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Suitability Assessment of Groundwater Quality for Irrigation Purpose with Reference to Percent Sodium

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Abstract: To assess the seasonal variation of quality of groundwater of two adjoining towns of the hill state, Himachal Pradesh in the north of India, a study has been carried out. The specific study zone covering an area of about 120 sq. km. was selected near the industrial townships of Nalagarh and Baddi in district Solan. A total of 25 and 40 groundwater samples were collected, from 65 different locations during post-monsoon season of 2011 and pre and post-monsoon seasons of 2012. The overall percent sodium (%Na) of groundwater was ranged from 5.715-27.869 and 5.064-26.992 at Nalagarh and Baddi industrial areas respectively. The overall averaged percent sodium value at Nalagarh and Baddi industrial areas were less than 100, hence suitable for agriculture purposes. The findings also suggest that most of the values of percent sodium of groundwater were far below the recommended standard values. However, proper treatment of effluents from urban and industrial areas is desirable to maintain the %Na of groundwater of the study areas to check further deterioration.
Keywords: Groundwater, Percent sodium, Platykurtic, Nalagarh, Baddi.

I. INTRODUCTION

Monitoring the quality of irrigation water is of paramount important in managing plant health. Irrigation waters, whether derived from surface or underground sources, contain significant quantities of dissolved substances collectively called salts, which may reduce crop yield and soil fertility. Furthermore the dissolve salts, which has been the prime problem for a couple of centuries, irrigation water always carries substances procured from its natural environment (geological strata) or from the anthropogenic activities (domestic, agriculture and industrial effluents). However, a number of trace elements are also found in water which can limit its use for irrigation. In governing water availability for irrigation, detail data is required on both the quality and quantity; however, the quality has often been failed to look after till date. Quality should infer how well a water supply satisfy the needs of the intended user and must be assessed on the basis of its suitability for the intended use. Several studies also suggested that if the quality of water (groundwater in particular) will decrease up to a certain level then it could unfit for domestic use, reduces crop yield and industrial productions. Therefore water is considered as a key input for sustainable development. The application of irrigation water to the soil brings salts near the root zone. Plant roots uptake water but absorb a very little salt from the soil solution. Similarly, when water evaporates from the soil surface but salts/dissolved solids remain behind. Both the processes are responsible for gradual accumulation of salts in the root zone, even with low salinity water. This condition may affect the crop plants in two ways: a) by turning out salinity hazards and water shortage; and b) by causing noxious and other related problems. Several different measurements are used to classify the suitability of water for irrigation, including sodium adsorption ratio (SAR), percent sodium (%Na), soluble sodium percentage (SSP), magnesium hazard (Mg haz.), Kelly's ratio (KR), residual sodium carbonate (RSC), base exchange (base exch.), meteoric genesis (met. gen.) etc. [1].

Many studies on quality of ground and surface water sources on drinking water standards have been carried out by several researchers [2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20]. Although many studies have been conducted on suitability of groundwater for domestic needs, however, no extensive study has been done on suitability of water for irrigation purposes in Solan district of the hilly state Himachal Pradesh. Realizing the importance of water use in agriculture sector and existing research gap a systematic study was planned and conducted. To assess the quality of groundwater of the two adjoining towns (Nalagarh and Baddi) for irrigation purpose, percent sodium (%Na) was calculated and discussed subsequently.

II. MATERIALS AND METHODS

A. Description of Study Area

To assess the seasonal variation of quality of groundwater of two adjoining towns of the hill state, Himachal Pradesh in the north of India, a study has been carried out. The specific study zone covering an area of about 120 sq. km was selected near the industrial townships of Nalagarh and Baddi in district Solan. Solan district is located between the latitudes 30° 03′ 00″ to 31° 09′ 00″ N and longitudes 76° 25′ 12″ to 77° 12′ 00″ E. Nalagarh and Baddi tehsils are located between the latitudes 30° 54′ 23″ to 31° 14′ 36″ N and longitudes 76° 35′ 21″ to 76° 51′ 30″ E. Natural storm drainage to the twin industrial towns of Nalagarh and Baddi is provided by a perennial river, named Sirsa. The river enters the Solan district near Baddi and soon enters the Punjab state. Near Ropar, it finally merges with river Sutlej. Secondary drainage of the region is provided by a number of tributaries, major among which are Chikni Khud near Nalagarh and Balad Nadi at Baddi [1].

B. Sampling of Groundwater

A total of 25 and 40 groundwater samples were collected, from 65 different locations of Nalagarh and Baddi industrial areas of Solan district, Himachal Pradesh. Sampling of groundwater samples was carried out from post-monsoon season 2011 to post-monsoon season 2012. The sampling sites were identified after reconnaissance of Nalagarh and Baddi industrial areas of Solan district, so as to represent the whole area. All the precautions were taken as given in standard methods for sampling and analysis [21].

C. Analytical Methods

The water samples were analysed at the Department of Civil Engineering in Environmental Engineering Laboratory (M.M. Engineering College, M.M University, Mullana) and all the precautions were taken as per standard methods22. Various analysed parameters/elements are sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}). Sodium (Na^+) and potassium (K^+) were estimated using EEL Flame Photometer. In irrigation water the %Na is computed with respect to relative proportions of other cations present in water. Percent sodium in water is a parameter generally computed to evaluate the suitability of water quality for irrigation [22]. In order to calculate the percent sodium (%Na) for irrigation purposes, following equation/formula was used (for calculation all values were taken in meq/l):

$$\%Na = [(Na^+ + K^+) \times 100] / (Ca^{2+} + Mg^{2+} + Na^+ + K^+) \quad \ldots\ldots(i) \quad [2]$$

Percent sodium (%Na) for irrigation purpose was calculated and presented in Figures 1A, 1Aa, 1AA, 2A, 2Aa and 2AA.

III. RESULTS AND DISCUSSIONS

Sodium hazard was an important factor in irrigation water quality. From the literature it was evident that, most crops and woody-type perennial plants are sensitive to low concentrations of sodium salt, but most annual crops are not so sensitive, but may be affected by higher concentrations. Application of high percentage sodium of water for irrigation can restricts the plant growth and sodium reacts with soil to reduce its permeability [23]. The finer the soil texture and the greater the organic matter content, the greater the impact of sodium on water infiltration and aeration. The adverse effect of percent sodium (%Na) will develop in water when the values exceed the maximum tolerance limits of 60 [24]. Whereas, water quality is considered as marginal (for irrigation) if, the values (%Na) fall in between 40-60 [24]. Values falling in between 20-40 considered as good and below 20 considered as very good in quality for irrigation purposes.

A. Percent Sodium (%Na) of Nalagarh Industrial Area

The %Na of the groundwater samples of industrial area of Nalagarh varied from a minimum value of 7.215 at sampling location N3 to a maximum value of 27.869 at sampling location N21 during post-monsoon season 2011, minimum 5.715 at sampling location N3 to maximum 24.667 at sampling location N20 during pre-monsoon season 2012 and minimum 6.970 at sampling location N3 to maximum 22.392 at sampling location N21 during post-monsoon season 2012. All the observations have been presented in Figures 1A, 1AAi, 1AAii, 1AAiii. The average values of %Na (at individual sampling locations) varied from a minimum value of 6.633 at sampling location N3 to a maximum value of 23.37 at sampling location N21 (Figures 1Aa and 1AAiv). The average values of %Na (average of all the 25 samples) were found to be 14.497±4.623, 14.129±4.893, and 13.545±4.508 during post-monsoon season 2011, pre-monsoon season 2012, and post-monsoon season 2012, respectively thus accounting for an overall average %Na value of the groundwater samples of industrial area of Nalagarh as 14.057±4.44 (Figure 1AAiv).

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From the observed %Na values, in the present investigation 92, 88, and 88% of groundwater samples were found very good and 8% (Inference drawn from sampling locations N14 and N21), 12% (Inference drawn from sampling locations N12, N18 and N20) and 12% (Inference drawn from sampling locations N14, N15 and N21) found good in quality for irrigation purposes during post, pre and post-monsoon season 2011, 2012 and 2012 respectively [24].

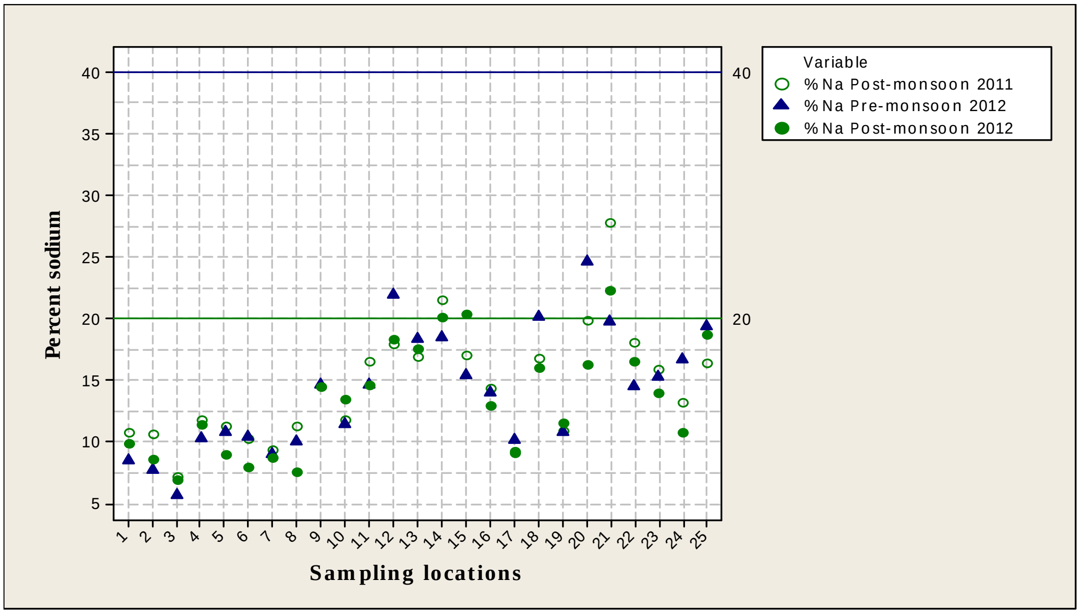

Fig. 1A Variation of %Na values of groundwater at sampling locations of Nalagarh industrial area

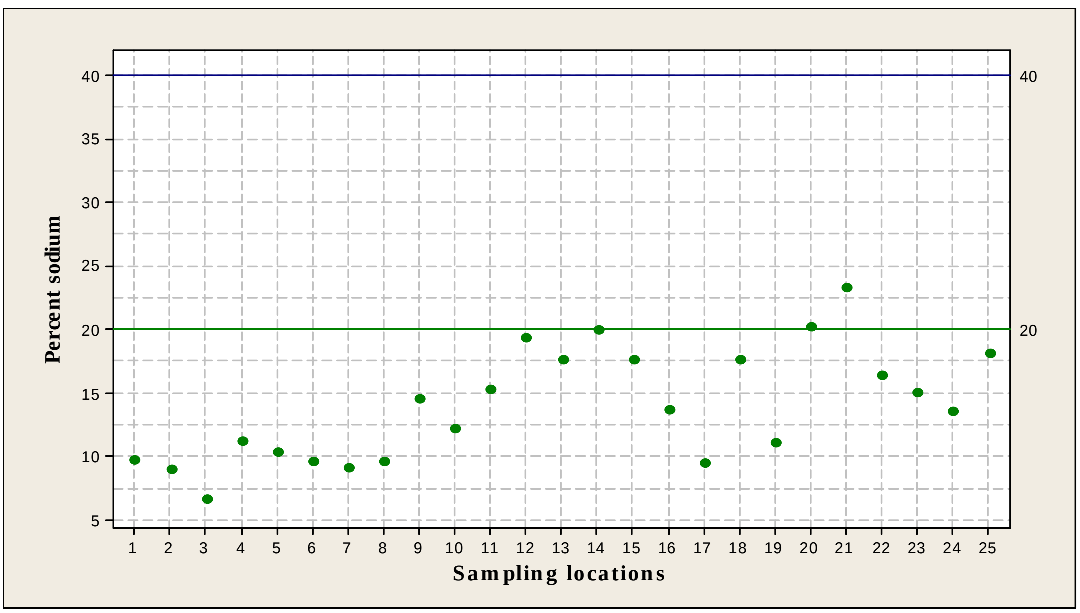

Fig. 1Aa Variation of average %Na values of groundwater at sampling locations of Nalagarh industrial area

Two horizontal lines (One green and other blue coloured) have been drawn on the Figures 1A and 1Aa to access the suitability of quality of groundwater for irrigation purposes. The green-coloured line indicates very good and blue-coloured line indicates good water in quality for irrigation purposes.

The graphical presentation of the statistical summary for %Na of groundwater samples is presented in Figures 1AA (i, ii and iii). The curve for %Na in Figures 1AA (i, ii and iii) are positively skewed (0.945, 0.341 and 0.277) indicating spatial variation of %Na for the groundwater samples within the study area. Figures 1AA (i, ii and iii) show that the curves are flat-topped which indicate that the curves are platykurtic or the values of the coefficient of fourth standardized moment $\beta_2 < 3$. The graphical presentation of the statistical summary for average %Na values of groundwater samples is also made in Figure 1AA(iv) and is found to be platykurtic.

Student's t-test conducted on the mean %Na values of groundwater samples of Nalagarh industrial area for different seasons is shown in Table 1. The test was conducted with two seasons dealt with at one time.

TABLE I

RESULTS OF THE STUDENT'S T-TEST OF THE MEAN VALUES OF PERCENT SODIUM OF GROUNDWATER SAMPLES OF NALAGARH INDUSTRIAL AREA

Seasons	t-value	Significant	Not significant
Post-monsoon 2011 *vs* Pre-monsoon 2012	0.273	X	√
Pre-monsoon 2012 *vs* Post-monsoon 2012	0.439	X	√
Post-monsoon 2011 *vs* Post-monsoon 2012	0.737	X	√

* $p > 0.05$

B. Percent Sodium (%Na) of Baddi Industrial Area

The %Na of the groundwater samples of industrial area of Baddi varied from a minimum value of 7.593 at sampling location B37 to a maximum value of 23.028 at sampling location B13 during post-monsoon season 2011, minimum 5.064 at sampling location B32 to maximum 26.992 at sampling location B13 during pre-monsoon season 2012 and minimum 6.276 at sampling location B37 to maximum 24.602 at sampling location B13 during post-monsoon season 2012. All the observations have been presented in Figures 2A, 2AAi, 2AAii, 2AAiii. The average values of %Na (at individual sampling locations) varied from a minimum value of 6.952 at sampling location B22 to a maximum value of 24.874 at sampling location B13 (Figures 2Aa and 2AAiv). The average values of %Na (average of all the 40 samples) were found to be 12.111±3.624, 11.481±5.206, and 11.52±4.421 during post-monsoon season 2011, pre-monsoon season 2012, and post-monsoon season 2012, respectively thus accounting for an overall average %Na value of the groundwater samples of industrial area of Baddi as 11.704±4.311 (Figure 2AAiv).

From the observed results 97.5, 90, and 92.5% of groundwater samples were found very good and 2.5% (Inference drawn from sampling location B13), 10% (Inference drawn from sampling locations B13, B14, B18 and B29) and 7.5% (Inference drawn from sampling locations B13, B14 and B29) found good in quality for irrigation purposes during post, pre and post-monsoon seasons of 2011, 2012 and 2012 respectively [24].

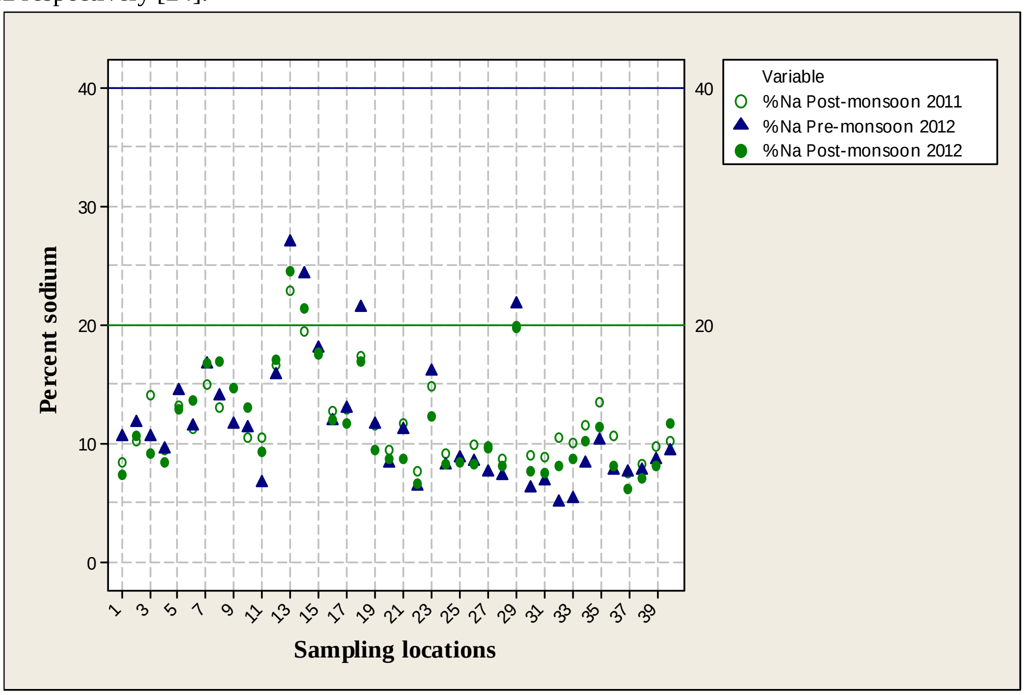

Fig. 2A Variation of %Na values of groundwater at sampling locations of Baddi industrial area

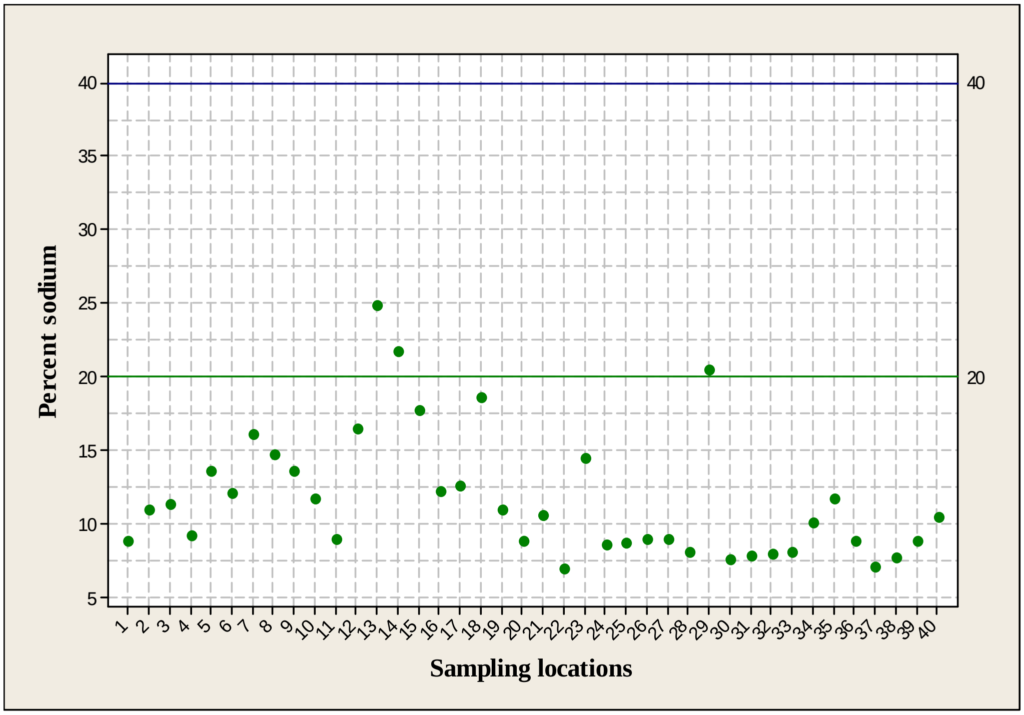

Fig. 2Aa Variation of average %Na of groundwater at sampling locations of Baddi industrial area

Two horizontal lines (One green and other blue coloured) have been drawn on the Figures 2A and 2Aa to access the suitability of quality of groundwater for irrigation purposes. The green-coloured line indicates very good and blue-coloured line indicates good water in quality for irrigation purposes.

The graphical presentation of the statistical summary for %Na of groundwater samples is presented in Figures 2AA (i, ii, and iii). The curves for %Na in the Figures are positively skewed (1.222, 1.356 and 1.221) indicating spatial variation of %Na for the groundwater samples within the study area. The figures show that the curves are platykurtic or the values of the coefficient of fourth standardized moment $\beta_2 < 3$. The graphical depiction of the statistical summary for average %Na values of groundwater samples is also presented in Figure 2AA(iv) and is observed to be platykurtic.

Student's t-test conducted on the mean %Na values of groundwater samples of Baddi industrial area for different seasons is shown in Table 2. The test was conducted with two seasons dealt with at one time.

TABLE II
RESULTS OF THE STUDENT'S T-TEST OF THE MEAN VALUES OF PERCENT SODIUM OF GROUNDWATER SAMPLES OF BADDI INDUSTRIAL AREA

Seasons	t-value	Significant	Not significant
Post-monsoon 2011 *vs* Pre-monsoon 2012	0.627	X	√
Pre-monsoon 2012 *vs* Post-monsoon 2012	0.036	X	√
Post-monsoon 2011 *vs* Post-monsoon 2012	0.653	X	√

*** p > 0.05**

IV. CONCLUSIONS

A. Significant Conclusions Derived from the Study are

1) Considering the average values 88% of groundwater samples were found very good and 12% were good in quality for irrigation purposes in both the industrial areas i.e. Nalagarh and Baddi.

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2) The overall %Na value (average of all sampling locations) shows that all (100%) the groundwater samples were found very good in quality for irrigation purposes in both the industrial areas.

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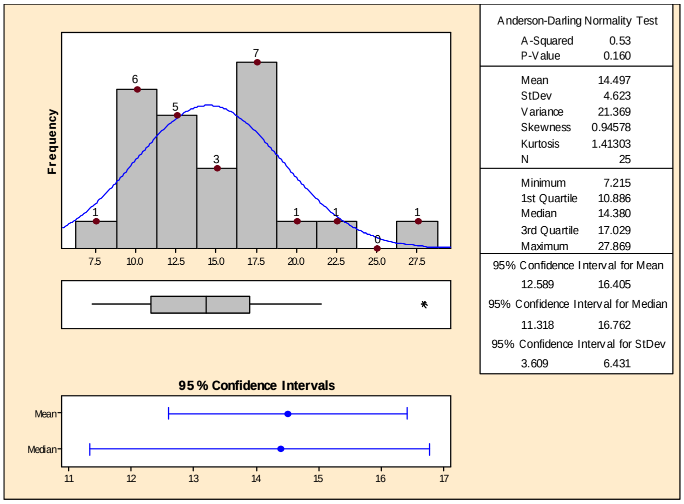
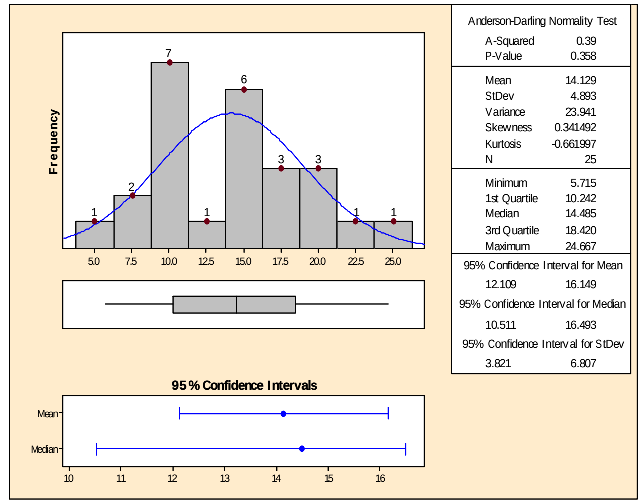
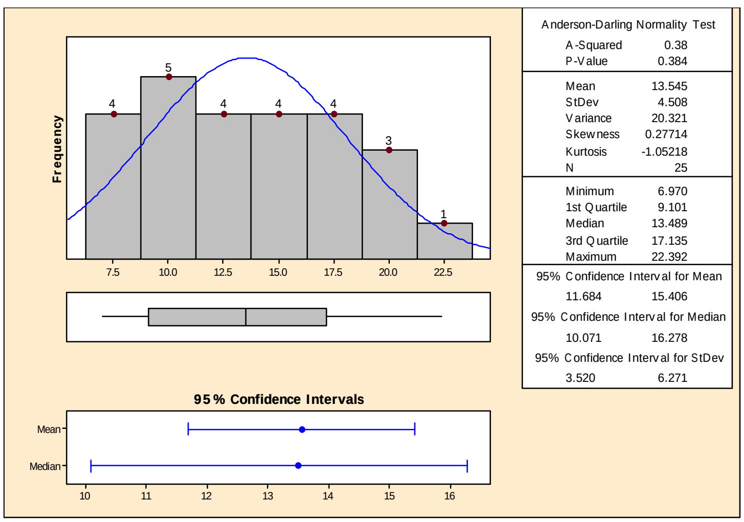


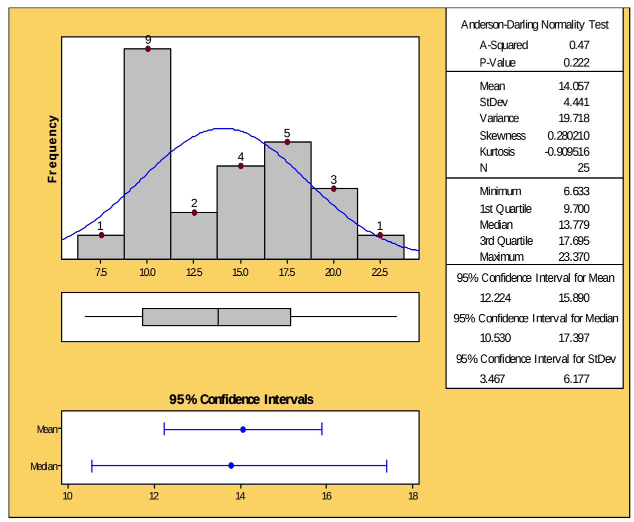
(i) Post-monsoon season 2011



(ii) Pre-monsoon season 2012

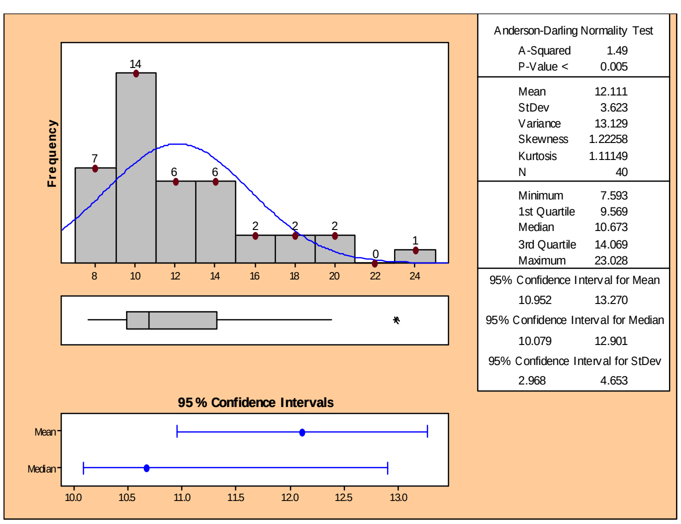


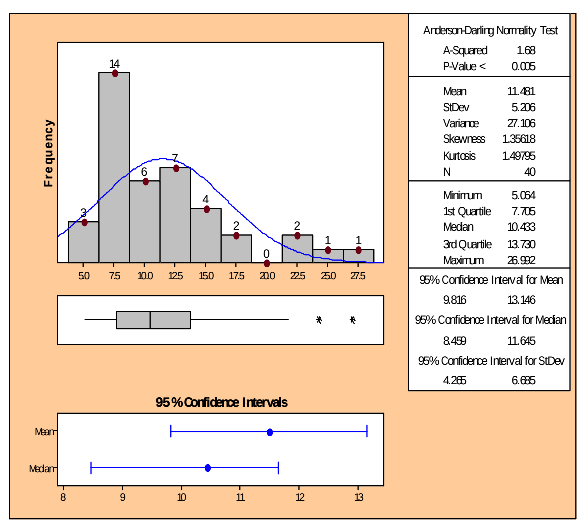
(iii) Post-monsoon season 2012



(iv) Average

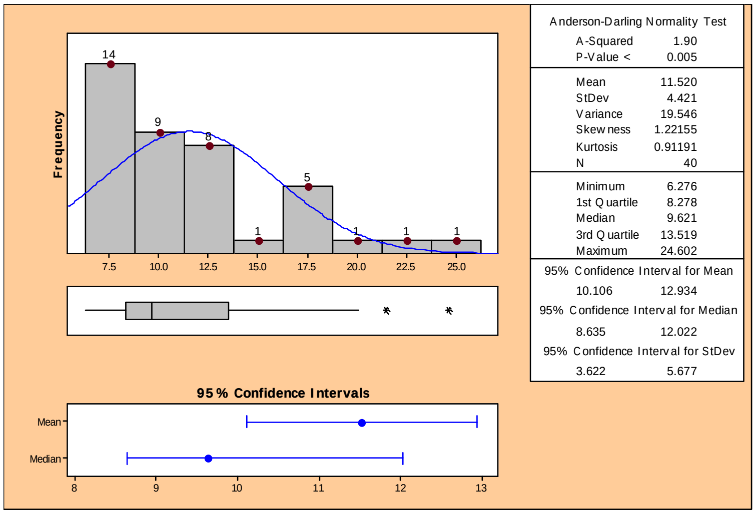
Fig. 1AA Graphical presentation of statistical summary for %Na of groundwater at Nalagarh industrial area

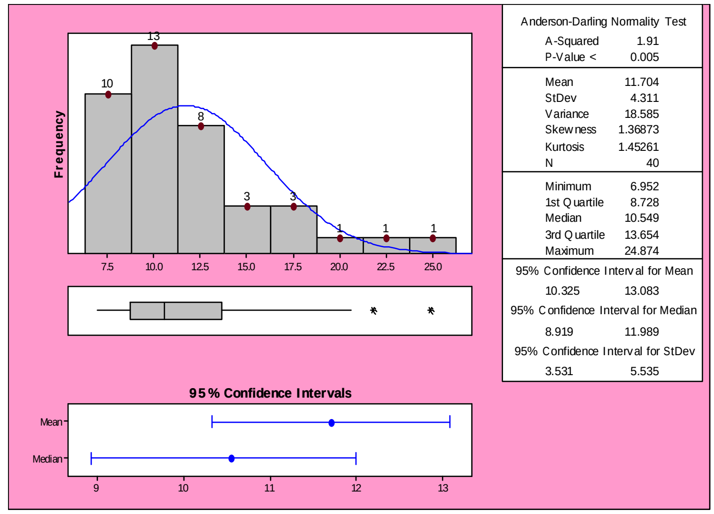




(i) Post-monsoon season 2011

(ii) Pre-monsoon season 2012





(iii) Post-monsoon season 2012

(iv) Average

Fig. 2AA Graphical presentation of statistical summary for %Na of groundwater at Baddi industrial area