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A WATER QUALITY INDEX APPROACH TO APPRAISE TEMPORAL VARIATION AND HEAVY METAL ACCUMULATION IN URBAN STORM WATER FLOW WITH SPECIAL EMPHASIS ON IRRIGATION UTILITY, CHANDIGARH, INDIA

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ABSTRACT

The present work has been done to evaluate and classify the water quality of a storm water rivulet (N-Choe), flowing through the heavily urbanized areas of the city Chandigarh for irrigation purposes, by using the model of irrigation water quality index (IWQI) developed in Brazil by Meireles et al. (2010). N-Choe which drains the major parts of the city was chosen as the study area to understand the water quality index approach during pre monsoon and post monsoon periods, as water of the N choe receiving toxic effluents from the industrial and residential areas of the city is being utilized by the farmers of the adjacent villages to grow crops. The results showed that the value of IWQI ranged between 70-85 for both the seasons thus falls under the 'Low restriction' category for irrigation purposes. Water in this category should be used in the soils with light texture or moderate permeability and should be avoided in soils with high clay. The study area witnessed heavy textured soil indicating that this water which was used for irrigation purpose was potentially leading to the sodicity problem in the area under investigation. The metal concentration in the samples taken from the study area showed the trend of Fe>Ni>Mn>Cd thus showed a severe drop in the water quality. Sodium absorption ratio (SAR), Residual sodium carbonate (RSC), Percent Sodium (% Na), Permeability Index (PI), and Kelly's Index (KI) was calculated for better understanding the suitability of water quality for irrigation purposes.

KEYWORDS: Irrigation Water Quality Index, Sewage Discharge, Temporal variation, Heavy metals, Irrigation suitability.

INTRODUCTION

Storm water is one of the major untapped urban water resources that can be exploited as an alternative water resource. Water that drains into the surface water is likely to increase the quantity of solutes thereby increasing the concentration of certain ions that ultimately lower the quality of water for irrigation purpose. Storm water carries a wide variety of contaminants as it run across rooftops, parking lots, lawns and other surfaces in our cities leading to urban storm water pollution. The hydrologic impact of urbanization may cause the changes to the hydrology of a developing watershed, increased peak discharges, increased volume of storm runoff, decreased travel time or time of concentration and increased frequency and severity of flooding (Mimi, 2008).

The quality of the surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban, industrial and agricultural activities and the human exploitation of water resources) (Jarvie et al., 1998; Liao et al., 2007; Mahavi et al., 2005; Nouri et al., 2008). The land use changes increase the amount of impervious surfaces resulting in storm runoff events that negatively affect stream ecosystems and water quality (Paul et al., 2001). The utilization of degraded quality waters in irrigation has been the main cause for the deterioration of the quality of soils and the agricultural crops grown in such soils (Ayers and Westcot, 1985). Water quality index provides a single number that expresses the overall water quality at a certain location and time, based on several water quality parameters. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a waterbody with numbers.

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Many researches have been conducted in many parts of the world to measure the surface water quality index. Meirles et al. (2010) classified water in the Acarau Basin, in the North of state of Ceara, Brazil for irrigation use. Shihab and Al-Rawi (1994) used water quality index (WQI) as a management tool for water quality of Tigris River within Mosul city for different uses. Abdul Jabbar. K. Al meine (2010) proposed a new technique to development (IWQI) and applied to assess the irrigation water quality of Tigris, Euphrates and Shatt Al Arab rivers in Iraq. Fulazzaky (2009) assessed the status and the suitability of the Citarum River water in Malaysia for agriculture use. Bhatti and Latif (2009) used water quality index to assess the water quality of Chenab River in Pakistan for irrigation use.

The present investigation is a step forward in the analysis of water samples taken from North- Choe (commonly known as N- Choe), a seasonal storm water rivulet for irrigation purposes by the applied model of IWQI developed by Meireles et al. (2010). Though this model has been applied by different workers in different parts of the world yet this approach has been used in the area under investigation and has given desired results in policy making to save the society from the harmful effects of using this drain water for irrigation.

STUDY AREA

Location and Extent

Chandigarh is a Union Territory of India located on the Indo-Gangetic alluvium at the foothills of the Siwaliks about 250 Km north of Delhi. Chandigarh lies between latitudes 30o 40’00’’ and 30o 46’30’’N and longitudes 76o 42’40’’ and 76o 51’00’’E. Chandigarh has an area of 114 sq.km. It is one of the fastest growing city with a total population of 10, 54, 686. The city Chandigarh was declared a Union Territory in the year 1966 with joint capital of both the states of Punjab and Haryana, India.

In the last few years, there has been an increasingly greater emphasis on the deterioration of water quality of the N-Choe due to continuous discharge of sewage in the drain. The North- Choe (commonly known as N- Choe) is a seasonal, highly polluted rivulet which originates from Sector 3, Chandigarh. Location map of the study area is given in Fig.1. It flows from northeast to southwest direction and traverses north central part of the city, before entering the adjoining township of Mohali which further carries it to the Ghaggar river in Haryana. The sewage treatment plants (STP’s) are rendered useless for the most part of the city as the municipal population is increasing at the exponential rate. The volume of waste water is also mounting at the same pace which is presently 264.95 million liters per day (MLD) and total capacity of all the sewage treatment plants in the city is 156 million liters per day (MLD), rest of the untreated sewage was directly being discharged into the N- Choe containing alarming level of organic and inorganic effluents. The drainage system in Chandigarh comprises of a hierarchy of natural and man-made drains and water bodies that ultimately discharge surface run-off into N- Choe.

This storm water drain was initially designed for the rain intensity of half an inch per hour. However due to increased green areas and open spaces coming under construction, the run off co-efficient has increased tremendously. An impervious surface collects and accumulates pollutants and these pollutants are quickly washed off and are rapidly delivered to storm water drains of the study area during the storm events. The choe where only rain water should flow, untreated sewage or polluted water is being directly discharged at various points in Chandigarh. Thus changes in the land use pattern of the city have resulted in the degradation of surface and subsurface water regimes. This water is being utilized by farmers for growing vegetables in the agricultural fields along the stream. Therefore it is a matter of increasing concern to prevent the bioaccumulation and biomagnification of toxic pollutants in the food chain.

Drainage in the study area

N-Choe, Sukhna Choe and Patiali ki Rao flows through the city perform important ecological function. All the three choes originate in the Siwalik Hills and provide seasonal drainage for the surface water runoff from their catchments during the monsoons. Their sandy beds also recharge the deep sub-soil aquifers which provide Chandigarh about 20% of its water supply. Many of Chandigarh’s tube wells are located in the beds of these choes. Unfortunately, several insensitive developments are taking place next to and within the choe beds both in the Union Territory (UT) and Punjab. Untreated sewage and solid waste of the residents in the UT is being thrown into these choes, thus destroying the local ecology and becoming a public health hazard, it is likely to pollute the sub-soil water threatening its water recharging capacity. Present study focuses on N choe because the following reasons

This storm water drain suffer from :

i) High degree of man made encroachments.

ii) High degree of water/environment pollution.

iii) Discharge of untreated sludge in the choe bed.

v) Low availability of fresh water for irrigation in the study.

Irrigation facilities in the area

The water table in the vicinity of these cities is very low and thus, it is very difficult for the farmers to provide their own tubewells for irrigation of their agricultural fields due to their poor financial conditions. Therefore, the farmers, having their fields adjoining to these drains, are using wastewater of drains for irrigation of their fields being cheapest and easily available source. The farmers of these villages are growing various types of vegetables to cater their own needs and to sell in the market to earn their livelihood, unaware of the harmful effects of these vegetables grown by the application of wastewater.

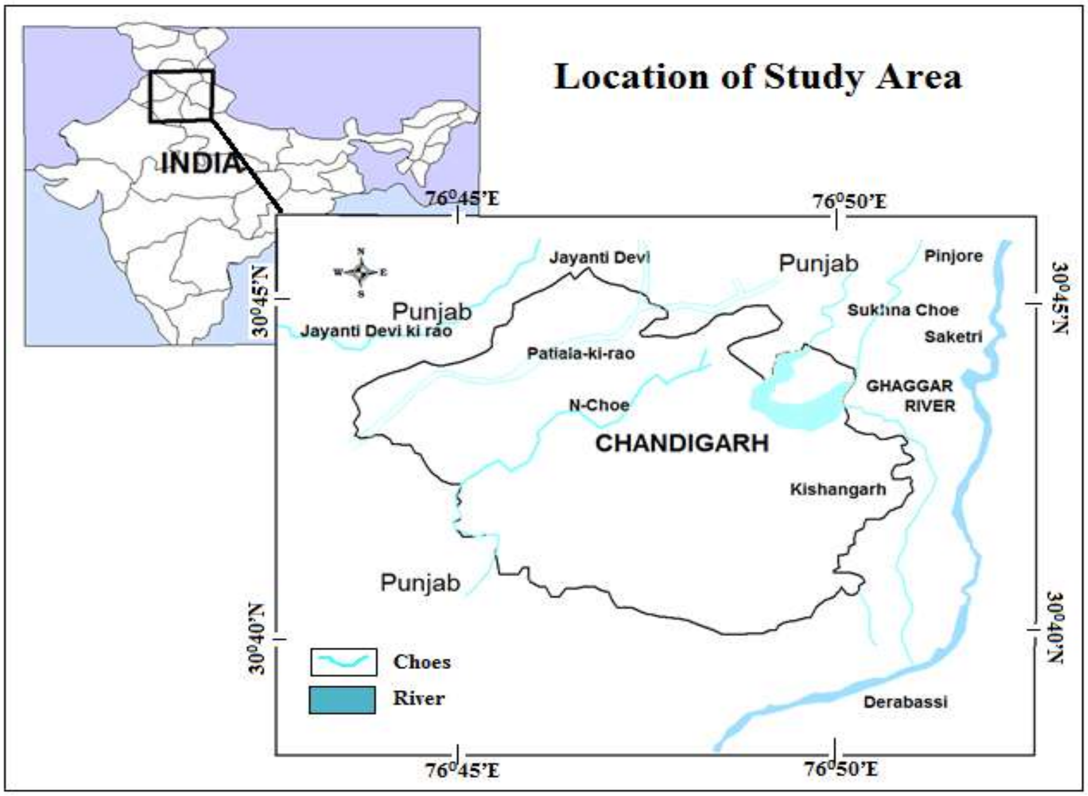

Fig.1.Location map of study area

MATERIAL AND METHODS

Sample Collection

Thirty three sampling points were located along and across the North Choe from upper, mid and downstream sites at about 20m interval. 33 samples were collected during pre monsoon (May 2012) and post monsoon (October 2012) seasons making a total of sixty six samples. Layout of the study area and sample collection sites is shown Fig. 2. Sampling, preservation and analytical protocols were conducted by standard methods. Good quality, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratory for analysis. The standard procedures of sampling were adopted and preservatives were added as per the nature of analysis during the collection of the samples. At the time of sampling, bottles were thoroughly rinsed with water to be sampled. Samples were analysed as per the standard methods (APHA, 2005) within a short period of time to get a more reliable and accurate results. Analysis were done for the pH, EC,TDS and the major ions Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, CO_3^{2-} and NO_3^-, BOD, COD and DO using APHA method. The parameters pH, EC and DO were monitored at the sampling sites and other parameters like Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^- were analysed by titration, Na^+ and K^+ were measured by flame photometry , NO_3^- and SO_4^{2-} by U.V. Spectrophotometer, BOD was measured by Winkler's method and COD were measured with

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Reflux digestion method. Heavy metal analysis was done using ICP-MS.

In this study IWQI model was applied on the data. In order to develop the water quality index EC, Na^+, Cl^-, SAR, HCO_3^- parameters were considered more relevant to the irrigation use (Meireles et al., 2010). The statistical software Minitab 16 and Rockworks 15 were employed for the calculations and data presentation.

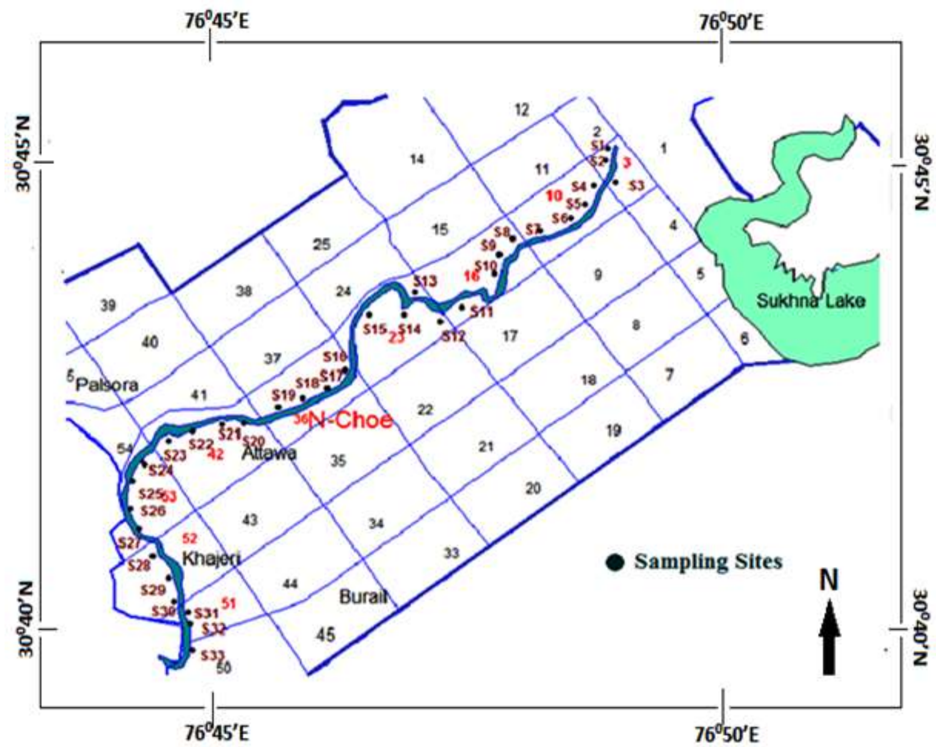

Fig.2.Map showing the sampling sites in the study area

RESULTS AND DISCUSSION

Irrigation Water Quality Index

The comparison of water quality parameters with the irrespective regulatory standards is the basis of water quality index. Irrigation water quality index model developed by (Meireles et al., 2010) was applied on the data. In order to develop the proposed water quality index; EC, Na+, Cl-, SAR, HCO3- parameters were considered more relevant to the irrigation use. In the next step, a definition of quality measurement values (qi) and aggregation weights (wi) was established. Values of (qi) were estimated based on each parameter value, according to irrigation water quality parameters proposed by the University of California Committee Of Consultants - UCCC and by the criteria established by Ayers and Westcot (1999), shown in Table 1. Water quality parameters were represented by a non-dimensional number; the higher the value, the better the quality water.

Table 1: Parameter Limiting Values for Quality Measurement (qi)

qi	EC	SAR	Na	Cl	HCO3
			meq/l	meq/l	meq/l
85-100	200≤EC<750	SAR<3	2≤Na<3	Cl<4	1≤ HCO3<1.5
60-85	750≤EC<1500	3≤SAR<6	3≤Na<6	4≤Cl<7	1.5≤ HCO3<4.5
35-60	1500≤EC<3000	6≤SAR<12	6≤Na<9	7≤Cl<10	4.5≤ HCO3<8.5

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0-35	EC<200 or EC≥3000	SAR≥12	Na<2 or Na≥ 9	Cl≥10	HCO3<1 or HCO3≥ 8.5

Source: after Ayers and Westcot , 1999

Values of q_i were calculated using the following equation, based on the tolerance limits shown Table 1 and analytical results of water quality.

$$q_i = q_{imax} - [(x_{ij} - x_{inf}) \times q_{iamp}) / x_{amp}] \quad [1]$$

q_{imax} = Maximum value of qi for the class.
x_{ij} = Estimated value of the water quality parameter obtained from the laboratory analysis.
x_{inf} = Corresponding value to the lower limit of the class to which the parameter belongs.
q_{iamp} = Class amplitude
x_{amp} = Class amplitude to which the parameter belongs.
In order to evaluate x_{amp} of the last class of each parameter, the upper limit was considered to be the highest value determined in the physico-chemical and chemical analysis of the water samples. Each parameter weight used was obtained by (Meireles et al., 2010) as shown in Table (1). The wi values were normalized such that their sum equals one.
The irrigation water quality index (IWQI) was calculated as:

$$IWQI = \sum_{i=1}^{n} qi \times wi \quad [2]$$

where IWQI is a dimensionless parameter ranging from 0 to 100, q_i is the quality of the n^{th} parameter, a number from 0 to 100, a function of its concentration or measurement; w_i is the normalized weight of the n^{th} parameter, a function of its importance in explaining the global variability in water quality. Restrictions to water use classes were characterized as shown in Table 3.
The value of IWQI was found to be 79.38 during the pre monsoon while value decreased to 72.58 during post monsoon showing the dilution impact during the storm events (Table 2). The water quality rating showed that water generally was in the class of 'Low restriction' during both seasons recommended for use in irrigated soils with light texture or moderate permeability. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay (Meireles et al., 2010).

Table 2: Calculation of water quality index for pre monsoon season

Parameters	Pre-monsoon				Post-monsoon			
	Observed Values (x_{ij})	Weight (w_i) (Meireles et al.,2010)	Quality Rating (q_i)	$w_i \times q_i$	Observed Values(x_{ij})	Weight (w_i) (Meireles et al.,2010)	Quality Rating (q_i)	$w_i \times q_i$
EC	466.30	0.211	64.6	13.50	570.5	0.211	50.6	10.67
Na^+	1.06	0.204	45.40	9.26	1.34	0.204	37.52	7.65
HCO_3^-	1.30	0.202	96.48	19.48	0.65	0.202	36.44	7.36
Cl^-	2.04	0.194	128.00	24.83	0.49	0.194	135.1	26.20
SAR	4.40	0.189	65.17	12.30	1.86	0.189	1.76	0.33
Total		1.000		IWQI = $\sum_{i=1}^{n} qi \times wi$ =79.38		1.000		IWQI = $\sum_{i=1}^{n} qi \times wi$ =72.58

Table 3. Water Quality Index Characteristics

IWQI	Water Use Restrictions	Recommendations	
		Soil	Plant
85-100	No restriction (NR)	May be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability	No toxicity risk for most Plants
70-85	Low restriction (LR)	Recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay	Avoid salt sensitive plants

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55-70	Moderate restriction (MR)	May be used in soils with moderate to high permeability values, being suggested moderate leaching of salts.	Plants with moderate tolerance to salts may be grown
40-55	High restriction (HR)	May be used in soils with high permeability without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2000 µS cm-1 and SAR above 7.0.	Should be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO3 values
0-40	Severe restriction (SR)	Should be avoided its use for irrigation under normal conditions. In special cases, may be used occasionally. Water with low salt levels and high SA require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO3.

Source: after Meireles et al., 2010

Temporal variation

Runoff from densely developed lands of the study area is typically contained high amounts of nutrients from lawn fertilizers, animal wastes and other non point sources. Runoff during the storms provides a path to these constituents to reach the storm water flow regime of the study area. The water sample showed the concentration of pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^+, K^+ , HCO_3^- , SO_4^{2-}, Cl^-, NO_3^-, BOD, COD, DO ranged from 6.4-8.4, 0.23-0.73 (dS/m) , 167-375 (mg/l), 0.54-3.32 (meq/l), 0.28-3.45 (meq/l), 0.32-1.82 (meq/l), 0.2-6.7 (meq/l), 0.49-2.13 (meq/l), 0.5-1.29 (meq/l), 0.2-6 (meq/l), 0-4.01(meq/l), 3.6-124 (mg/l), 23-333 (mg/l), Below detectable limit (BDL)-10.2 (mg/l) respectively during the pre monsoon period and were ranged from 6.4-8.4, 0.27-0.73 (dS/m), 181-487 (mg/l), 0.54-3.78 (meq/l), 0.22-1.96 (meq/l), 0.21-2.46 (meq/l), 0.8-7.2 (meq/l), 0.27-0.90 (meq/l), 0.22-0.24 (meq/l), 0.16-0.67 (meq/l), 0-3.21 (meq/l), 2-111.2 (mg/l), 21.2-318 (mg/l), Below detectable limit(BDL)-11.4 (mg/l) respectively during the post monsoon period. The result showed that during both rainy and dry season, the concentration of soluble cations and anions, the interacting effect of salinity are well within the acceptable limits for irrigation of crops (Table 4.) despite the large content of sewage effluents characterized by some of the areas. Mean value of BOD and COD are more pronounced in the pre monsoon than post monsoon season, this may be due to the dilution effect during monsoon season. Thus organic and nutrient pollution has been observed in the storm water of the study area which is due to the natural organic matter decomposition. This suggests that during the pre monsoon.

season, the volume of the water in choe is significantly reduced and there is a substantial addition of organic materials from residential areas along the choe and the value lowered in the post monsoon season were due to aeration and dilution of contaminants of surface water of N choe by storm water runoff. Elevated BOD level and depleted DO has an adverse effect on aquatic flora and fauna.

S. No.	Parameters	No. of samples	Usual range in irrigation water Food and Agriculture Organization (F.A.O.), 1990	Pre- Monsoon			Post-Monsoon		
				Range	Mean	Standard Deviation	Range	Mean	Standard Deviation
1.	pH	33	6.0-8.5	5.6-7.2	6.64	0.36	6.4-8.4	7.68	0.44
2.	EC(dS/m)	33	0-3	0.23-0.69	0.46	0.11	0.27-0.75	0.57	0.16
3.	TDS(mg/l)	33	0-2000	167-446	303.3	62.44	181-487	366	105.10
4.	Ca^{2+} (meq/l)	33	0-20	0.54 – 3.32	1.80	0.65	0.54-3.78	2.70	0.84
5.	Mg^{2+}(meq/l)	33	0-5	0.28 -4.26	2.12	0.90	0.22-3.41	1.23	0.77
6.	Na^{+} (meq/l)	33	0-40	0.32- 1.82	1.06	0.46	0.21-2.46	1.34	0.76
7.	K^{+} (meq/l)	33	-	0.005-0.17	0.05	0.03	0.02-0.18	0.09	0.05
8.	Cl^{-}(meq/l)	33	0-30	0.2 – 6.0	2.04	1.12	0.16-0.84	0.49	0.16
9.	HCO_3^{-}(meq/l)	33	0-1	0.49-2.13	1.33	0.44	0.27-0.90	0.65	0.17
10.	SO_4^{2-} (meq/l)	33	0-20	0.46-1.29	0.78	0.21	0.21-0.26	0.24	0.01
11.	NO_3^{-} (mg/l)	33	0-10	BDL-4.0	0.88	1.14	BDL-3.7	0.86	1.09
12.	DO(mg/l)	33	-	3.6-124	47.5	3.02	2-111.2	36.99	3.53
13.	COD(mg/l)	33	-	23-333	127.7	111.60	21.2-318	98.17	90.3
14.	BOD(mg/l)	33	-	BDL-10.2	5.1	46.85	BDL-11.4	5.7	38.65

Box and Whisker Plot Showing Seasonal variation
Box and Whisker plots were used to show the temporal variation of the major ions (Fig.3). Box plot provides the visual impression of the location and shape of the underlying distributions. The upper and lower quartiles (Q1 & Q3) of the data defines the top and bottom of the rectangular box. The line across the box represents the median value and the size of the box represents the spread of the central value. The whiskers extend to the lowest and highest observations inside the region defined by Q1-1.5 (Q3 - Q1) and Q3 +1.5 (Q3-Q1). Individual points with values outside these limits (outliers) are plotted with asterisks. The abundance of major cations were in the order of Ca2+> Mg2+ > Na+>K+ and major anions were in the order of Cl- >HCO3- >SO42- during pre monsoon while during post monsoon the abundance of major cations were in the order of Ca2+>Na+>Mg2+ > K+ and major anions were in the order of HCO3-> Cl-> SO42-.Through the interpretation of Box and Whisker plot it has been well observed the accumulation of contaminants by impervious surfaces of the city is being transported to the choe along with the storm runoff, therefore these parameters need a close attention.

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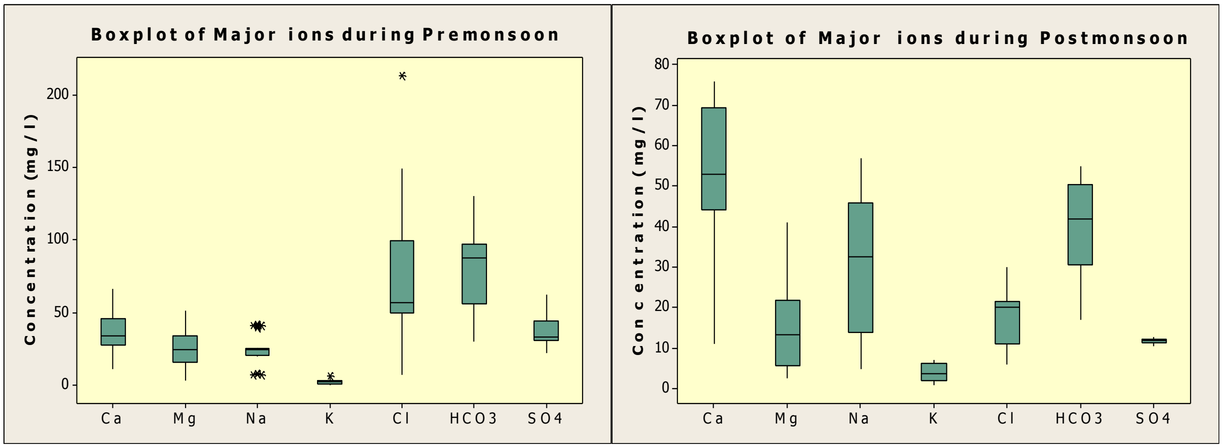

Fig.3.Box and Whisker plot for pre monsoon and post monsoon

Heavy metal analysis

Analysis of surface water for heavy metals Pb, Fe, Cd, Cr, Cu, Ni, As, Zn, Mn revealed that elemental concentration of Fe in stream sediments was followed by Ni, Mn and Cd i.e. Fe>Ni>Mn>Cd (Table 5.). Heavy metals are very harmful because of their non bio-degradable nature, long biological half lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Comparing the values of metals with the standard values given by FAO it was found that 90% samples were high in Fe, 72.7% samples were high in Ni, 36.3% samples were high in Mn and 12.1% samples were high in Cd. All the other metals were within the safe limits considering the FAO criteria for irrigation quality.

Heavy metals including Cd, Cu, Cr, Fe, Mn, Ni, Pb & Zn often originates from infrastructures like roads, guardrails and constructional materials, when precipitation lands on these and other impervious surfaces it picks up contaminants and finds their way to the storm water drain. Irrigation water with the high content of Fe level is the cause of bacterial activity (redort disease). Presence of these Iron bacteria which derive their energy from oxidation of Fe(II) to Fe(III) can cause a rotten egg odor in water and a sheen on the water surface. High Fe content in surface water can also lead to the clogging of drip irrigation emitters and also the discoloration on foliage plants in overhead irrigation applications. In the stream high iron content can also cause algal blooms, which further elevates the BOD level, resulting in deterioration of aquatic flora and fauna. High Ni concentration has also been observed in the study area The most common type of reaction to Ni exposure is a skin rash at the site of contact. Skin contact with metallic or soluble Ni compounds can produce allergic dermatitis.

Table 5. Results of the heavy metal analysis in the study area

S.No.	Parameters	No. of samples		Analytical Results		
			Range	F.A.O. Irrigation Water Standards	No. of samples above permissible limit	Percentage of samples above permissible limit
1.	Pb(mg/l)	33	0.013-0.056	5	Nil	Nil
2.	**Cd(mg/l)**	**33**	**0-0.6**	**0.01**	**4**	**12.1%**
3.	Cr(mg/l)	33	0.001-0.046	0.1	Nil	Nil
4.	Cu(mg/l)	33	0.001-0.059	0.2	Nil	Nil
5.	**Fe(mg/l)**	**33**	**0.4-52**	**5**	**30**	**90%**
6.	**Mn (mg/l)**	**33**	**0.04-0.467**	**0.2**	**12**	**36.3%**

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7.	**Ni(mg/l)**	**33**	**0.002-5.786**	**0.2**	**24**	**72.7%**
8.	As(mg/l)	33	0.001-0.005	-	Nil	Nil
9.	Zn(mg/l)	33	0.058-0.358	2	Nil	Nil

Sodium Absorption Ratio

There is a significant relationship between the SAR value of irrigation water and the extent to which the sodium is absorbed. If the water used for irrigation is high in Na+ and low in Ca2+ the ion exchange complex may become saturated with Na+ which destroys the soil structure, due to dispersion of clay particles. This dispersion results in the breakdown of soil aggregates. The soil becomes hard and compact when dry and reduces the infiltration rate of water and air into the soil affecting its structure.

Sodium absorption ratio has been calculated as follows:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{2+} + Mg^{2+}/2}} \qquad [3]$$

Where all ionic concentration are expressed in meq/l. SAR values in the study area ranged from 1.59 to 7.8 meq/l and 0.62 to 5 meq/l during pre monsoon and post monsoon seasons respectively. According to the Richard's classification all the samples in the study area have been classified as excellent for irrigation (Table.6.).

A more detailed analysis of the suitability of water for irrigation was made by plotting the data on US Salinity Laboratory Diagram. The US salinity lab's diagram (US Salinity Lab Staff, 1954) is used widely for rating irrigation waters, where SAR is plotted against EC. The analytical data plot is shown in Fig. 4. The majority of water samples falls in C2S1 category (medium salinity with low sodium) in both seasons which can be used for irrigation on all types of soil without danger of exchangeable sodium.

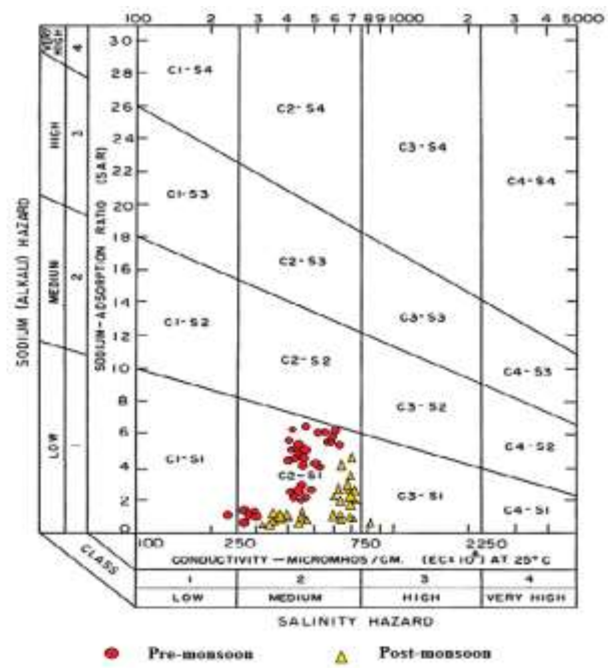

Fig. 4 USSL diagram for irrigation water quality classification (USSL 1954)

Percent Sodium (% Na)

Sodium is an important ion used for the classification of irrigation water due to its reaction with soil which reduces its permeability. The % Na is computed with respect to the relative proportion of cations present in the water as

$$\%Na = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100 \qquad [4]$$

Where all ionic concentration are expressed in meq/l. Percentage sodium value in the study area ranged from 15.0 to 44.7 meq/l during pre monsoon and 11.6 to 52.5 meq/l during the post monsoon season. The elevated value of percent sodium in the samples of village Khajeri was due to the contribution of sewage discharge from the nearby slum areas directly into the storm water drain.

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Wilcox Classification
Wilcox (1955) diagram is adopted for classification of irrigation, wherein the EC is plotted against the percentage of Na. Based on Wilcox classification, during pre monsoon season, 90% of the samples belong to the excellent to good category, while during the post monsoon season, 85% of the samples belong to good to permissible category (Fig.5.).

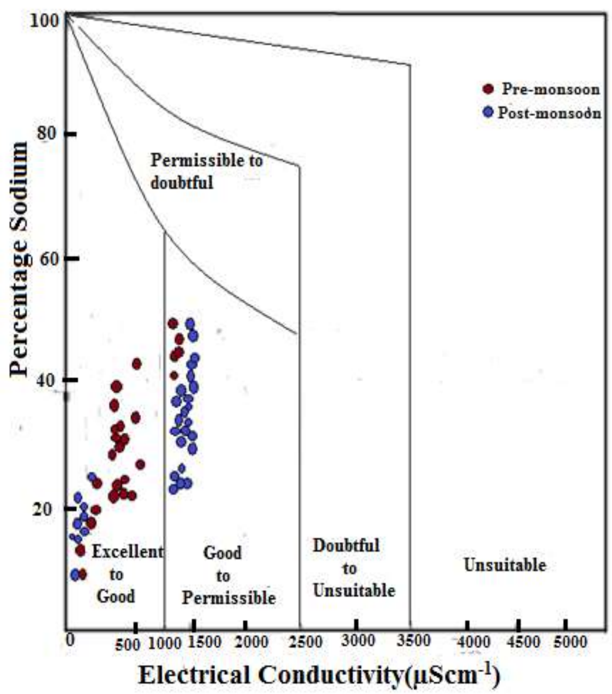

Fig. 5. Wilcox diagram for irrigation water quality classification

Residual sodium carbonate (RSC)
Residual sodium carbonate is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water used for agricultural activity. The land irrigated with the water having high RSC value becomes infertile owing to the deposition of sodium carbonate as known from the black color of the soil and long term application of high RSC water affects the crop yield.

It is determined by the formula:

$$RSC = (HCO_3^- + CO_3^-) - (Ca^{2+} + Mg^{2+}) \quad [5]$$

Where all ionic concentrations are expressed in meq/l. Residual sodium carbonate in the study area ranged from -5.6 to -0.83 meq /l and -5.0 to -1.78 meq/l during pre monsoon and post monsoon respectively. The value of the RSC is negative at all sampling sites, indicating that there is no complete precipitation of calcium and magnesium.

Permeability index (PI)
Doneen (1964) classified irrigation waters based on the permeability index (PI). PI is defined by

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad [6]$$

where concentration are expressed in meq/l.
Class I and class II orders water are categorized as good for irrigation with 75% or with more of maximum permeability. Class III waters are unsuitable with 25% of maximum permeability.
During pre monsoon season, 87.7% of water samples fall in Class-I, while 12.1% of the samples fall in Class II and during post monsoon season, 21.2 % of the water samples fall in Class-I and 75.7% of the samples fall in Class-II and one sample fall in the Class III category in the Doneen's chart (Domenico and Schwartz, 1990), implying that the water is of good quality for irrigation purposes with 75% or more of maximum permeability (Fig.6.)

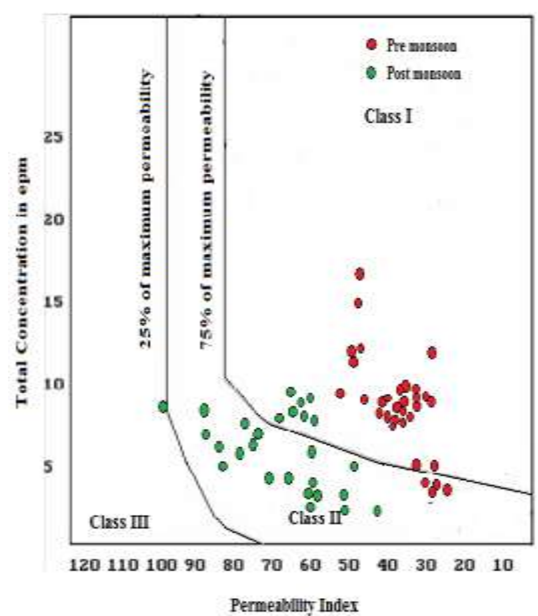

Fig.6.Classification of irrigation water for soils of medium permeability

Kelly's Index
Kelly's index is used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium is considered for calculating this parameter.

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$$KI = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

Waters with KI <1 is suitable for irrigation, while those with greater ratio are unsuitable (Kelly, 1940). KI in the present study varied between 0.12 to 0.39 and 0.08 to 0.8 during the pre monsoon and post monsoon respectively. Therefore, in the study area all the samples fall in the suitable category for both seasons.

Table 6.Classification and distribution of irrigation water based on EC, SAR, %Na, RSC, PI, KI

Parameters	Rate of hazard	Water Class	Pre monsoon		Post monsoon	
			Range	No. of samples	Range	No. of samples
Salinity(EC) (µS/cm)	<250 250-750 750-2250 2250-5000	Excellent Good Permissible Unsuitable	0 - 235 254 - 692 - -	1 sample 32 samples - -	- 275 - 736 753	- 32 samples 01 sample -
Sodium Absorbtion Ratio(SAR) (meq/l)	<10 10-18 18-26 >26	Excellent Good Fair Poor	1.59 - 7.8 - - -	33 samples - - -	0.6 - 2-5 - - -	33 sample - - -
Percent Sodium (%Na) (meq/l)	<20 20-40 40-60 60-80 >80	Excellent Good Permissible Doubtful Unsuitable	15 - 18 21.9 - 39.7 40.7 - 44.7 - -	5 samples 23samples 5 samples - -	11.6-19.5 22.4 - 40.8 43.9 - 52.5 -	07 samples 21 samples 05 samples
Residual Sodium Carbonate(RSC) (meq/l)	<1.25 1.25-2.50 >2.50	Safe Doubtful Unsuitable	-5.6 - -0.8	33 samples - -	-5.0 - -1.78	33 samples - -
Kelly's Index(KI) (meq/l)	<1 >1	Suitable Unsuitable	0.12 - 0.39 -	33 samples -	0.08 - 0.80 -	33 samples -

CONSLUSION

The value of IWQI ranged between 70-85 for both the seasons thus falls under the 'Low restriction' category for irrigation purposes. Water in this category should be used in the soils with light texture or moderate permeability and should be avoided in soils with high clay. The study area witnessed heavy textured soil indicating that this water which was used for irrigation purpose was potentially leading to the sodicity problem in the area under investigation. Significant deteriorated conditions were detected during the pre monsoon season due to low dilution capacity of the water during the pre monsoon period when discharge rates are low. It was observed during sampling that the various outlets from the residential and commercial area are discharging wastewater in the storm water drain which should be avoided to maintain the quality of storm water flow. The most affected parameters were alkalinity, BOD, COD and DO thus these parameters needs a close attention. High level of BOD clearly indicates the bacteriological load which is not even fit for basic marine life, thus all the discharge of sewage flow should be diverted immediately and strict law in this regard should be implemented by the concerned authorities. The assessment of water for irrigation use shows that the water is of good to permissible quality. Keeping in view of the high concentration of heavy metals at some of the sampling sites of the study area due to the inadequate treatment of the domestic and industrial effluent, prior treatment measures should be adopted. Assessment of various physico-chemical parameters for its suitability for irrigation purposes showed that despite the large content of sewage effluents characterized by some of

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the sampling sites in the study area, physico-chemical parameters remain within the safe limits for irrigation purposes. The results revealed that water of some polluted stations like village Khajeri and village Attawa are unsuitable upto a certain extent. The most important issue of concern includes the improper management of industrial and domestic effluents, therefore sewage treatment plant (STP) should be installed to prevent the outbreak of water borne diseases and to avoid the precarious situation in the area. It is equally necessary to educate the common people and make them understand the necessity of keeping the surface water clean by not letting the sewage water mix with storm water which urgently needs to be protected from the perils of contamination.

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