Proceedings of the International Academy of Ecology and Environmental Sciences

Vol. 9, No. 3, 1 September 2019

ISSN 2220-8860

9 772220 886009 >

International Academy of Ecology and Environmental Sciences

International Academy of Ecology and Environmental Sciences

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Proceedings of the International Academy of Ecology and Environmental Sciences RSS
ISSN 2220-8860
CODEN PIAEBW

ISSN 2220-8860
9 772220 886009

Publisher: International Academy of Ecology and Environmental Sciences
E-mail: piaees@iaees.org

Volume 9, Number 3, 1 September 2019

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Article

Assessment of suitability of irrigation canal water for agriculture: A study based on New Mutha Right Bank Canal waters from Pune, Maharashtra, India

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Received 22 March 2019; Accepted 30 April 2019; Published 1 September 2019

Abstract
Food security is the greatest priority, next to availability of drinking water, and hence agriculture is a dominant component of the global economy. Water is the most important input required for agricultural development and hence irrigation systems are seen to have found its roots in the history of mankind since earliest beginning as they help in reducing the uncertainties (particularly the climatic uncertainties) in agriculture practices. All water sources used in irrigation contain impurities and dissolved salts irrespective of whether they are surface or groundwater and hence precautions are warranted to follow proper irrigation practices in the agriculture. In the present study the water samples from the New Mutha Right Bank Canal in the Pune district of Maharashtra have been assessed for their suitability for the agricultural use. For this the canal water samples (7 samples) along with irrigation well water samples (5 samples) and drinking well water samples (2 samples) were analyzes for their chemical constituents. Using the chemical analysis data the Sodium Adsorption Ratio (SAR) values were computed to assess whether the canal water pose any threat to the crops. The results show that the all the canal water samples collected in May, September and November 2015 do not pose any threat to the vegetation, as the SAR values are well below 3.00. Although the water samples collected from the drinking water wells and irrigation wells, adjacent the canal, show variable SAR values they are also excellent for agricultural uses.

Keywords irrigation canal water; agriculture use; Sodium Adsorption Ratio; Pune; India.

Proceedings of the International Academy of Ecology and Environmental Sciences
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URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
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According to Khangembam and Kshetrimayum (2019), an analysis of hydrogeochemical processes and water quality indices of various water bodies can help in assessing their usability for agricultural, domestic and industrial purposes. Threats to soil characters and crop yields are mostly associated with the quality of irrigation water which itself is a complex phenomenon involving the combined effects of many water quality parameters (Khalaf and Hassan, 2013). Various issues pertaining to the quality of the irrigation water has been addressed by many workers worldwide (Meireles, 2010; Sayyedand Wagh, 2011; Aly et al., 2013; Grmay, 2016; Mora-Orozco, 2017; Abbasnia et al, 2018; Zahedi, 2017, etc.). Bouaroudj et al. (2019) carried out a comprehensive assessment of water quality of Beni Haroun Dam and suggested that for minimizing the detrimental effects of irrigation waters on agricultural lands suitable protection measures are necessary. Waters drawn from various surface water sources greatly vary in their quality for agricultural use (Lothropa, 2018) which is particularly true when such waters are intermittently contaminated by runoff from rainfall or direct entry of pollutants in the upstream areas. It has been well documented that many water bodies (including surface water and ground water), used for agricultural purposes, have water quality issues (Barrel et al,, 2000; Barrera-Escorcia et al., 2013; Tomasini-Ortiz, 2013; Tomasini-Ortiz, 2013; Rosales-Hoz, 2013, etc.). The use of poor quality water in agriculture is growing due to the increasing shortage of fresh water globally (Raychaudhuri, et al., 2014). Agriculture is the most sensitive to water scarcity among all the sectors of water use and water quality. In spite of agricultural sector being viewed as a 'residual' user of water, it accounts for 70% of global freshwater withdrawals with more than 90% of consumptive use and hence it is the sector with the largest scope or potential for adjustment (FAO, 2012). The quality of the irrigation water has to be evaluated to avoid or, at least, to minimize impacts on agriculture (Mohammed, 2011). Irrigation Water Quality (IWQ) is mainly determined by estimating/calculating certain water quality parameters (Ayers and Westcot, 1994; Spandana et al., 2013; Bauder et al., 2014; Bortolini et al., 2018, etc.) which are mainly grouped in to

a) Salinity hazard, mostly in terms of electrical conductivity;
b) Sodium hazard in terms of sodium adsorption ratio (SAR);
c) Permeability and Infiltration problems;
d) Residual sodium carbonate (RSC);
e) Specific ion toxicity (e.g. sodium, chloride, borate, sulphate and nitrate) causing ionic imbalance in plants or phytotoxicitys;
f) Trace element toxicity ((Fe, Mn, Zn, Cu, Pb, Cd, Cr, Ni and F); and
g) Miscellaneous problems.

Absolute and relative concentrations of principal cations like Ca^{++}, Mg^{++} and Na^{+} determine the Alkali (or sodium) hazard in irrigation water (Mandal et al., 2019). With the higher proportion of Na^{+}, the alkali hazard is high and when Ca^{++} and Mg^{++} predominate such hazard is low. The alkali hazard is associated with water infiltration problem i.e. an excessive Na^{+} in irrigation water promotes the structural breakdown, infiltration problem and dispersion of soils (Brady and Weil, 2012). To avoid degradation of the soil structure and also the salt accumulation around plant roots an appropriate salt balance in the root zone and its subsequent leaching is needed (Letey et al., 2011; Skaggs et al., 2012). Irrigation waters with sodium hazard (i.e. high SAR values) indicates replacement of soil Ca^{++} and Mg^{++} with Na^{+} through ion exchange mechanism. Under such situation the soil structure and permeability is damaged ultimately affecting the soil fertility with corresponding low crop yield (Laze et al., 2016).

While the water quality parameters like SAR and %Na are most widely used in assessing quality of water (Baharand Reza, 2010; Raju et al., 2012; Mashura et al., 2016; Sener et al., 2017; Laxmi and Kshetrimayum, 2018) the Water Quality Index (WQI) is recently used in the assessment of the water quality (Sami, 1992; Varol and Davraz, 2014; Edith et al., 2016; Muñoz et al., 2016; Bouderbala, 2017; Tirkey et al., 2017; Acharya et al., 2018; Kumar et al., 2018; Ponsadailakshmi et al., 2018).

2 Study Area and Methodology

2.1 Study area

Most of the irrigation canals carrying fresh water pass by the towns, villages, hamlets, hutments. Normally considerable land is left on either sides of the canal for possible widening of canal in future, but much of such lands are encroached and occupied by local people for construction of dwelling houses, urinals, latrines etc. allowing the human waste/effluents into the fresh water canal. At many places the canal banks are used as open lavatories while many of the residents use irrigation canals as main outlets for the drainage and sewage produced by them. Further the canal when passing through the city limits and also the surrounding villages is used as the dumping sites for the human and animal wastes etc. The sum total of all such practices is that the canal water is severely polluted by the time it reaches the tail end. The present study was aimed at collection and physicochemical analysis of water samples from New Mutha Right Bank Canal so as to determine the extent of pollution, the impact of activities by residents of surrounding areas that is a continuous threat to canal water resources, its ecosystem and suitability for required use.

In the recent years, because of excellent facilities for education and industrial development, Pune and its surrounding suburbs are experiencing an unprecedented population spurt. As a result of population growth a large number of residential colonies have been built along with unplanned slums in the government lands as well as along the hill slopes. The slum dwellers, who use free water from the Mutha Right Bank Canal, are offering adverse impacts on the quality of its water. Pawar et al. (1987) have studied the effects of pollution on the quality of this open flowing canal water when it was used for drinking purposes also by the Pune Municipal Corporation. Based upon their suggestion and conclusion that the canal water was considerably contaminated due to the human activities the Pune Municipal authorities started bringing the water to the water-works through the closed pipes from the Khadakwasla dam. However the main purpose of this canal is to provide water for irrigating lands in the rural parts of eastern part of Pune district and it would be essential to monitor the water quality.

2.2 Methodology

For the purposes of this study 07 sampling stations from the New Mutha Right bank canal were selected (C-1 to C-7) starting from the Khadakwasla dam wall (Fig. 1). Samples from 5 irrigation wells (IW-1 to IW-5) and 02 drinking water wells (DW-1 and DW-2) were also collected for the comparison. The water samples were collected in three seasons i.e. May 2015 (summer), September 2015 (monsoon) and November 2015 (winter) and were analyzed for their chemistry. Using the values of Na^{+}, Ca^{++} and Mg^{++} from the chemical data, Sodium Adsorption Ratio (SAR) was calculated (Table 1).

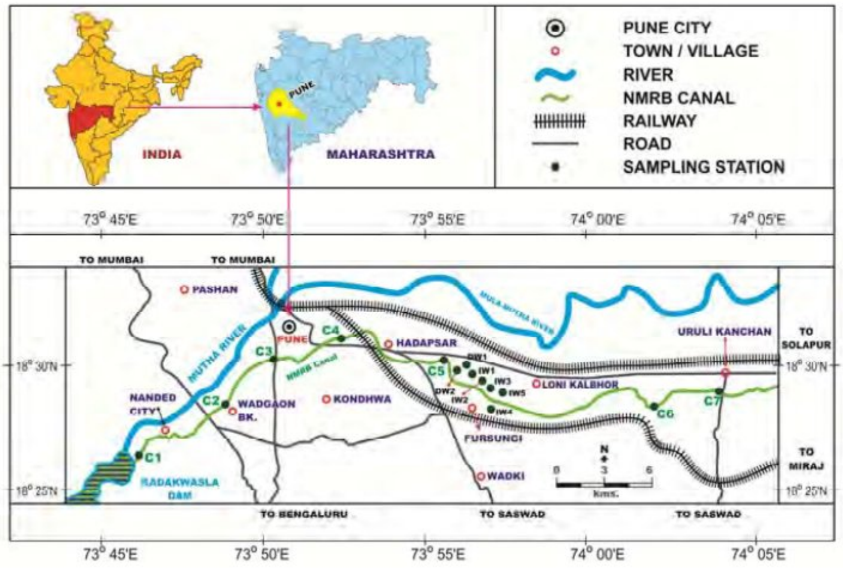

Fig. 1 Location map of the study area showing the sapling stations.

Table 1 Concentrations of Mg^{++}, Na^{+}, Ca^{++}, and Sodium Adsorption Ratio (SAR) from the water samples.

Water Type	Sampling Station	Mg^{++} (meq/L)			Na^{+} (meq/L)			Ca^{++} (meq/L)			Sodium Adsorption Ratio (SAR)		
		May-15	Sep-15	Nov-15	May-15	Sep-15	Nov-15	May-15	Sep-15	Nov-15	May-15	Sep-15	Nov-15
Irrigation Canal	C-1	0.32	0.42	0.90	0.10	0.13	0.10	0.40	0.56	0.96	0.16	0.18	0.11
	C-2	0.40	0.50	0.85	0.10	0.13	0.11	0.40	0.56	0.88	0.15	0.17	0.11
	C-3	0.40	0.50	0.94	0.10	0.13	0.11	0.40	0.56	1.04	0.15	0.18	0.11
	C-4	0.37	0.54	1.02	0.10	0.13	0.11	0.48	0.64	1.04	0.15	0.16	0.11
	C-5	0.40	0.50	1.01	0.10	0.13	0.10	0.40	0.56	0.88	0.16	0.18	0.11
	C-6	0.48	0.42	0.99	0.10	0.12	0.10	0.40	0.56	1.12	0.16	0.17	0.10
	C-7	0.40	0.59	0.77	0.10	0.12	0.11	0.40	0.64	0.88	0.16	0.15	0.12
	Average	***0.40***	***0.49***	***0.93***	***0.10***	***0.13***	***0.11***	***0.41***	***0.58***	***0.97***	***0.16***	***0.17***	***0.11***
Drinking Water Well	DW-1	1.26	1.02	5.13	0.12	0.15	0.50	1.84	1.44	2.57	0.10	0.13	0.26
	DW-2	0.64	0.75	1.18	0.11	0.14	0.10	0.40	0.72	1.44	0.15	0.16	0.09
	Average	***0.95***	***0.89***	***3.16***	***0.11***	***0.14***	***0.30***	***1.12***	***1.08***	***2.00***	***0.12***	***0.15***	***0.17***
Irrigation Water Well	IW-1	1.48	1.47	3.68	1.99	1.67	2.20	1.55	1.52	2.81	1.61	1.37	1.22
	IW-2	1.89	1.78	2.43	1.85	2.24	0.91	2.08	1.36	3.32	1.31	1.79	0.54
	IW-3	2.03	1.82	3.33	0.96	0.63	2.45	1.92	2.24	2.49	0.68	0.44	1.43
	IW-4	1.18	1.20	1.90	0.27	0.24	0.43	1.04	1.20	2.24	0.25	0.22	0.30
	IW-5	1.60	2.00	2.29	0.36	0.32	0.32	1.60	2.00	2.08	0.28	0.22	0.22
	Average	***1.64***	***1.65***	***2.73***	***0.10***	***1.02***	***1.26***	***1.64***	***1.67***	***2.39***	***0.83***	***0.81***	***0.74***

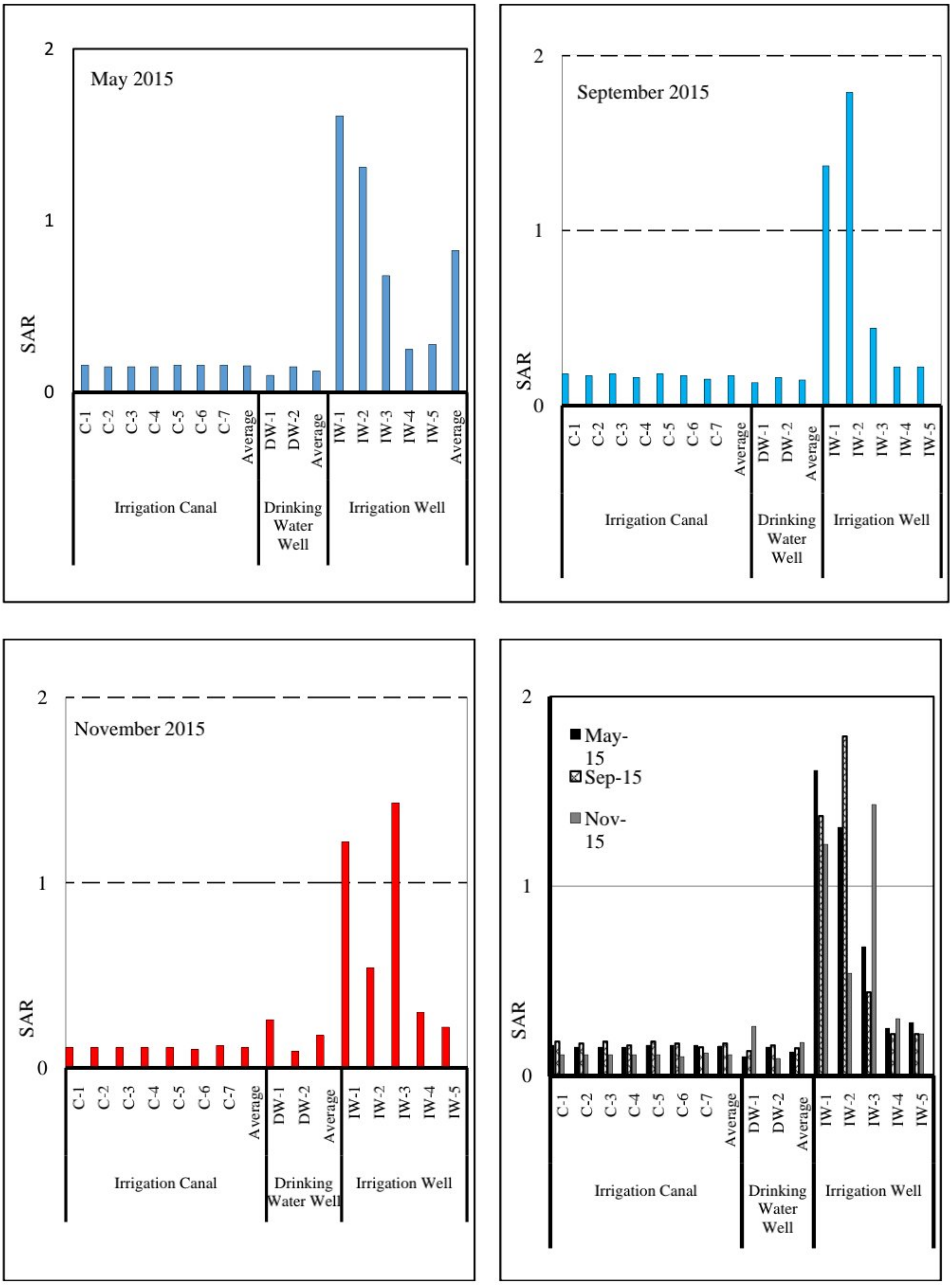

Fig. 2 Variations in the SAR values in the three sampling seasons.

3 Results and Discussion

For all water samples, Sodium Absorption Ratio (SAR) values were calculated which express the activity of Na^+, ions and determines their ability to rotate with cations such as Ca^{++} and Mg^{++} adsorbed by soil colloids. Sodium adsorption ratio (SAR) was computed by using the following formula.

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

where concentrations of Na^+, Ca^{++} and Mg^{++} are expressed in milliequivalents/liter.

Usually SAR less than 3.0 will not be a threat to vegetation while SAR greater than 12.0 is considered sodicand threatens the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability (Kuipers et al., 2004). Water containing SAR values >6 contains higher concentration of Na^+ compared to the concentration of Ca^{++}, reflecting that this water is not suitable for irrigation (Venugopal et al., 2008). Richards (1954) categorized the groundwater on the basis of SAR values (<10 as excellent; between 10-18 as good; 18-26 as fair; and > 26 as of poor quality). It has been found that the magnitude of adsorption of Na^+ by soils has a direct relationship to SAR. For the irrigation canal water samples from the study area the average values of SAR (Table 1; Fig. 2) are 0.16 (May 2015), 0.17 (September, 2015) and 0.11 (November 2015). While the drinking water well samples show lower average values of SAR (0.12 in May 2015), (0.15 in September 2015) and (0.17 in November 2015); the irrigation well samples show higher average values (0.83 in May 2015), (0.81 in September 2015) and (0.74 in November 2015).

The SAR values obtained for the canal waters do not indicate much anthropogenic inputs either from the domestic, industrial or agricultural activity and hence they are found to be excellent for the agricultural use.

4 Conclusions

Sodium Adsorption Ratio values for the water samples from the study area suggest the following

1. The New Mutha Right Bank Canal water, although passing through the densely populated Metropolitan area of Pune, does not pose any threat to the agricultural crops.
2. The drinking well waters, adjacent to the canal, also show SAR values within limits for their use in agriculture.
3. Irrigation well waters, however, show quite variable SAR values. The wells IW-1 and IW-2 show rather higher values of SAR which could be either due to excessive use of fertilizers/pesticides and/or due to lesser withdrawal of well waters thereby increasing water-rock interactions because of prolong residence time. Wells IW-3, IW-4 and IW-5 are close to the irrigation canal and are recharged mainly from the canal water. Also there is quite substantial withdrawal of water from these wells and hence SAR values are quite less.
4. From the SAR values it can be concluded that the waters from the irrigation canal are excellent for the agricultural use as they does not pose any threat to the agricultural crops. Similarly the drinking water wells as well as irrigation wells, can also be used for the agricultural productions.

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