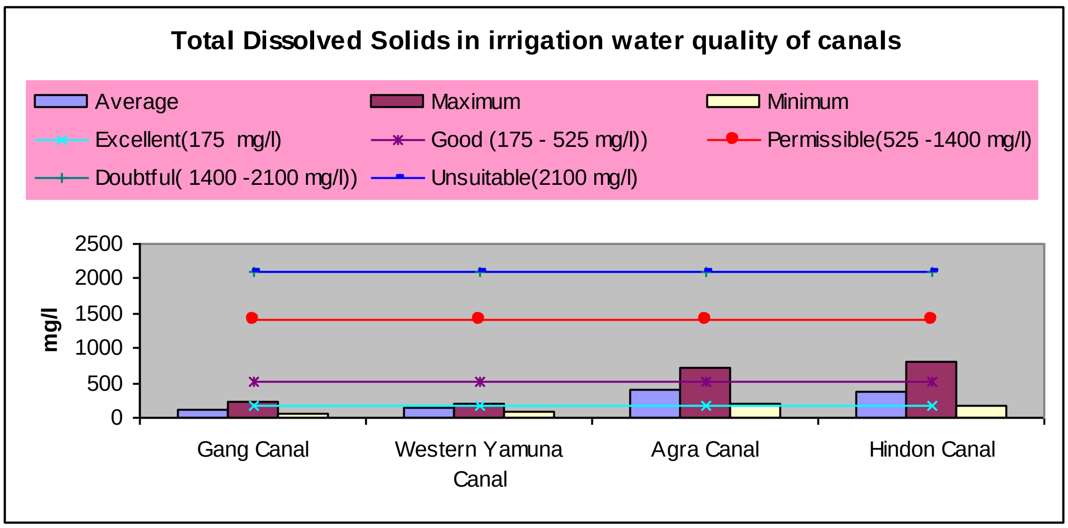

Figure 3. Average TDS in water quality of irrigation canals

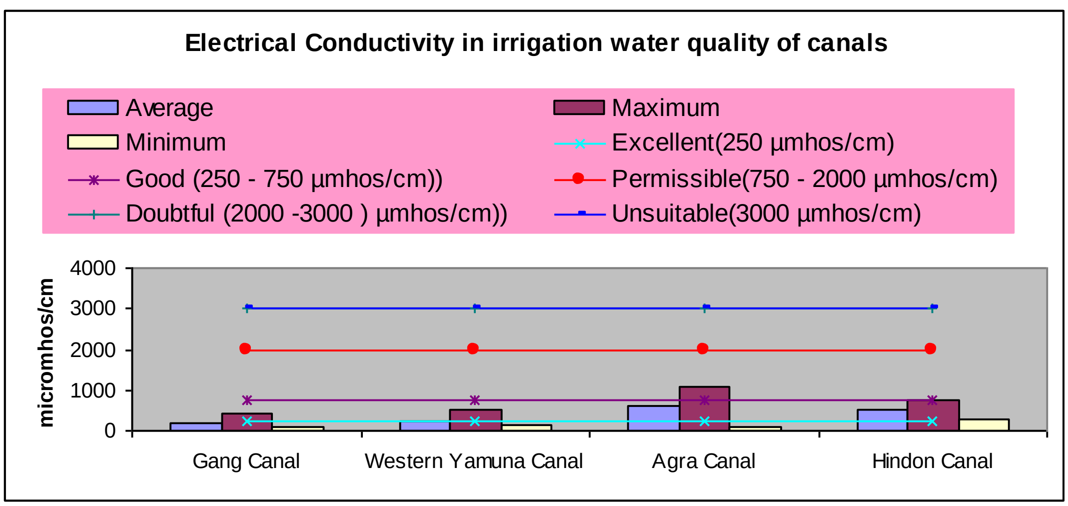

Figure 4. Electrical Conductivity in water quality of irrigation canals

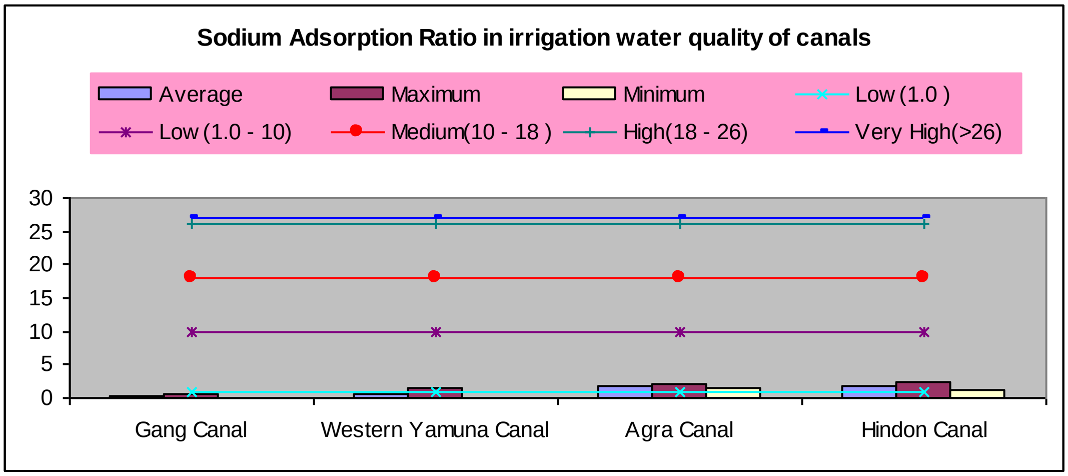

Figure 5. Average SAR in water quality of irrigation canals

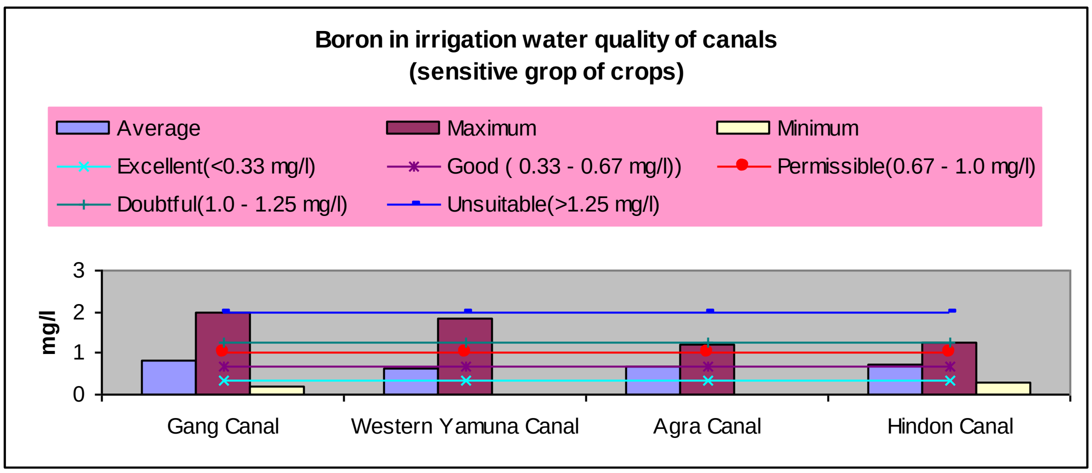

Figure 6a. Average Boron in water quality of irrigation canals

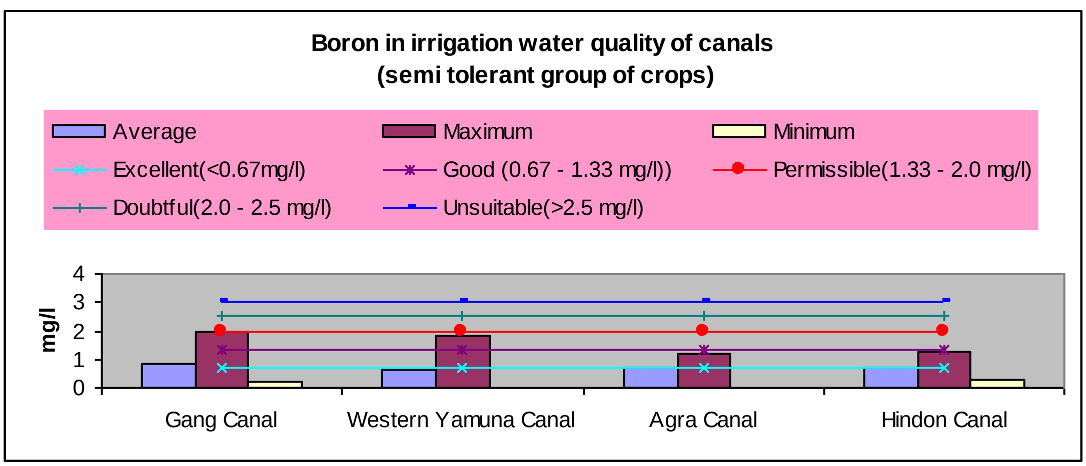

Figure 6b. Average Boron in water quality of irrigation canals

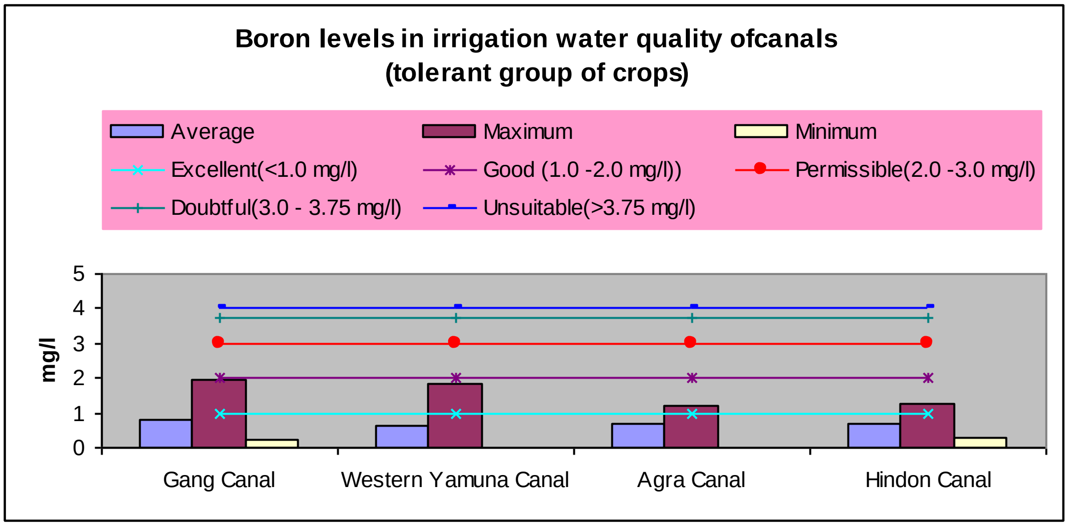

Figure 6c. Average Boron in water quality of irrigation canals

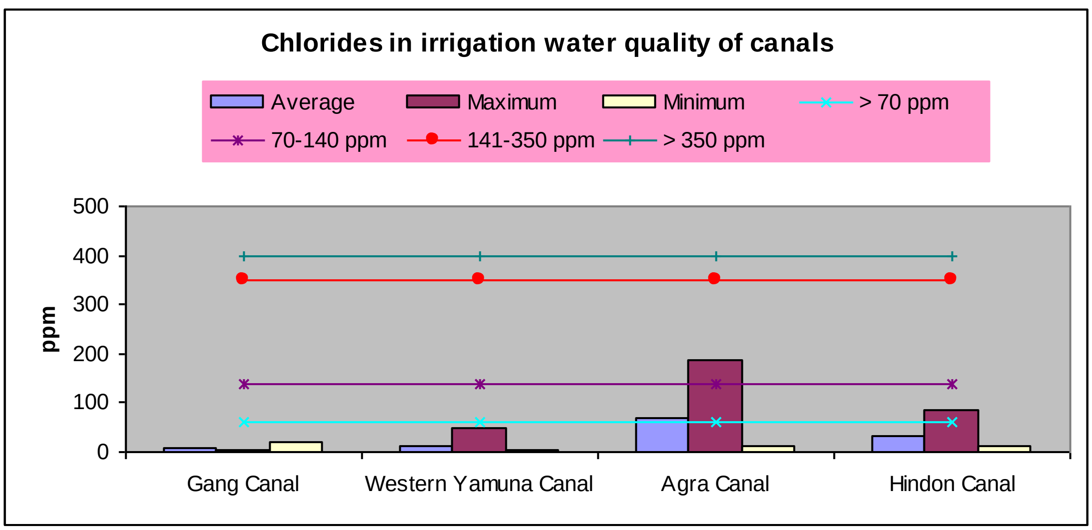

Figure 7. Chlorides in water quality of irrigation canals

Conclusion

Average TDS levels of 63 to 188 mg/l, indicated excellent to good water quality suitable for irrigation. The average Electrical Conductivity of 197.6 to 611.5 µmhos/cm were also suitable for irrigation water. A water body may not be fit for irrigation in respect of critical pollutants of pH, TDS, electrical conductivity, SAR and boron together. Gang Canal and Western Yauna Canal were fit for irrigation in terms of TDS, electrical conductivity and SAR for sensitive crops whereas, boron levels in these canals were suitable for tolerant crops. Water quality of Agra Canal and Hindon Canal was suitable for irrigation in terms of SAR, and boron. Thus, deficiency and excess of critical pollutants determined the suitability of canal waters for irrigation to various type of crops. However, maximum levels of critical pollutants, as per Primary Water Quality Criteria, may not be suitable for irrigation to various sensitive, semi tolerant and tolerant group of crops. There is an urgent need to classify surface waters to various classes of irrigation waters in order to protect sensitive, semi tolerant and tolerant variety of crops in India.

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REFERENCES

Bauder TA, Waskom RM and.Davis J G (2010). *Irrigation Water Quality Criteria*, Colorado State University Extension no. 0,506, 7/03, Revised.(3/07), Updated Wednesday, May 12,2010.

CPCB (1978-79). Scheme for Zoning and Classification of Indian Rivers, Esturies and Coastal Waters (Part One:Sweat Water). *Aaaessment and Development Study of River Basin Series* **3** Central Pollution Control Board,Delhi,

CPCB(1999). Bio-mapping of rivers; *Parivesh Newsletter* **5** (iv) Central Pollution Control Board, Delhi.

Joshi DM, Kumar A and Agrawal N (2009). Assessment of the Irrigation water quality of River Ganga in Haridwar district. *Rasayan Journal of Chemistry* **2** (2) 285-292.

CPCB (1998-99). Application of artificial substratum for bioassessment of water bodies. *Laboratory Analytical Technique Series* **13** Central Pollution Control Board Delhi.

IS2296 (1992). *Water Quality Standards in India*.

OSPCB (2007). Water Quality Status of Major Rivers of Orissa. State Pollution Control Board Orissa Bhubaneswar-751012.

Mass (1987). Salt toleranc of plants. *CRC Hand book of Plant Science in Agriculture* edited by Cristie BR, CRC Press Inc. Boron sensitivity of selected Colorado plants.

Rowe DR and Abdel- Magid IM (1995). Handbook of Waste Water Reclaimation and Reuse. *CRC Press Nature* 550.Published in EPA/625/R-04?108 September,2004 *Guidelines for Water Reuse* US Environmental Protection Agency.

Sakthivel R (2007). TDS levels for traditional crops, TDS – resistant crops submitted by India Water Portal on November5,2007-00:10 *International Land Development Consultants*,1981. WES, *Net India*, New Delhi.