

Irrigation Water Quality: A Case Study of Khadki Nala basin, Mangalwedha Taluka, Solapur District, Maharashtra, India

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ABSTRACT- Groundwater may be considered as one of the most precious and one of the basic needs for human existence and the survival of mankind providing him the luxuries and comforts in addition to fulfilling his basic necessities of life. Groundwater forms the major source of water supply for drinking purposes in most parts of India. Historically, surface water has accounted for most of the human consumption, because it is easily accessible with the exception of arid and semi-arid regions, where ground water may be the only reliable source of water. Modern development and population growth however has greatly increased water demands. With the growing inter and intra sectorial competition for water and depleting fresh water resources, the utilization of poor and marginal quality water for potable purposes in rural areas has been posed a new challenge for the management of limited water resources. In present investigation Khadki Nala basin which falls geographically under Solapur district of Maharashtra, has been taken up for groundwater development. The area falls under the rain shadow zone and frequent drought is a common feature in the area due to adverse climatic conditions. Geologically the area falls under the hard rock terrain consisting of basaltic lava flows. Geology of Khadki Nala basin contain massive basalt, vesicular, weathered or zeolitic basalt and quaternary soil. The study area is located on Survey of India Topo Sheet No.470/6, 470/7 on the scale of 1: 50,000. It lies between latitudes 17° 19' 00" N to 17° 33' 00" N to and longitude 75° 17' 00" E to 75° 25' 00" E. The total area is about 167.26 sq.km. Irrigation water quality has been carried out for pre and post monsoon 2011 and 2014 for parameters like, Sodium Absorption Ratio (SAR), Percentage Sodium (%Na), Residual Sodium Bicarbonate (RSBC), Soluble Sodium Percentage (SSP), Kelley's Ratio (KR), Magnesium Adsorption Ratio (MAR), Chloro Alkaline Indices (CAI-I), Permeability Index (PI). Physico-chemical properties of groundwater of pre and post monsoon 2011 and 2014 shows that it is mostly suitable for irrigation use.

Keywords: SAR, % Na, SSP, RSBC, KR, CAI-I, MAR, PI

INTRODUCTION

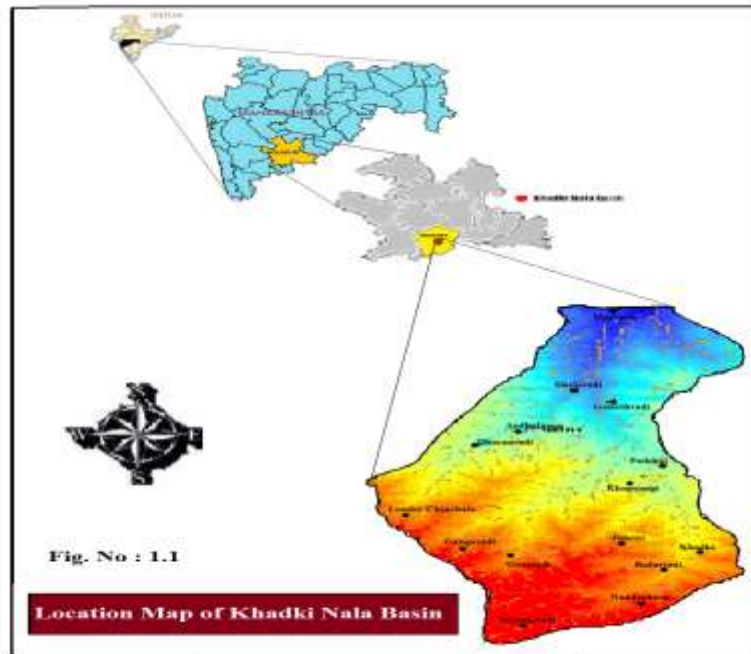
Water is the source of life; it is one of the potent element. For most of us have access to clean water means food can safely be prepared as well as sanitation and hygiene properly be practiced. There are some places where a barrel of water costs more than barrel of oil or a glass of milk. Water is life and has played a great role in the creation, growth, and sustenance of life on the earth. The life and health is directly related to the quality of water and its availability in adequate quantity. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for agricultural and industrial sectors also. India's rapidly rising population and changing lifestyle has also increased the pressure for domestic need for water. The water deficiency affects leaving standards of population adversely. Oceans are the store houses of water and withdrawal of water from ocean is by the process of evaporation, condensation and precipitation. Supply of water on the surface of the earth results in runoff and recharge. Any minute change in this hydraulic cycle destabilize the equilibrium and affect the survival of life. Water is needed to ensure food security, feed livestock, take up industrial production and to conserve the biodiversity and environment. The study area is located on Survey of India Topo Sheet No.470/6, 470/7 on the scale of 1: 50,000. It lies between latitudes 17° 19' 00" N to 17° 33' 00" N to and longitude 75° 17' 00" E to 75° 25' 00" E. The total area is about 167.26 sq.km. The sampling of groundwater from 72 locations have been carried out. All the groundwater samples were taken from open dug wells. The samples then brought to laboratory and subjected for analysis. All samples were tested for 8 irrigation water quality parameters.

RESULT AND DISCUSSIONS

The groundwater samples have been checked for irrigation purpose by using following parameters

1) Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply. A high sodium concentration changes soil properties and reduce soil permeability. The suitability of water for irrigation purpose is determined by the mathematical equation: $SAR = Na / \sqrt{Ca + Mg/2}$. The cation measurements are expressed in milliequivalents per liter (meq/L). Water with SAR value ≤ 10 is considered as of excellent quality, 10 to 18 is good, between 18 to 26 is fair and above 26 is said to be unsuitable for irrigation. The calculated SAR value from study area for pre & post monsoon 2011 and pre & post monsoon 2014 were less than 10 meq/l. It is observed that in pre monsoon 2011, lowest SAR concentration was reported at sample no 28 (0.2655 meq/l), while highest SAR concentration was reported from sample no 17 (1.2088 meq/l). In post monsoon 2011, lowest SAR concentration was reported at sample no 28 (0.247 meq/l) and high SAR



concentration was reported at sample no 45 (1.718 meq/l). While in pre monsoon 2014, lowest SAR concentration was reported at sample no 62 (0.274 meq/l) and high SAR concentration was reported at sample no 24 (1.216 meq/l). In post monsoon 2014 low SAR concentration was reported at sample no 62 (0.2208 meq/l) and high SAR concentration was reported at sample no 24 (1.234 meq/l). All the 72 groundwater samples were found less than 10. Hence all the groundwater samples were considered suitable for irrigation use.

2) Percent Sodium (% Na)

Sodium hazard was an important factor in irrigation water quality. The use of high percentage sodium of water for irrigation was stunts, the plant growth and sodium reacts with soil to reduce its permeability (Joshi et al., 2009). The finer the soil texture and the greater the organic matter content, the greater the impact of sodium on water infiltration and aeration. This value is defined by the expression: $\% Na = Na + K / (Ca + Mg + Na + K) \times 100$. High % Na in irrigation water causes exchange of sodium in water, and exchange of calcium and magnesium contents in soil having poor internal drainage. The % Na < 60 represents safe water while it is unsafe if > 60 (Eaton, 1950). It is analyses that for pre monsoon 2011 lowest concentration of % Na was reported at sample no 28 (12.23 meq/l) and highest concentration of % Na was reported at sample no 17 (43.92 meq/l). In post monsoon 2011 lowest concentration of % Na was reported at sample no 28 (12.28 meq/l) and highest concentration of % Na was reported at sample no 17 (42.91 meq/l). While in pre monsoon 2014 lowest concentration of % Na was reported at sample no 61 (14.16 meq/l) and highest concentration of % Na was reported at sample no 17 (41.89 meq/l). In post monsoon 2014 lowest concentration of % Na was reported at sample no 61 (15.49 meq/l) and highest concentration of

% Na was reported at sample no 17 (41.81 meq/l). The % Na values from study area for pre & post monsoon 2011 and pre & post monsoon 2014 does not exceed the limit of 60 as stated by Eaton (1950). As per this criterion the groundwater from Khadki Nala basin is safe for irrigation purpose.

3) Residual Sodium Bicarbonate (RSBC)

It is calculated as the difference of bicarbonate to calcium and classified as:

$RSBC = HCO_3^- - Ca^{++}$. The values of RSBC < 5 epm is satisfactory; between, 5-10 epm is marginal and > 10 epm is unsatisfactory. All the values of pre and post monsoon 2011 and 2014 were >10 epm, hence groundwater of the basin was safe for irrigation purpose.

4) Soluble Sodium Percentage (SSP)

The sodium in irrigation waters indicates quantitatively the adverse effect of sodium content involving the process of Base Exchange that replaces the calcium in the soil, which in turns lower soil permeability. SSP for groundwater samples of the study area was determined by the formula as $SSP = [(Na^+ + K^+) / (Ca^{++} + Mg^{++} + Na^+ + K^+)] \times 100$. The groundwater having SSP values ≤ 50 is categorized as good quality whereas values > 50 are unsuitable for irrigation. All the SSP values of pre and post monsoon 2011 as well as pre and post monsoon 2014 collected from Khadki Nala basin areas lie within the limit of SSP ≤ 50 . It is analyses that for pre monsoon 2011 lowest concentration of SSP was reported at sample no 28 (12.23 meq/l) and highest concentration of SSP was reported at sample no 17 (43.92 meq/l). In post monsoon 2011 lowest concentration of SSP was reported at sample no 28 (12.28 meq/l) and highest concentration of SSP was reported at sample no 17 (42.91 meq/l). While in pre monsoon 2014 lowest concentration of SSP was reported at sample no 61 (14.16 meq/l) and highest concentration of SSP was reported at sample no 17 (41.89 meq/l) In post monsoon 2014 lowest concentration of SSP was reported at sample no 61 (15.49 meq/l) and highest concentration of SSP was reported at sample no 17 (41.81 meq/l). Based on the computed SSP values the groundwater from Khadki Nala basin area is categorized as good quality in nature and ultimately suitable for irrigation purpose.

5) Kelley's Ratio (KR)

It is the ratio of sodium ion to calcium and magnesium ion is expressed as Kelley's Ratio (KR) (Kelley's 1963) and is expressed mathematically as $KR = Na^+ / (Ca^{++} + Mg^{++})$. The groundwater having KR < 1 is considered to be good quality for irrigation whereas KR > 1 is considered to be unsuitable for irrigation and causes alkali hazard (Karanth, 1987).

Based on the Kelley's Ratio (KR) in pre monsoon 2011, lowest concentration was reported at sample no 28 (0.128 meq/l), while highest concentration was reported from sample no 17 (0.772). In post monsoon 2011, lowest concentration was reported at sample no 28 (0.129 meq/l) and high concentration of KR were reported at sample no 17 (0.741 meq/l). While in pre monsoon 2011, lowest concentration of KR was reported at 62 (0.152 meq/l) and high concentration of KR were reported at 17 (0.711 meq/l). In post monsoon 2014 lowest concentration was reported at sample no 27 (0.173 meq/l) and high concentration of KR was reported at sample no 17 (0.707 meq/l). All the groundwater samples of the study area were <1 hence it is suitable for irrigation use.

6) Magnesium Adsorption Ratio (MAR)

In natural waters, Mg in equilibrium state will adversely affect crop yields (Nagaraju et al., 2006). The magnesium hazard (MAR) of irrigation water is proposed by Szabolcs and Darab (1964) and redefined by Raghunath (1987). Magnesium Adsorption Ratio (MAR) was calculated by the equation Raghunath as: $MAR = Mg \times 100 / (Ca + Mg)$, where all the ionic concentrations are expressed in meq/L. The MAR value exceeding 50 is considered harmful and unsuitable for irrigation use. In analyzed groundwater samples of pre monsoon 2011 low MAR concentration was reported from sample no 09 (20.66 meq/l) and high MAR concentration was reported from sample no 50 (48.94 meq/l). In post monsoon 2011 low MAR concentration was reported from sample no 68 (19.98 meq/l) and high MAR concentration was reported from sample no 50 (49.83 meq/l). While in pre monsoon 2014 low MAR concentration was reported from sample no 05 (21.01 meq/l) and high MAR concentration was reported from sample no 44 (49.38 meq/l). In post monsoon 2014 low MAR concentration was reported from sample no 05 (19.86 meq/l) and high MAR concentration was reported from sample no 44 (48.87 meq/l). After the analysis of all 72 groundwater samples of pre & post monsoon 2011 and pre & post monsoon 2014 MAR concentration were below 50 which is indicating that groundwater is suitable for irrigation use.

7) Chloro Alkaline Indices (CAI-I)

It is essential to know the changes in chemical composition of groundwater during its travel in the ion exchange between the groundwater and its host environment. The Chloro-alkaline indices used in the evaluation of Base Exchange are calculated using the Equations:

$$\text{Chloro Alkaline Indices } 1 = [\text{Cl} - (\text{Na} + \text{K})] / \text{Cl}$$

If there is ion exchange of Na and K from water with magnesium and calcium in the rock, the exchange is known as direct when the indices are positive. If the exchange is reverse, then the exchange is indirect and the indices are found to be negative. It is observed that for pre monsoon 2011 the lowest CAI-I concentration is reported from sample no 30 (-2.808 meq/l), while highest CAI-I value is reported from sample no 58 (7.069 meq/l). The post monsoon 2011 shows lowest CAI-I concentration from sample no 12 (-1.612 meq/l) and highest concentration from sample no 7 (5.908 meq/l). The pre monsoon 2014 show lowest concentration from sample no 69 (-1.762) and highest concentration is reported from sample no 23 (6.584 meq/l). The post monsoon 2014 shows lowest concentration from sample no 69 (-1.612) and highest concentration is reported from sample no 23 (6.105) In analyzed groundwater samples for pre monsoon 2011, it is observed that 52 groundwater samples were positive and 20 groundwater samples were negative. In post monsoon 2011 it is observed that 57 groundwater samples were positive and 15 groundwater samples were negative. While in pre monsoon 2014 it is observed that 60 groundwater samples were positive and 12 groundwater samples were negative. In post monsoon 2014 it is observed that 63 groundwater samples were positive and 09 groundwater samples were negative.

8) Permeability Index (PI)

According to Doneen (1964), soil permeability is affected by long term use of irrigation water and depend mainly upon soil characteristics, sodium content, bicarbonate content etc., which is expressed as: $PI = [(\text{Na}^+ + \sqrt{\text{HCO}_3^-}) / (\text{Ca}^{++} + \text{Mg}^{++} + \text{Na}^+)] \times 100$. It is represented by class I, class II, and Class III depending upon total concentration and PI values. The PI concentrations for pre monsoon 2011 was ranges from 21.99 to 60.72. The lowest concentration was reported from sample no 28, while highest concentration was reported from sample no 12. The PI concentration for post monsoon 2011 was ranges from 24.46 to 69.01 The lowest concentration was reported from sample no 28, while highest concentration was reported from sample no 12. The PI concentrations for pre monsoon 2014 was ranges from 28.44 to 84.28 The lowest concentration was reported from sample no 60 while highest concentration was reported from sample no 11. The PI concentrations for post monsoon 2014 was ranges from 29.26 to 72.32 The lowest concentration was reported from sample no 60 while highest concentration was reported from no 17.

Table-1.1 Classification of Irrigation Groundwater Based on Doneen (1964) For pre monsoon 2011

Sr. No.	Category of Irrigation Water	Sample Numbers (Locations samples)	Total No. of Locations	Percentage (%)
1	Class -I	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,667,68,69,70,71,72	71	98.61
2	Class- II	17	01	1.38
3	Class- III	----	----	----

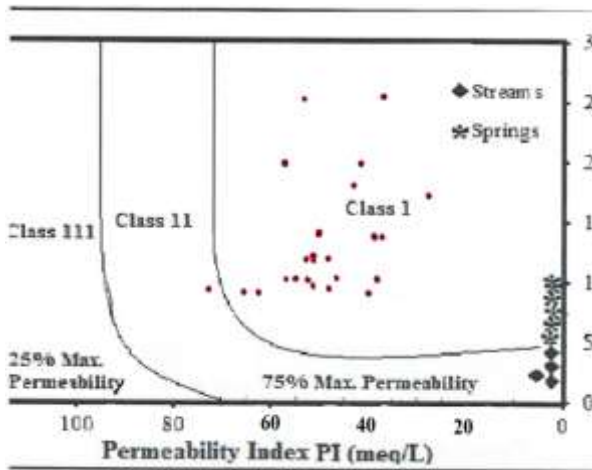


Fig No 1.2 Permeability index (PI) vs Total concentration diagram from sample no 1-24 for Pre Monsoon 2011 at Khadki Nala basin

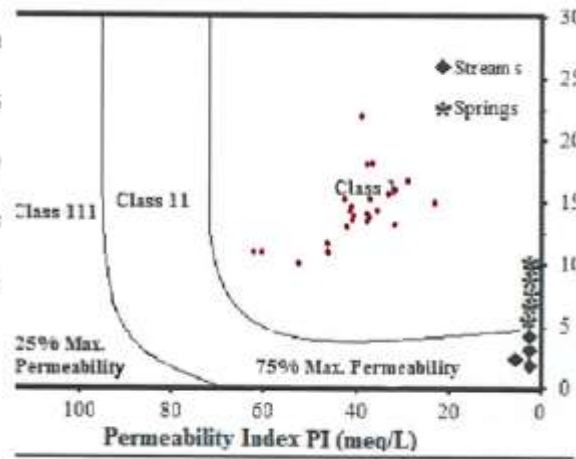


Fig No 1.3 Permeability index (PI) vs Total concentration diagram from sample no 25-48 for Pre Monsoon 2011 at Khadki Nala basin

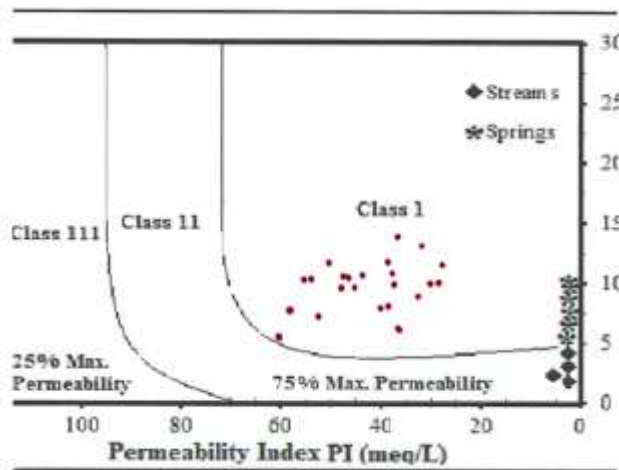


Fig No 1.4 Permeability index (PI) vs Total concentration diagram from sample no 49-72 for Pre Monsoon 2011 at Khadki Nala basin

Table-1.2 Classification of Irrigation Groundwater Based on Doneen (1964) for Post Monsoon 2011

Sr. No.	Category of Irrigation Water	Sample Numbers (Locations samples)	Total No. of Locations	Percentage (%)
1	Class -I	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,667,68,69,70,71,72	71	98.61
2	Class- II	17	1	1.38
3	Class- III	----	----	----

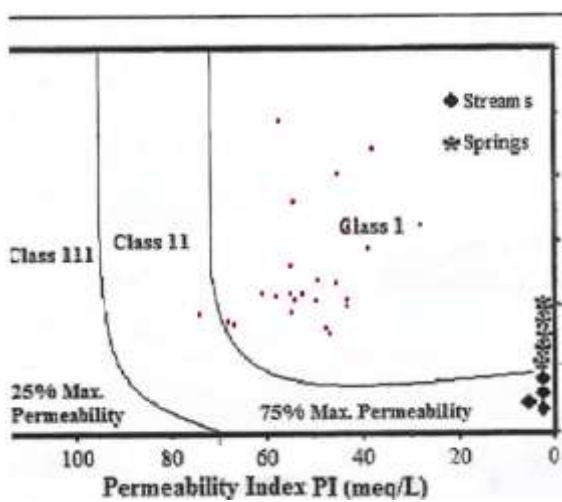


Fig. No 1.5 Permeability index (PI) vs Total concentration diagram from sample no 1-24 for Post Monsoon 2011 at Khadki Nala basin

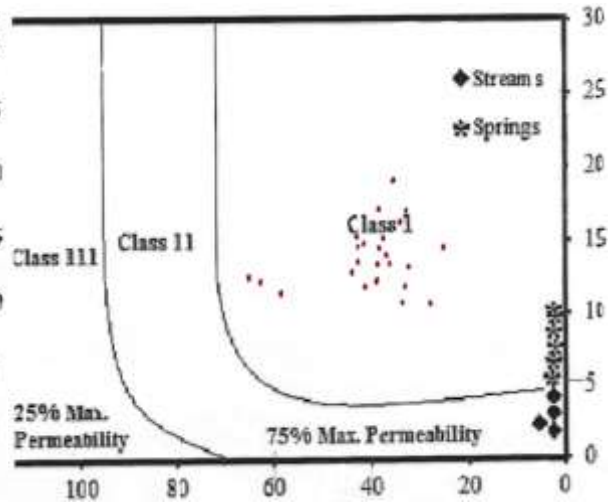


Fig. No 1.6 Permeability index (PI) vs Total concentration diagram from sample no 25-48 for Post Monsoon 2011 at Khadki Nala basin.

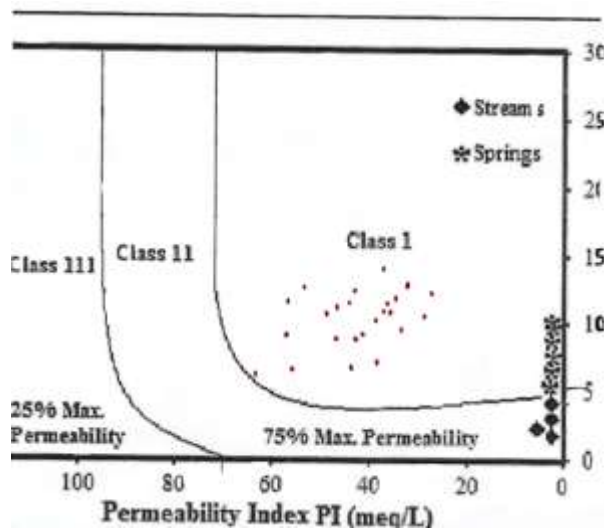


Fig. No 1.7 Permeability index (PI) vs Total concentration diagram from 49-72 for Post Monsoon 2011 at Khadki Nala basin

Table-1.3 Classification of Irrigation Groundwater Based on Doneen (1964) for Pre Monsoon 2014

Sr. No.	Category of Irrigation Water	Sample Numbers (Locations samples)	Total No. of Locations	Percentage (%)
1	Class -I	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,18, 19,20,21,22,23,24,25,26,27,28,29,30,31,32 33,34,35,36,37,38,39,40,41,42,43,44,45,46 47,48,49,50,51,52,53,54,55,56,57,58,59,60, 61,62,63,64,65,66,667,68,69,70,71,72	70	97.22
2	Class- II	11, 17	2	2.77
3	Class- III	----	----	----

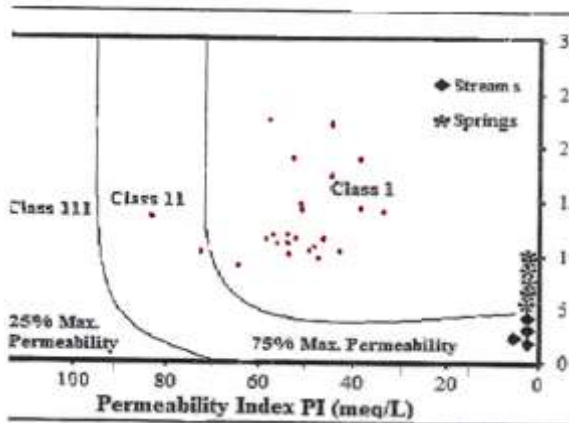


Fig. No 1.8 Permeability index (PI) vs Total concentration diagram from 49-72 for Post Monsoon 2011 at Khadki Nala basin

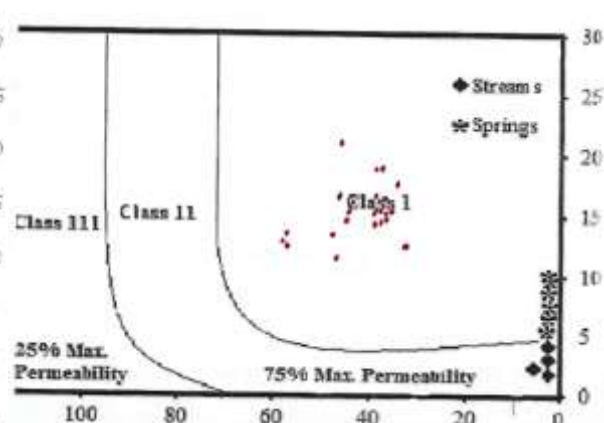


Fig. No 1.9 Permeability index (PI) vs Total concentration diagram from 49-72 for Post Monsoon 2011 at Khadki Nala basin

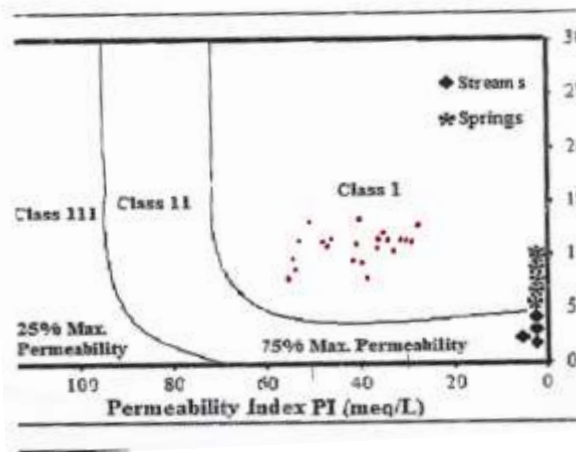


Fig. No 1.10 Permeability index (PI) vs Total concentration diagram from 49-72 for Post Monsoon 2011 at Khadki Nala basin

Table-1.4 Classification of Irrigation Groundwater Based on Doneen (1964) for Post Monsoon 2014

Sr. No.	Category of Irrigation Water	Sample Numbers (Locations samples)	Total No. of Locations	Percentage (%)
1	Class -I	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,667,68,69,70,71,72	71	98.61
2	Class- II	17	1	1.38
3	Class- III	----	----	----

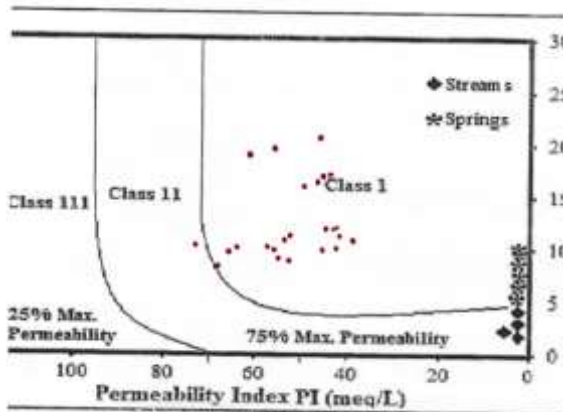


Fig. No 1.11 Permeability index (PI) vs Total concentration diagram for sample no 1-24 for Post Monsoon 2014 from Khadki Nala basin

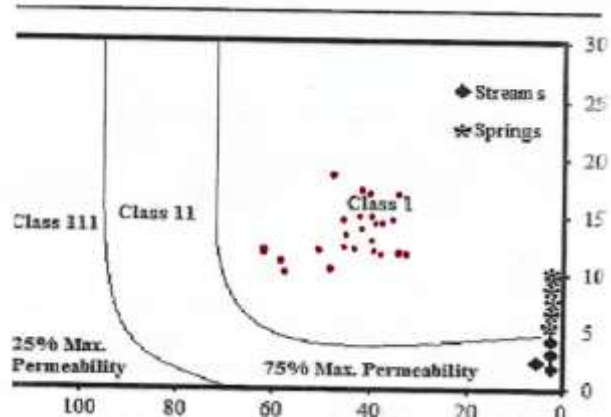


Fig. No 1.12 Permeability index (PI) vs Total concentration diagram for sample no 1-24 for Post Monsoon 2014 from Khadki Nala basin

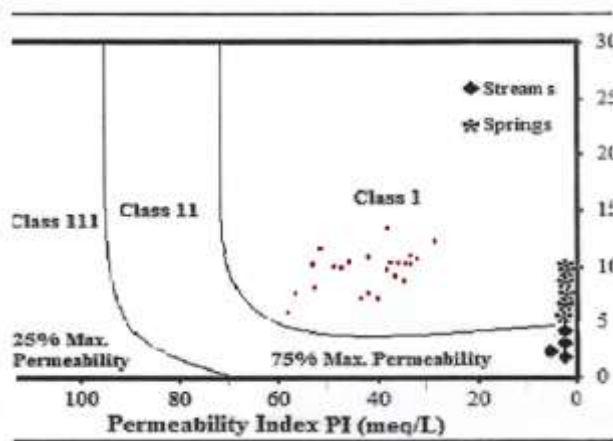


Fig. No 1.13 Permeability index (PI) vs Total concentration diagram for sample no 1-24 for Post Monsoon 2014 from Khadki Nala basin

CONCLUSION

From the above studies it is clear that the all the irrigation water quality parameters of 72 groundwater samples from Khadki Nala basin at Mangalwedha taluka, Solapur district, Maharashtra, India were under permissible limit as prescribed by BIS 1987. Therefore, it is concluded that groundwater from Khadki Nala basin was suitable for irrigation use.

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