Volume: 8 Issue: VIII Month of publication: August 2020

DOI: https://doi.org/10.22214/ijraset.2020.30883

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

Water Pollution due to Discharge of Industrial Effluents in Sutlej River and its Impact on Groundwater

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Abstract: The main objective of this study is to find out the effect on Sutlej River water in Nangal from the discharge of industrial effluent through National Fertilizers Limited, Nangal Drain (NFL Drain) and also its further impact on the Groundwater in the nearby villages. For this in our study a total of 40 Sutlej River water samples were taken from 5 different selected locations from adjoining areas of floodplain of River Sutlej and National Fertilizers Limited (NFL Nangal) Drain and a total of 80 Groundwater samples were taken from 10 different selected villages on the downstream side of NFL Drain and the Sutlej River. Groundwater samples were collected from hand pumps, bore wells, tube wells of different depths according to ease and availability at the particular selected location. Both the Sutlej River water and the Groundwater samples were collected twice a month from December, 2109 to March, 2020. Various Physico-Chemical Parameters and Heavy metals which are used in the analysis are; For Sutlej River water analysis - pH, Total Dissolved Solids, Total Hardness, Total Alkalinity, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Nitrates, Sulphates, Chlorides, Calcium and Magnesium and for Groundwater analysis - pH, Total Dissolved Solids, Hardness, Alkalinity, Nitrates, Sulphates, Chlorides, Fluorides, Cadmium, Chromium, Copper, Iron, Manganese and Lead. All the parameters were analysed according to the protocol prescribed by the American Public Health Association (APHA, 2005). In the present study for finding out a comparative effect of a particular parameter on all the selected locations, Spatial and Temporal Variation charts including Regression Curves are being generated using Microsoft Excel 2013 for all the selected parameters for both the Sutlej River water and Groundwater analysis.
Keywords: Sutlej River water, Nangal, NFL Drain, Groundwater, Physico-Chemical Parameters and Heavy metals, Spatial and Temporal Variation, Microsoft Excel 2013.

I. INTRODUCTION

Water is a basic, common, relentless, life-supporting ware for individuals in everyday life. Be that as it may, these days it is getting out of reach because of expanding water contamination as a result of quickened industrial and urban development (Shankhwar and Srivastava 2015). It is completely comprehended to us now that for carrying on with a solid life, clean water is extremely basic. The science of surface waters is directed by gracefully of different components from both natural and anthropogenic sources (Krishnaswami and Singh 2005). Surface water has been a significant source of water for many reasons, and it supports the advancement of profoundly populated neighbourhoods because of its ideal conditions (Mustapha et al. 2013). In spite of the fact that the waterways have the limit of self-purification, this limit is modified due to abundance anthropogenic exercises, prompting the devastation of this significant biological system (Rashid and Romshoo 2013). Surface waters are generally exposable to contamination because of their availability for removal of wastewaters. In India, because of colossal urbanization and industrialization, the issue of water contamination has expected a disturbing circumstance and about 70% rivers in India are polluted (Sharma 2012). Any contamination occurrence in the surface water will enormously influence the hydrogeological frameworks (Weng and Chen 2000; Celik 2001). Communications between surface water and groundwater can have effective effects on water quality (Fernald and Guldan 2004). In the event that the surface water is polluted, it will undoubtedly influence the groundwater and the other way around (Edet and Worden 2009). At the point when untreated effluents are straightforwardly discharged to land and water bodies, it conceivably contaminates soil and groundwater with harmful metals (Aryal et al., 2017; Liu et al., 2016; Yegemova et al., 2018). There are many sources of contamination but discharge of chemical waste from industrial units is one of the major sources of surface water contamination and its pollution (Kumar et al., 2020). Although few Heavy metals, (for example, Cu, Co, Fe and Mn and so forth.) are required for metabolic procedures in living creatures at modest quantities, however these metals can cause health complications at higher concentrations (Huang et al., 2019).

Obviously as the area near to Ropar and Nangal contain a large number of industries, so the surface water quality near these areas is quite polluted due to the discharge of highly polluted wastes into the river.

Groundwater is the water found in spaces between soil particles and rocks, and inside breaks of the bedrock. It structures one of the significant wellsprings of consumable water. The hydrogeochemistry of groundwater decides its potability for residential and farming use. The pace of withdrawal of groundwater is expanding ceaselessly because of quicker pace of populace development joined by rural and modern turn of events. This has expanded the worry on groundwater asset assessment and its administration for practical turn of events (Singh et al., 2013). Groundwater has become a basic product in late decades because of industrialization and impromptu urbanization (Kumari et al. 2012). In any case, fast development of ventures and framework has gotten threatening, representing a hazard to the wellbeing and government assistance of the individuals because of arrival of toxins from businesses and urban sewage (Ntengwe 2006). The nature of groundwater is similarly significant as its amount attributable to the reasonableness of water for different purposes (Yidana and Yidana 2010). The chemical properties of groundwater likewise rely on the science of water in the energize territory just as on the distinctive geochemical forms that are happening in the subsurface. These geochemical forms are answerable for the seasonal and spatial varieties in groundwater science (Matthess, 1982). To survey the destiny and effect of the synthetic release on to the dirt, it is critical to comprehend the hydro-geochemistry of the dirt groundwater connections (Miller 1985). By and large, groundwater at the release zones will in general have higher mineral fixation when contrasted with that at the energize zones because of the more drawn out habitation time and delayed contact with the spring grid (Freeze and Cherry 1979). Groundwater contamination is one of the most critical natural intricacies in the current reality where substantial metal contamination has principle worry because of its high poisonousness even at low focus (Momodu and Anyakora 2010). The greater part of the ventures release their effluents without legitimate treatment into close by open pits or pass them through unlined channels, which move towards the low lying discouragements ashore, bringing about the sullying of groundwater (Purandara and Varadarajan 2003). There are various ventures working all over India for example Pharmaceuticals, petrochemicals, power plants, metals and metalloids, material, agro-based and so on and every one of them devour tremendous measure of water either for creation purposes or other. Numerous examinations recommended that if the quality just as amount of water (groundwater specifically) will diminish up to a specific level then it could ill-suited for local use, lessens the horticulture and mechanical creations too. In this manner water is considered as a key contribution for economical turn of events (Rout C et al., 2018). In creating nations like India, around 80 % of all infections are straightforwardly identified with helpless drinking water quality and unhygienic conditions (Olajire and Imeokparia, 2001).Colossal contributions of toxins have been taking the contaminations levels past the absorptive limit of the earth. Given this colossal assortment of ventures, there are similarly enormous quantities of substantial metals, natural solvents and hydrocarbons related with them. Ground Water ceaselessly involves broke down and suspended substance of natural and mineral source. At the point when these substances in water go over as far as possible is called as water contaminants. There are numerous reasons of groundwater defilement. These contaminants include: Careless human methodology, destructive fluids spill from rebellious capacity tanks into the groundwater source, inadequately assembled landfills or septic frameworks, overflow from prepared regions, cows zones, wild mines and modern zones and dumping of family squanders heavy them on the ground. Promisingly, these affiliations are notable and unsurprising. Data planned absolutely to help perceive businesses and materials well on the way to become groundwater contaminations. Numerous researchers made important examinations on groundwater tainting and have demonstrated that it is sullied to shifting strides at various Industries (Rao et al., 2014).

II. MATERIAL AND METHODS

A. *Study Area*

Ropar district is situated in the eastern piece of the Punjab State and geographically lies between North latitudes of 76°19′00″ and 76°45′00″ and East longitudes of 30°44′00″ and 31°25′00″. The topographical extent of the territory is 1440 sq.km. The region is bounded by Himachal Pradesh in the north and north east, Hoshiarpur, Nawanshahr and Ludhiana district in the west, Fatehgarh Sahib District in the South and district of Mohali in the south east. Administratively the new Ropar region is divided into four tehsils – Rupnagar, Chamkaur Sahib, Anandpur Sahib and Nangal contain five development blocks. The district contains 4 Tehsils, Rupnagar, Anandpur Sahib, Chamkaur Sahib and Nangal and incorporates 617 villages and 6 towns which are; Rupnagar, Chamkaur Sahib, Anandpur Sahib, Morinda, Kiratpur Sahib and Nangal (CGWB 2017). Nangal is a town and municipal council in district of Rupnagar in Punjab, India. It is 60 km from Rupnagar in the province of Punjab in northwest India. It sits at the foot of the Shiwalik Hills where it was set up after designs for a dam required the development of recently settled villages

The River Sutlej enters India close to Mansarover and streams North Westwards. It crosses extraordinary Himalayan reaches on its way from the Shipkipass. It streams upto Gobind Sagar Lake over which Bhakra dam is built. Around 14 Kms. downstream of Bhakra dam, Nangal head-works are developed at Nangal. From here onwards, the Waterway of Sutlej River takes southern heading. In the wake of streaming for another around 50 Kms, it enters the plains near Ropar. The total length of Sutlej river in the province of Punjab is around 440 km. Average discharge of Sutlej river in the territory of Punjab as estimated at Ropar is roughly 500 m^3/sec. The total area of catchment of Sutlej River in the territory of Punjab is roughly 20303 Sq. km (Action Plan for Clean River Sutlej, 2019). Location of Ropar District is shown in Fig. 1 below.

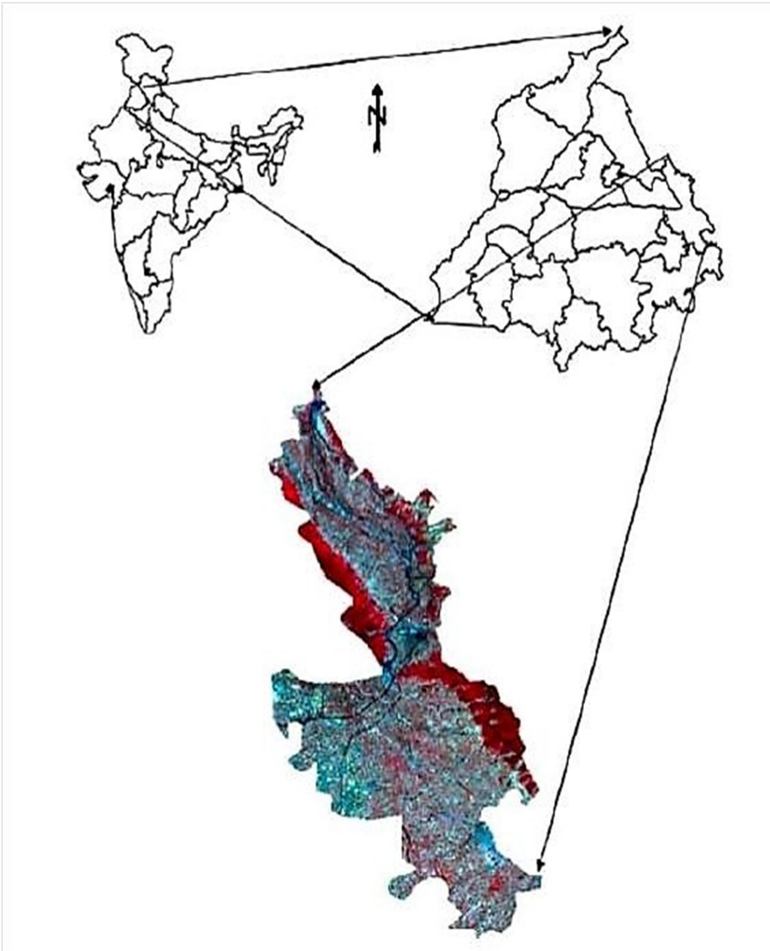

Fig. 1. Location of Ropar District

B. Rainfall And Climate

The district of Ropar gets normal yearly precipitation of 776 mm, which was spread over a period of 41 days. 78% of the yearly precipitation is contributed by southwest storm. Generally, precipitation increases from southwest to north-eastern part of the region. The climate of the region can be delegated as tropical steppe hot and semi-arid type (CGWB 2012).

C. Hydrogeology of Study Area

The Quaternary alluvial stores having a place with the huge Indo-Gangetic Alluvium happening in the southern squares of the district forms the fundamental aquifer system. The aquifers in the northern part are principally Siwalik development, Intermontane Valleys and Kandi/Sirowal arrangement. From west to east the granular zones turns out to be less conspicuous and clay horizons with gravel or kankar become prevalent. Groundwater occurs under phreatic condition in the shallow aquifers of Quaternary alluvium stores, intermontane valley and Kandi formation. Groundwater happens under leaky confined to confined conditions in the more profound aquifers of alluvium. On account of unconfined aquifers, the depth to water level differs from 2.7 to 10.3 m during pre-monsoon and 2.1 to 11.6 m during post-monsoon (CGWB 2012).

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D. Sampling

The present study has been done on two types of different water samples.

1) Sutlej River water samples
2) Groundwater samples

The samples for both the types of water were collected twice in the month from November 2019 to March 2020. Therefore, a total of 40 Sutlej River water samples were taken from 5 different selected locations from adjoining areas of floodplain of River Sutlej and National Fertilizers Limited (NFL Nangal) Drain. And a total of 80 Groundwater samples were taken from 10 different selected villages on the downstream side of NFL Drain and the Sutlej River. Groundwater samples were collected from hand pumps, bore wells, tube wells of different depths according to ease and availability at the particular selected location.

The samples were always collected in polypropylene bottles which were initially washed with nitric acid and rinsed thoroughly with distilled water. All the samples were kept under 4^0 C in the Laboratory till the completion of all the testing of different Physico-chemical parameters and Heavy metals. Samples were filtered with MF-Millipore Membrane Filter, 0.22 µm pore size before using them for testing. Locations of both the Sutlej River water and Groundwater samples taken are shown below in Fig. 2 and Fig. 3 respectively.

1) Sampling Period: Both the Sutlej River water and the Groundwater samples were collected twice a month from December, 2109 to March, 2020. Five different locations were selected for collecting Sutlej River water samples and ten different villages were selected near to the Sutlej River for collecting Groundwater samples for our study. So a total of 40 Sutlej river water samples and 80 Groundwater samples were collected making a full total of 120 Samples.

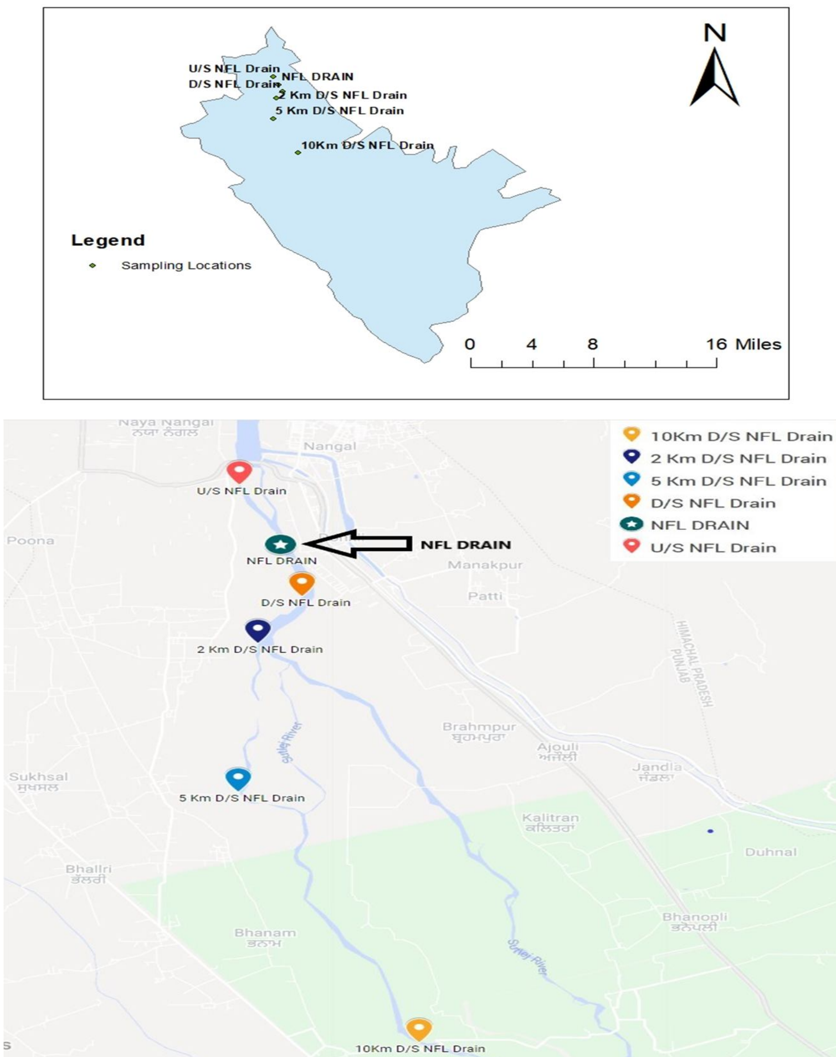

Fig. 2. Location of Sutlej River water Sampling Stations

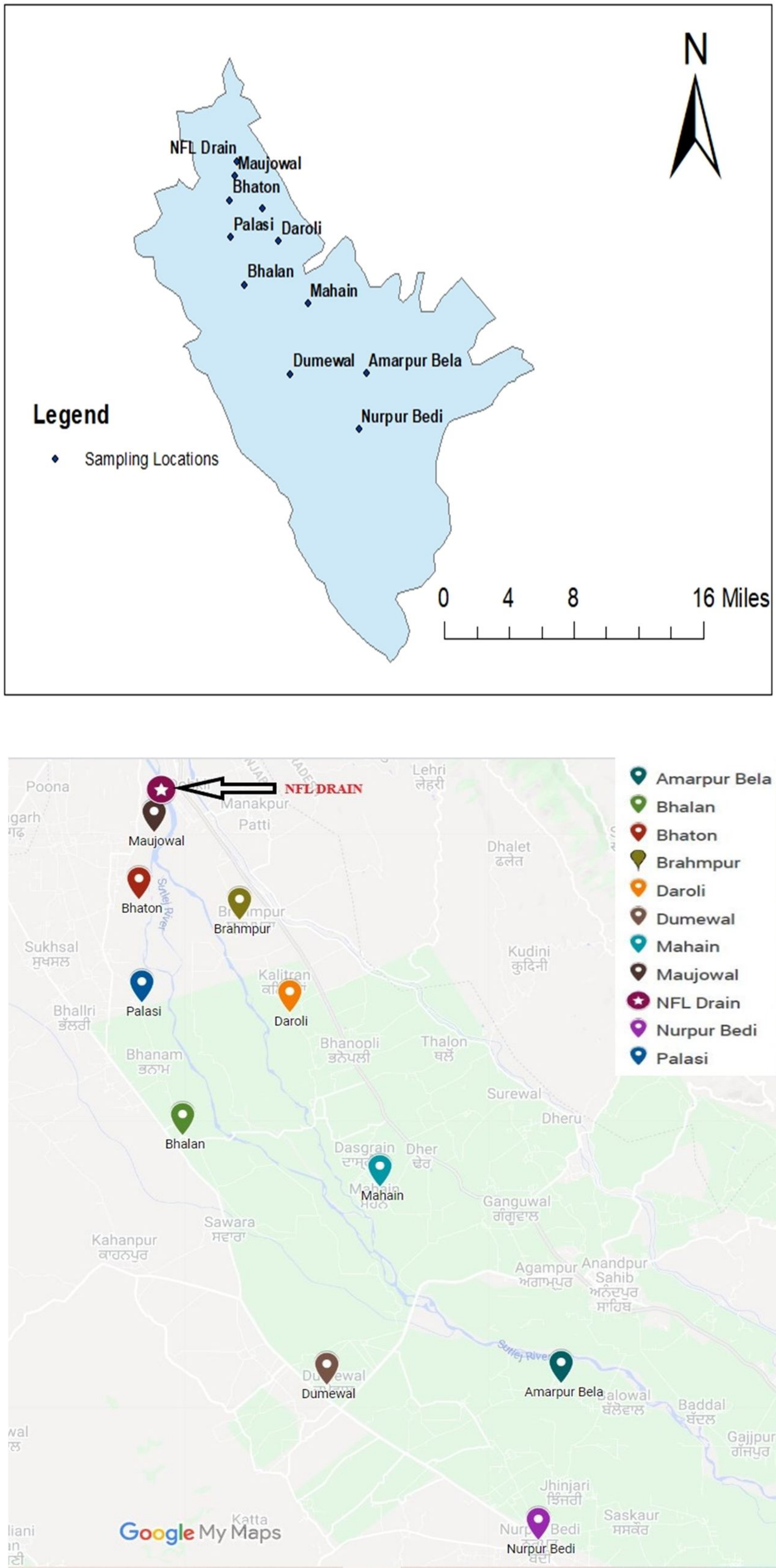

Fig. 3. Location of Groundwater Sampling Stations

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2) *Various Physico:* Chemical Parameters and Heavy metals used for the analysis are;
a) *For Sutlej River water Analysis*: pH, Total Dissolved Solids, Total Hardness, Total Alkalinity, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Nitrates, Sulphates, Chlorides, Calcium and Magnesium.
b) *For Groundwater Analysis*: pH, Total Dissolved Solids, Total Hardness, Total Alkalinity, Nitrates, Sulphates, Chlorides, Fluorides, Cadmium, Chromium, Copper, Iron, Manganese and Lead.

All the parameters were analysed according to the protocol prescribed by the American Public Health Association (APHA, 2005).

3) *Methods and Equipment used in the analysis of various Physico:* Chemical Parameters and Heavy metals of the Sutlej River water and Groundwater samples.

Sr. No.	Parameter	Method	Instrument/Equipment Used
1	pH	Electrometric	Digital pH meter
2	Total Dissolved Solids	Gravimetric	Drying Oven
3	Total Hardness	EDTA Titration Method	Titrimetry
4	Total Alkalinity	Volumetric Titration	Titrimetry
5	Dissolved Oxygen	Winkler's Method	Titrimetry
6	BOD	5 Days Incubation followed by Titration	BOD Incubator
7	Nitrates	Ultraviolet–Visible Spectrophotometry	UV-2550 Spectrophotometer
8	Sulphates	Ultraviolet–Visible Spectrophotometry	UV-2550 Spectrophotometer
9	Chlorides	Ultraviolet–Visible Spectrophotometry	UV-2550 Spectrophotometer
10	Fluorides	Ultraviolet–Visible Spectrophotometry	UV-2550 Spectrophotometer
11	Calcium	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
12	Magnesium	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
13	Cadmium	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
14	Chromium	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
15	Copper	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
16	Iron	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
17	Manganese	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer
18	Lead	Inductively Coupled Plasma Method	ICAP-6000 Series ICP-OES Spectrometer

Table – 1. Methods and Equipment used in the study

III. ANALYSIS

In the present study for finding out a comparative effect of a particular parameter on all the selected locations, Spatial and Temporal Variation charts including Regression Curves are being generated using Microsoft Excel 2013 for all the selected parameters for both the Sutlej River water and Groundwater analysis.

A. *Sutlej River Water Analysis*

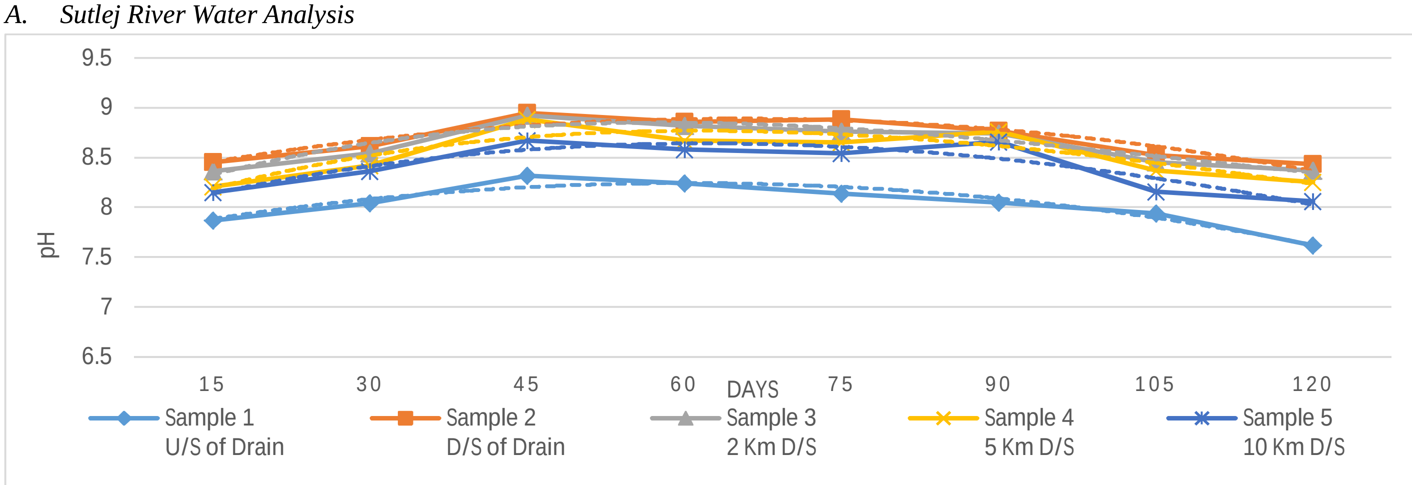

Fig. 4.1. Spatial and Temporal variation chart of pH of Sutlej River water Sampling stations during the sampling period

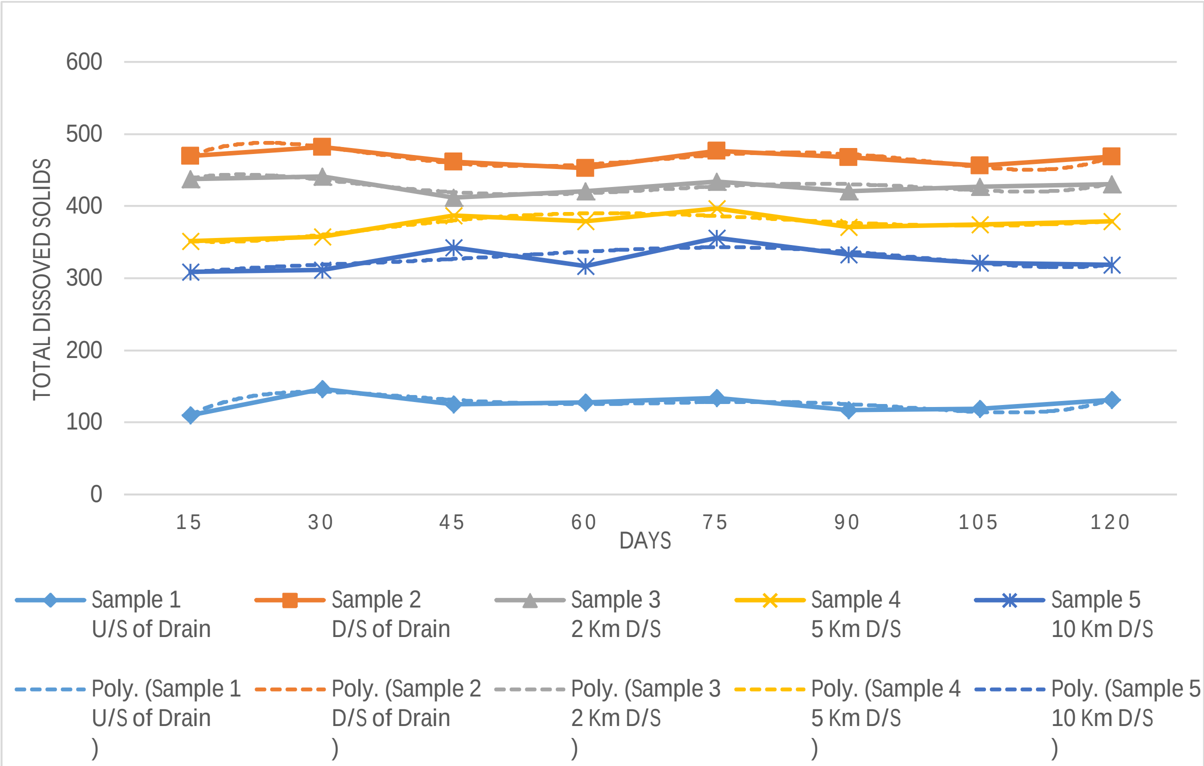

Fig. 4.2. Spatial and Temporal variation chart of TDS of Sutlej River water Sampling stations during the sampling period

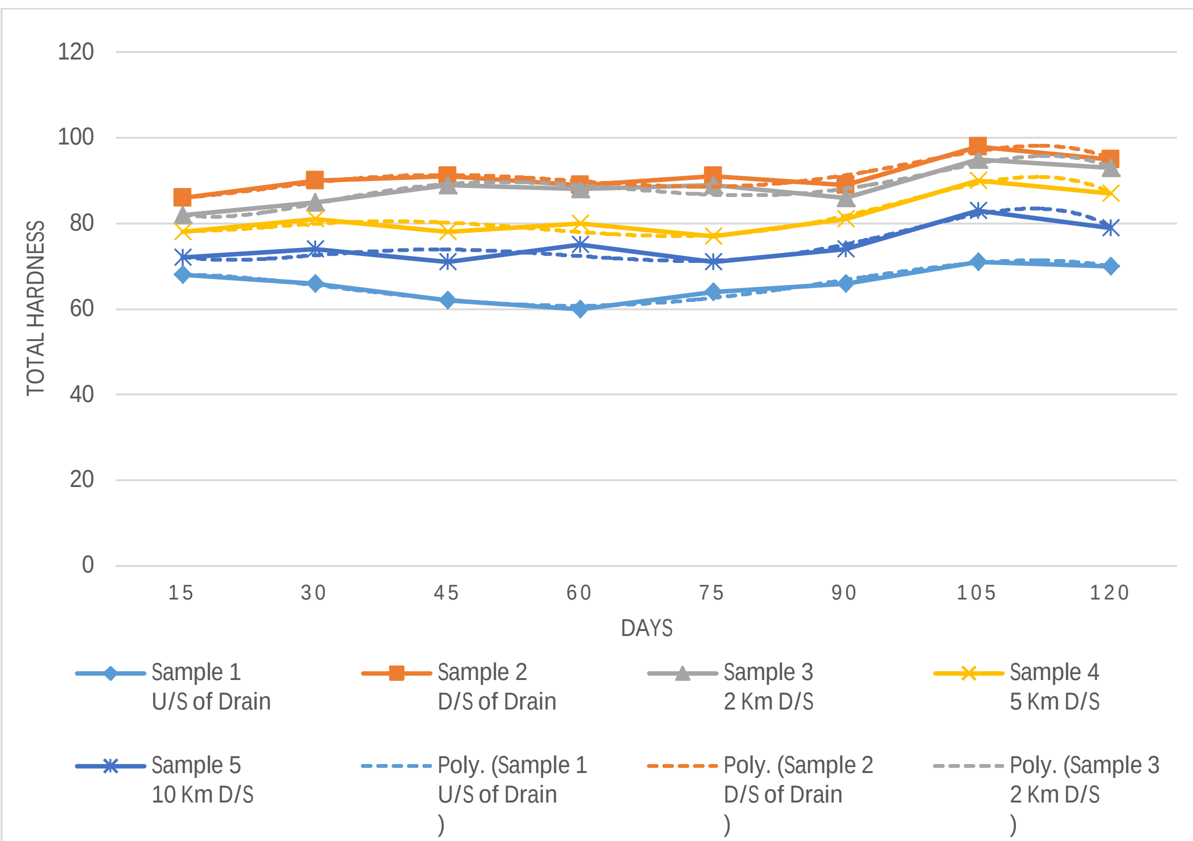

Fig. 4.3. Spatial and Temporal variation chart of Total Hardness of Sutlej River water Sampling stations during the sampling period

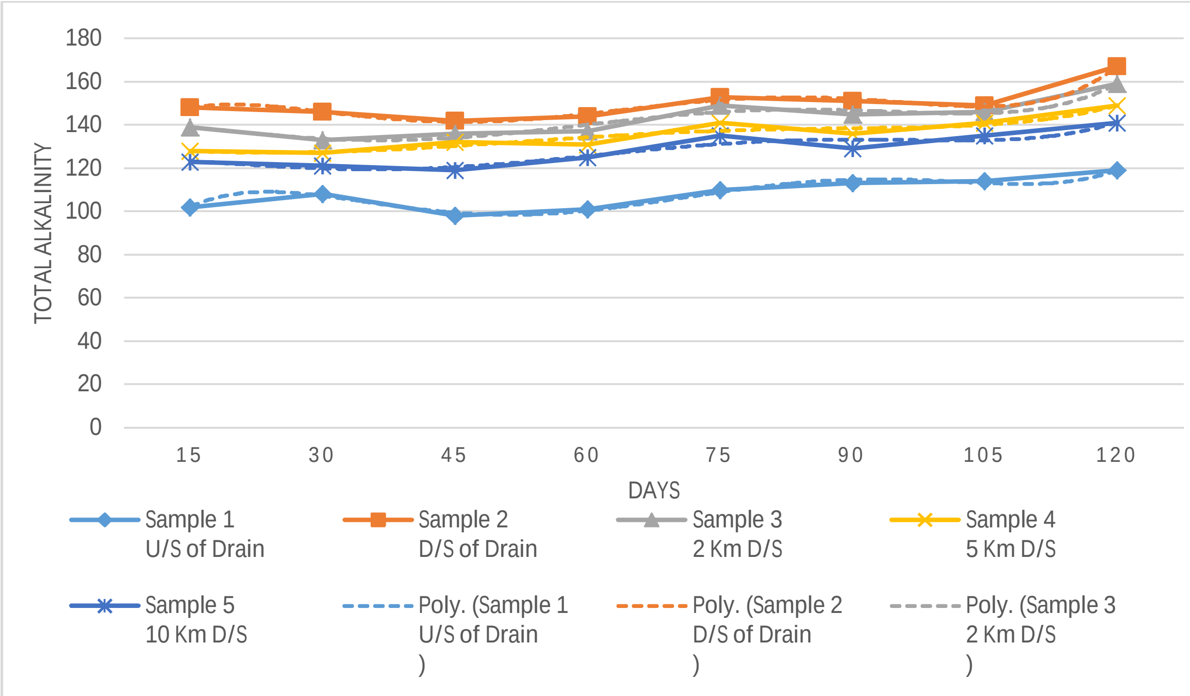

Fig. 4.4. Spatial and Temporal variation chart of Total Alkalinity of Sutlej River water Sampling stations during the sampling period

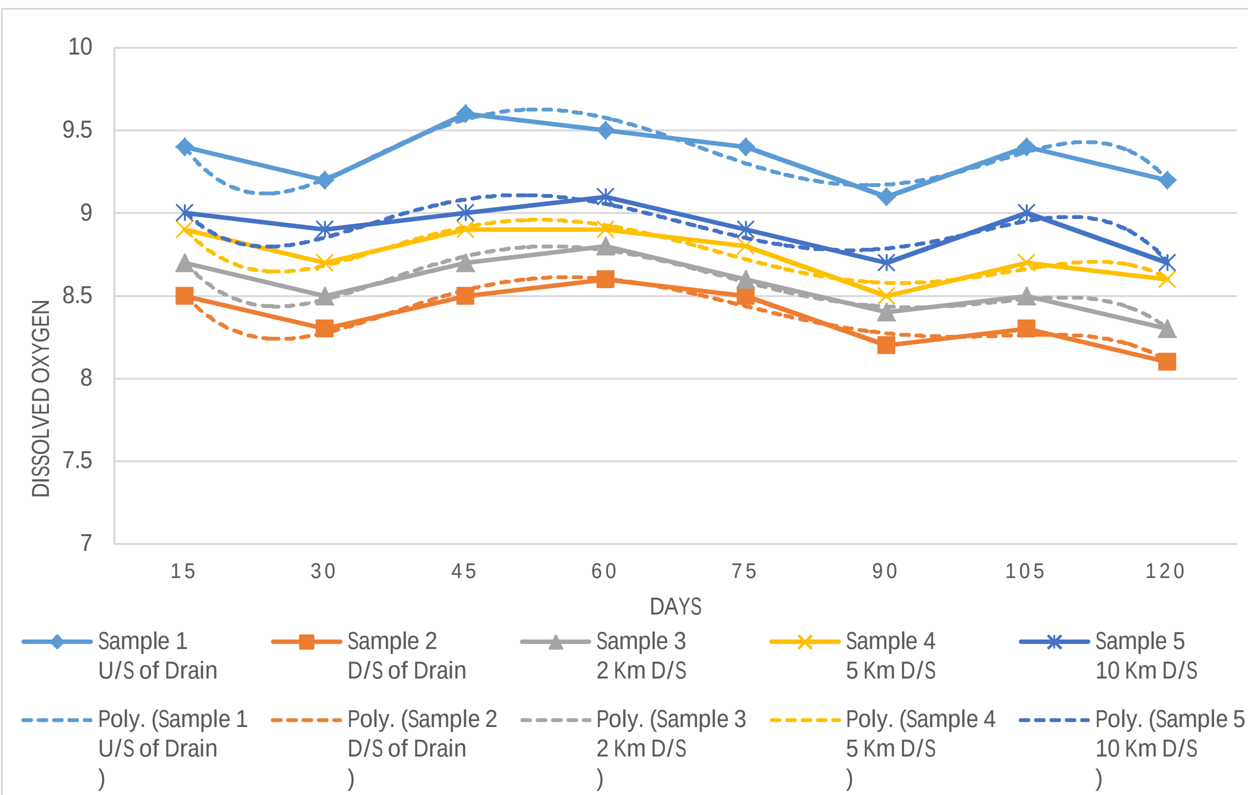

Fig. 4.5. Spatial and Temporal variation chart of Dissolved Oxygen of Sutlej River water Sampling stations during the sampling period

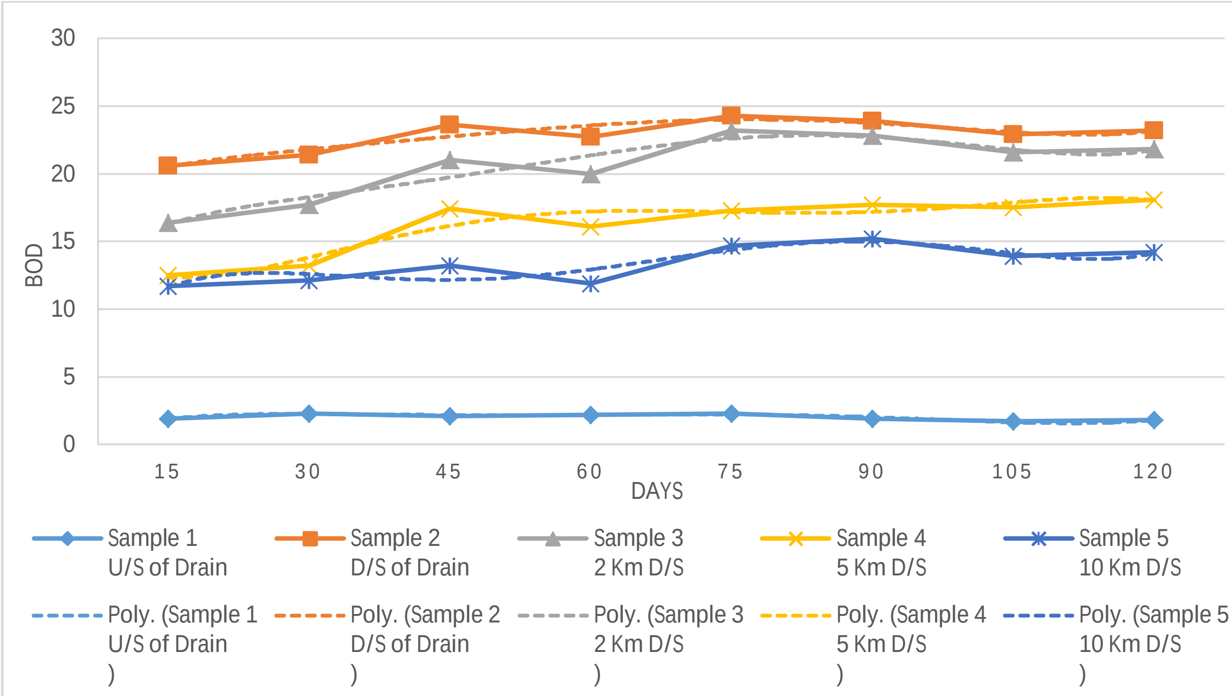

Fig. 4.6. Spatial and Temporal variation chart of BOD of Sutlej River water Sampling stations during the sampling period

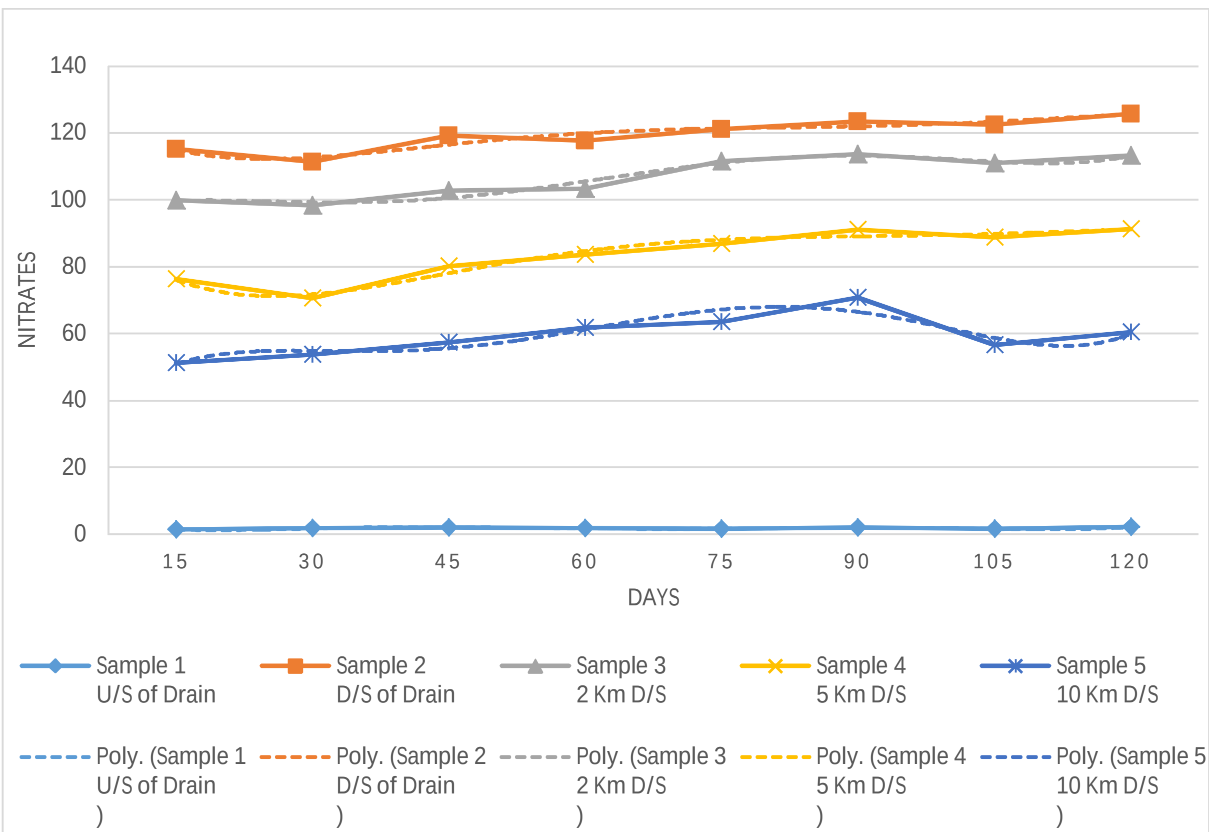

Fig. 4.7. Spatial and Temporal variation chart of Nitrates of Sutlej River water Sampling stations during the sampling period

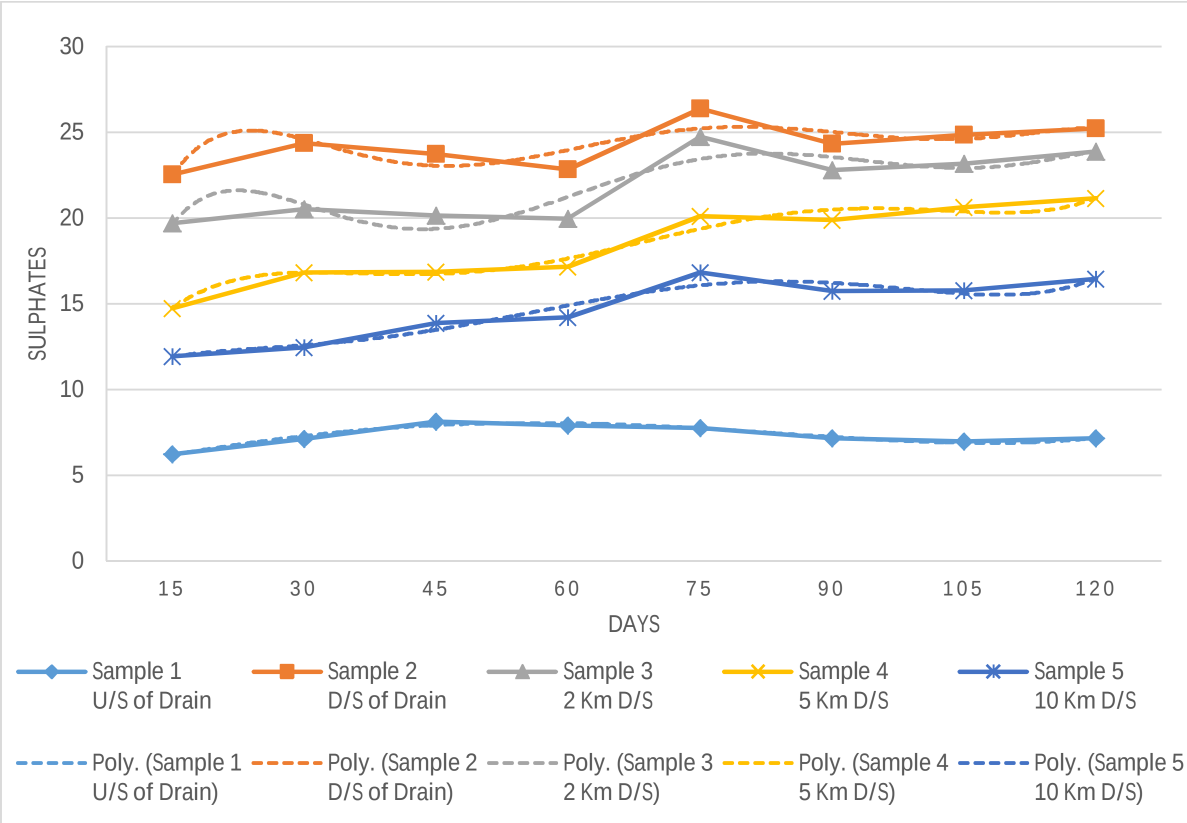

Fig. 4.8. Spatial and Temporal variation chart of Sulphates of Sutlej River water Sampling stations during the sampling period

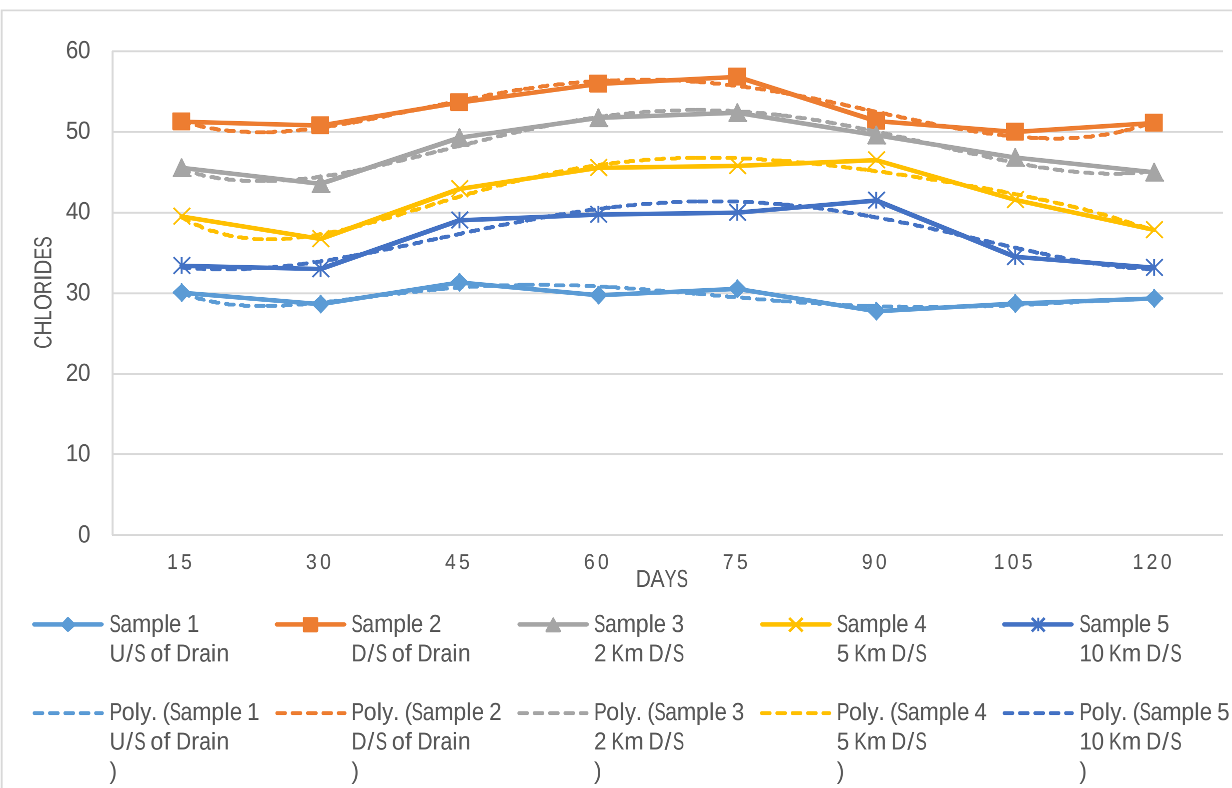

Fig. 4.9. Spatial and Temporal variation chart of Chlorides of Sutlej River water Sampling stations during the sampling period

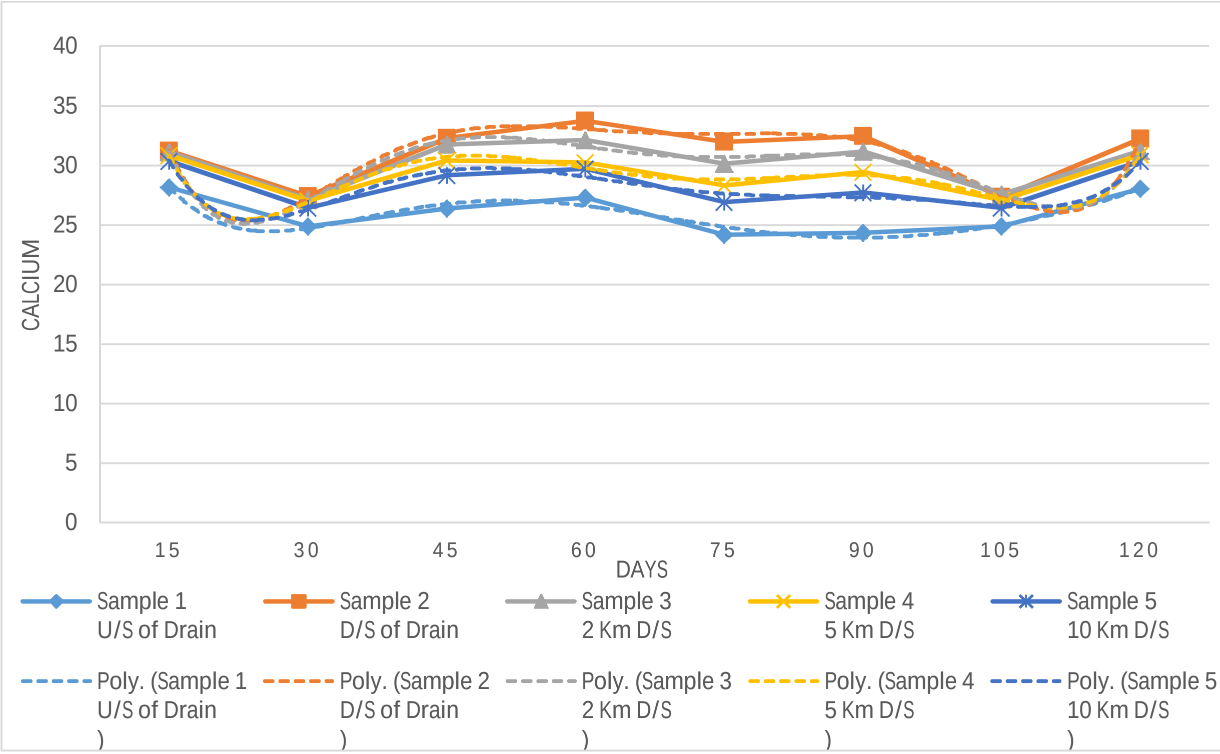

Fig. 4.10. Spatial and Temporal variation chart of Calcium of Sutlej River water Sampling stations during the sampling period

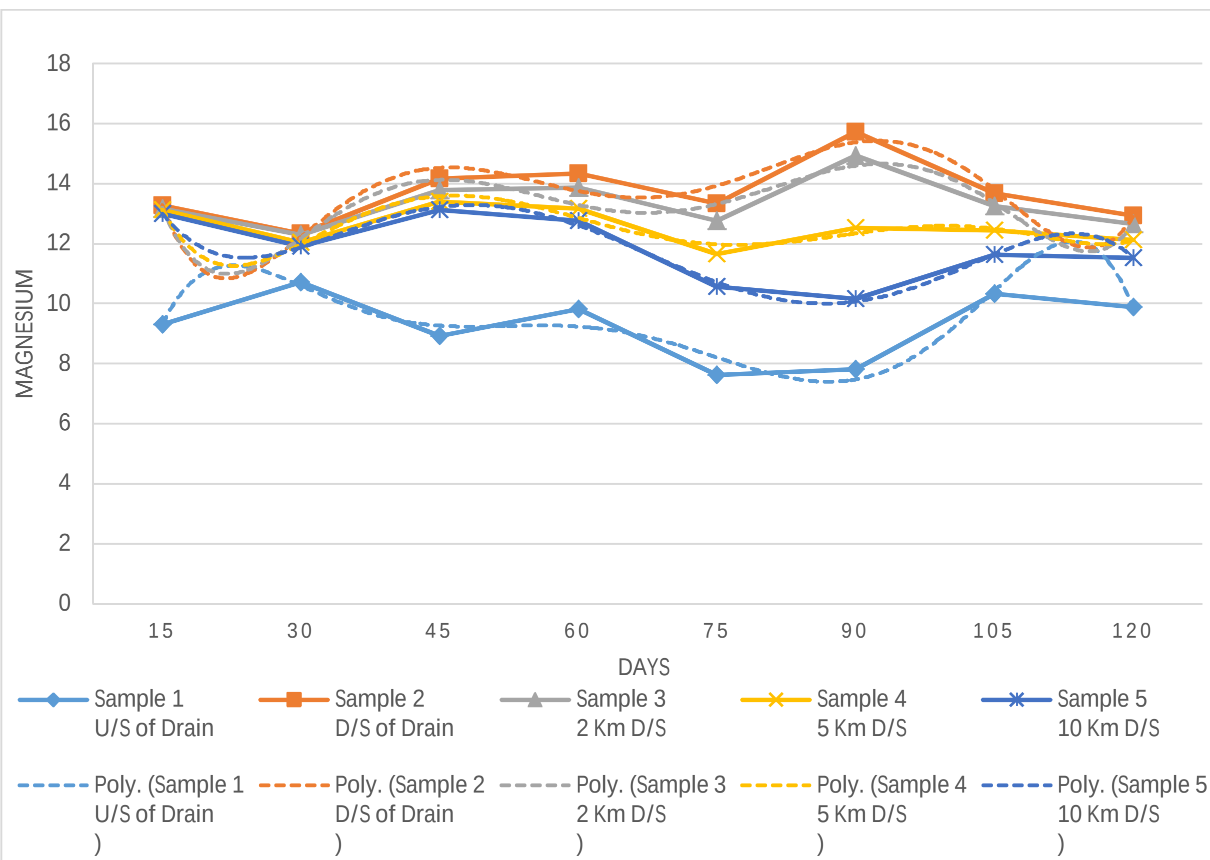

Fig. 4.11. Spatial and Temporal variation chart of Magnesium of Sutlej River water Sampling stations during the sampling period

B. *Groundwater Analysis*

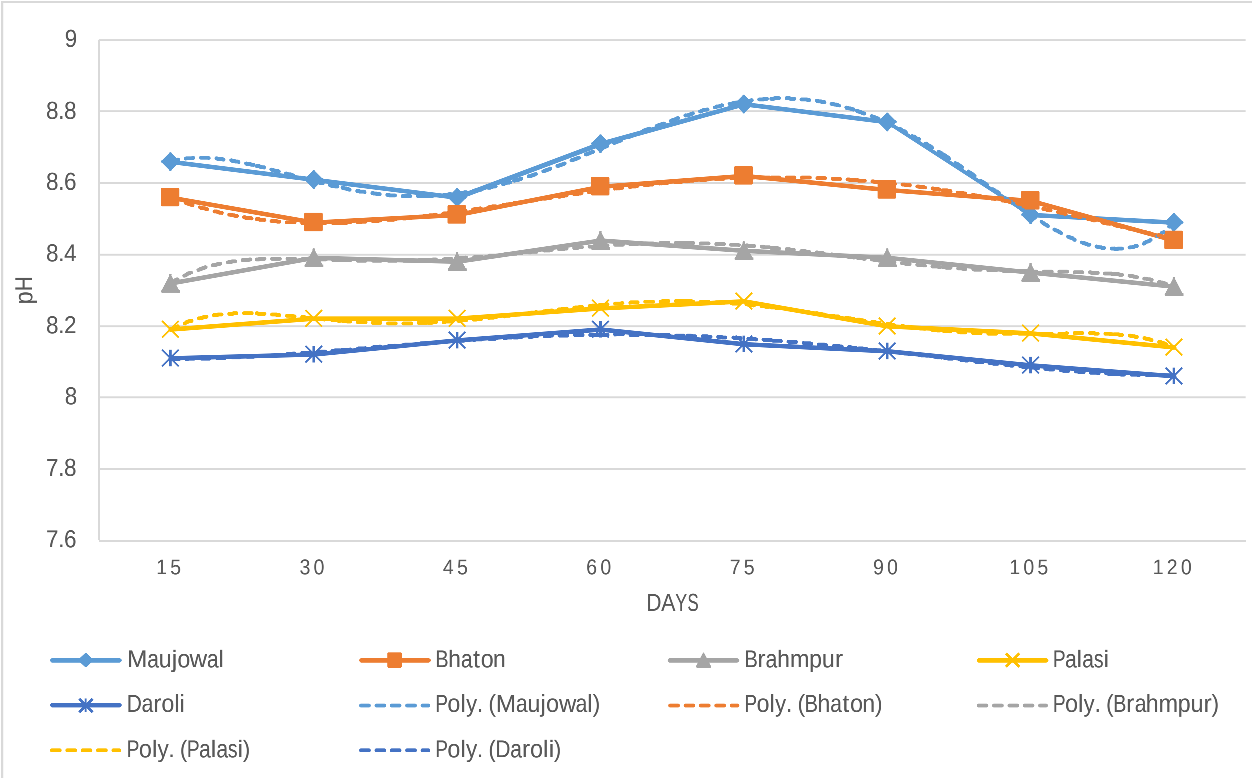

Fig. 5.1(a). Spatial and Temporal variation chart of pH of Groundwater Sampling stations during the sampling period

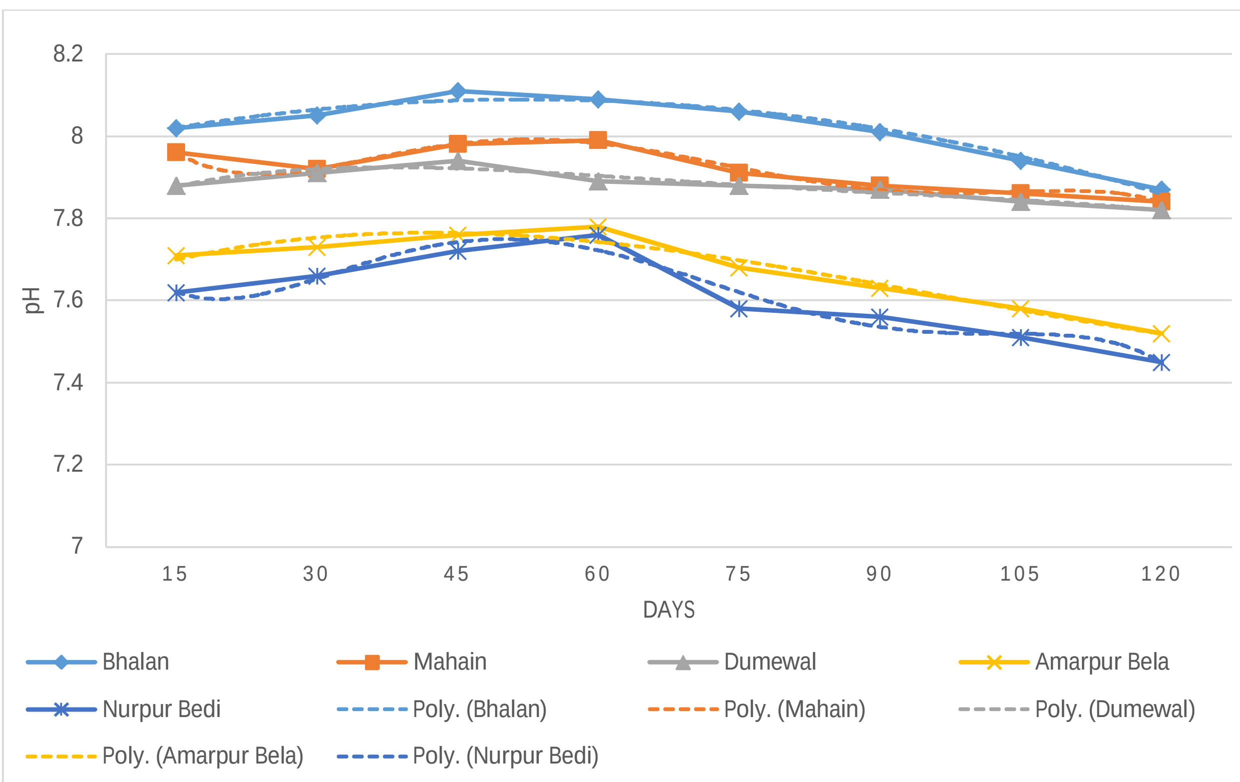

Fig. 5.1(b). Spatial and Temporal variation chart of pH of Groundwater Sampling stations during the sampling period

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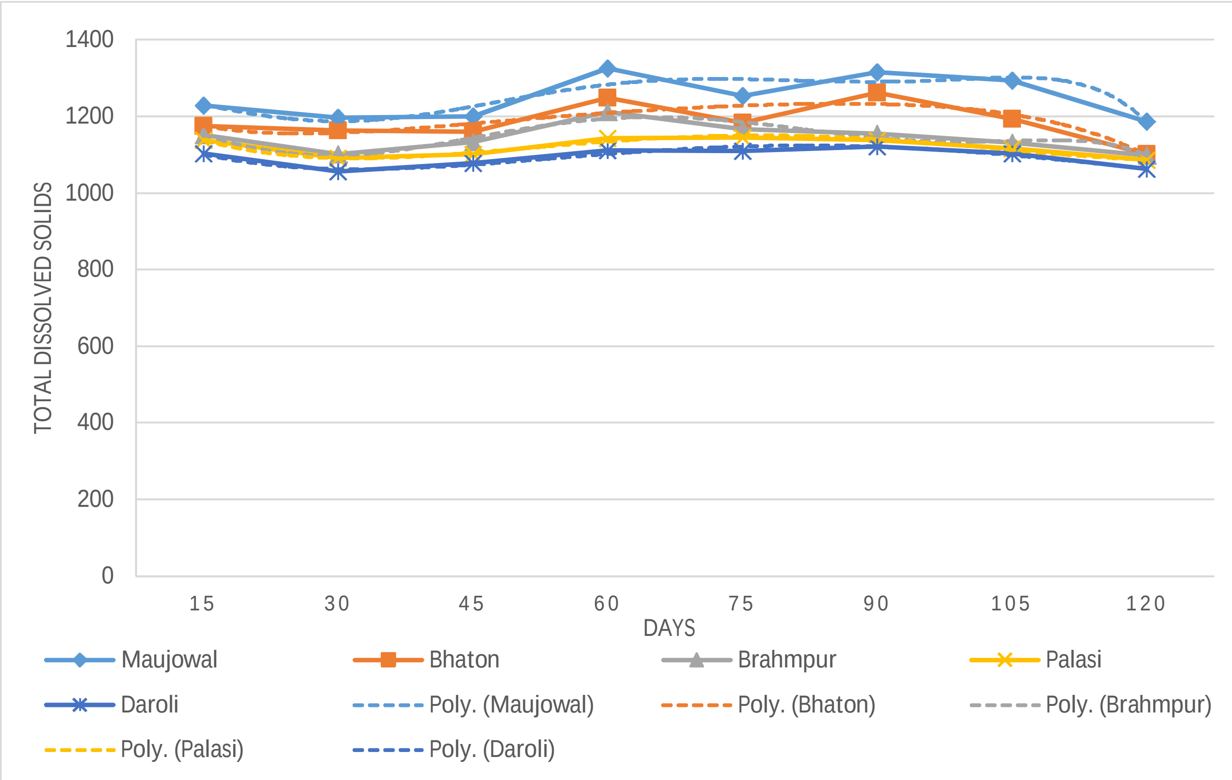

Fig. 5.2(a). Spatial and Temporal variation chart of TDS of Groundwater Sampling stations during the sampling period

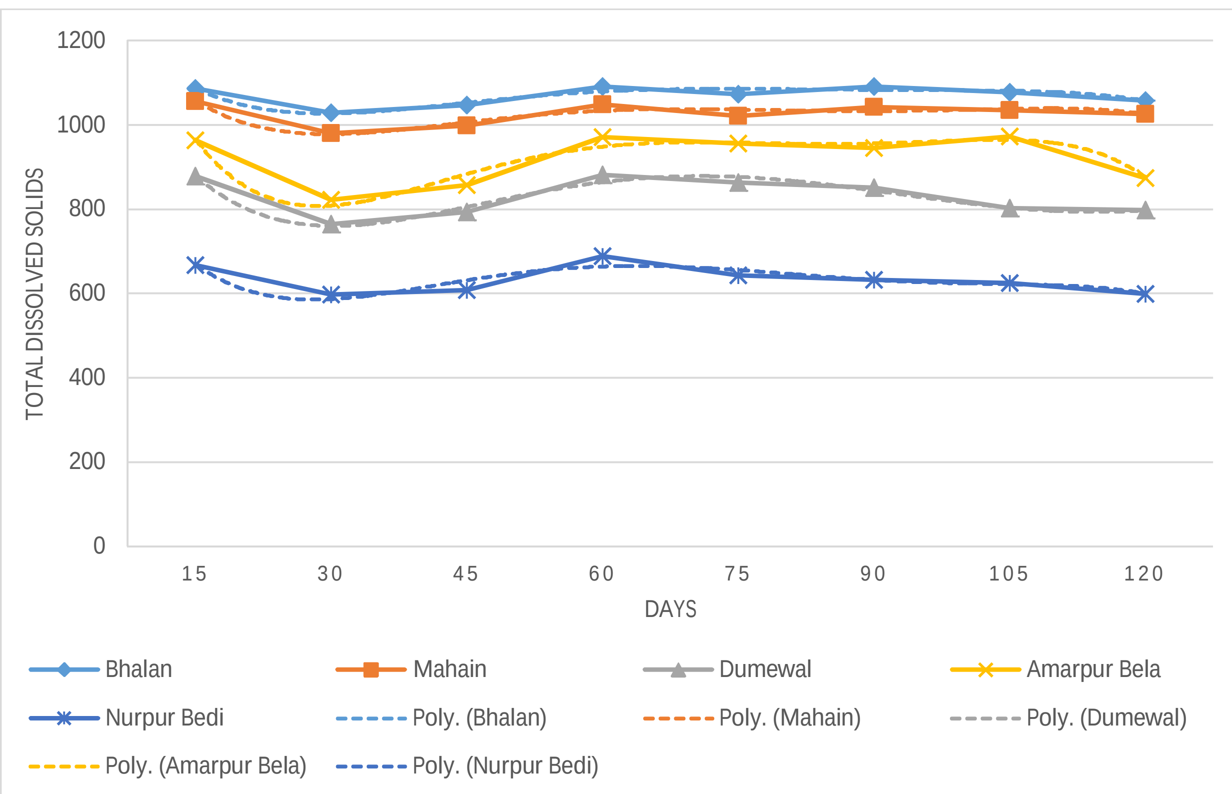

Fig. 5.2(b). Spatial and Temporal variation chart of TDS of Groundwater Sampling stations during the sampling period

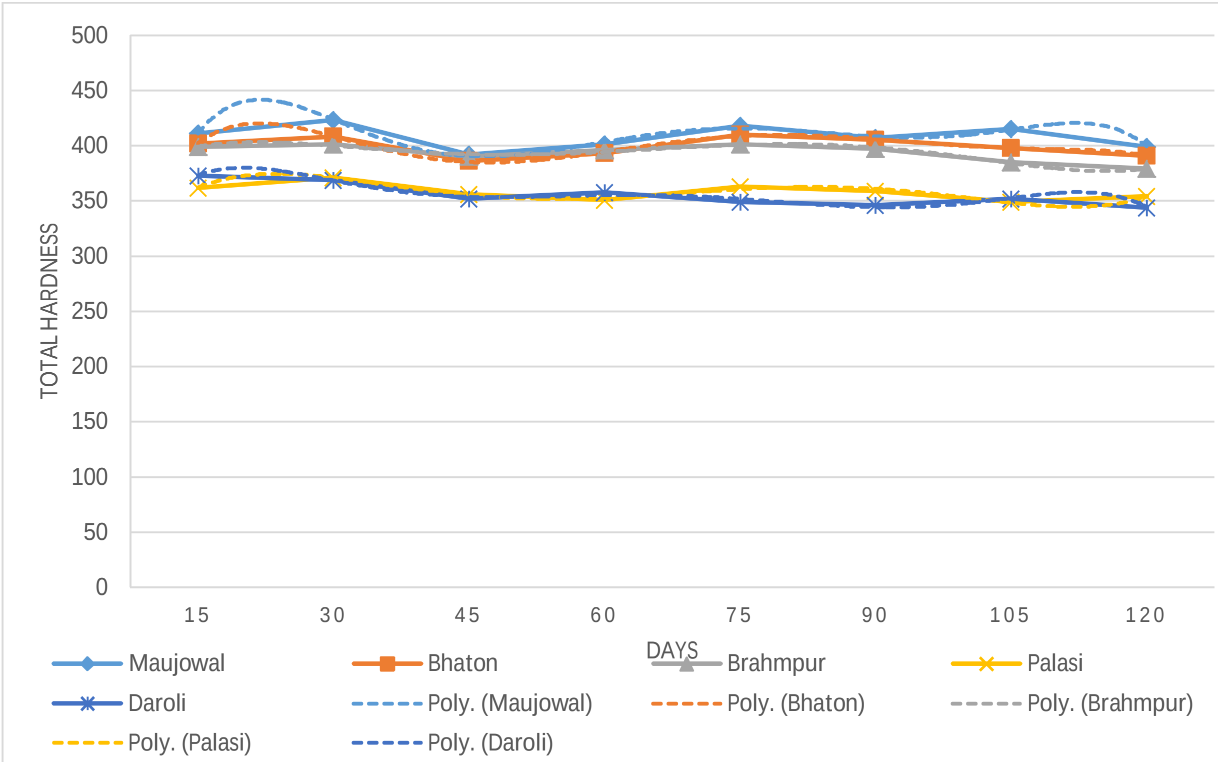

Fig. 5.3(a). Spatial and Temporal variation chart of Total Hardness of Groundwater Sampling stations during the sampling period

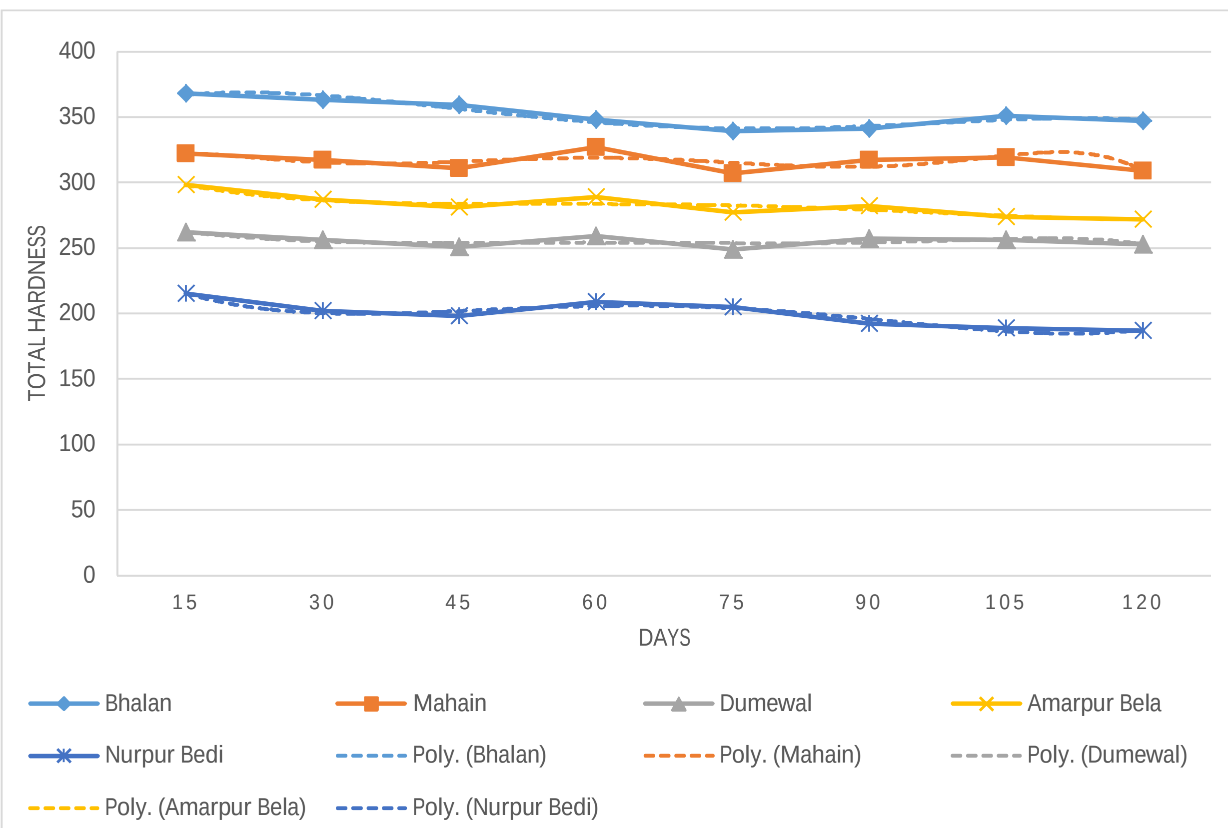

Fig. 5.3(b). Spatial and Temporal variation chart of Total Hardness of Groundwater Sampling stations during the sampling period

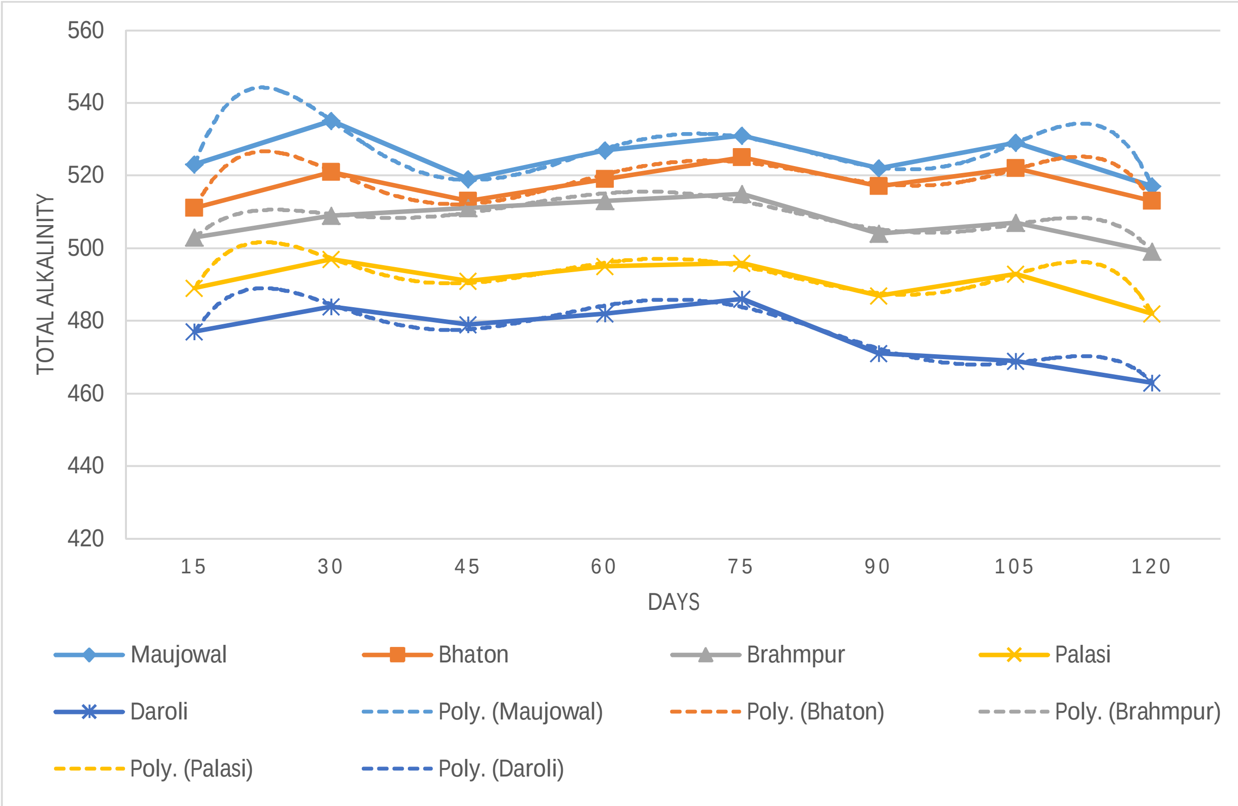

Fig. 5.4(a). Spatial and Temporal variation chart of Total Alkalinity of Groundwater Sampling stations during the sampling period

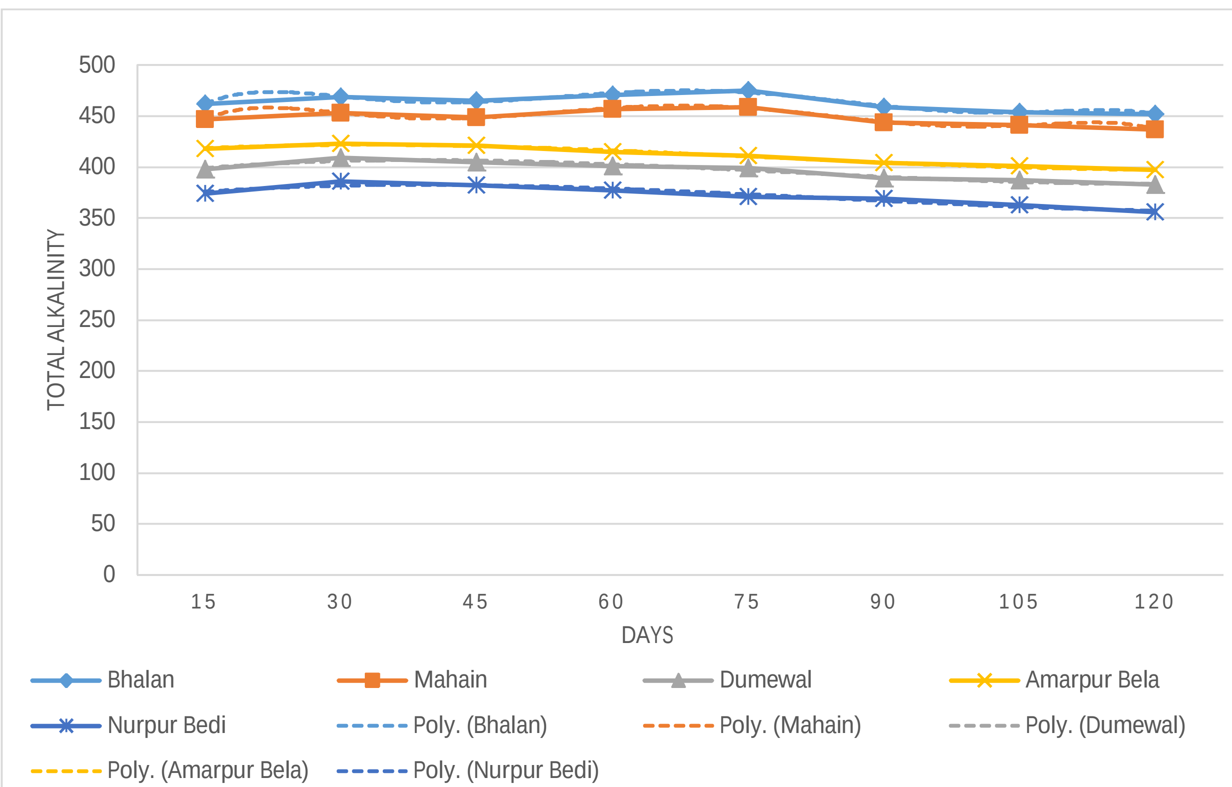

Fig. 5.4(b). Spatial and Temporal variation chart of Total Alkalinity of Groundwater Sampling stations during the sampling period

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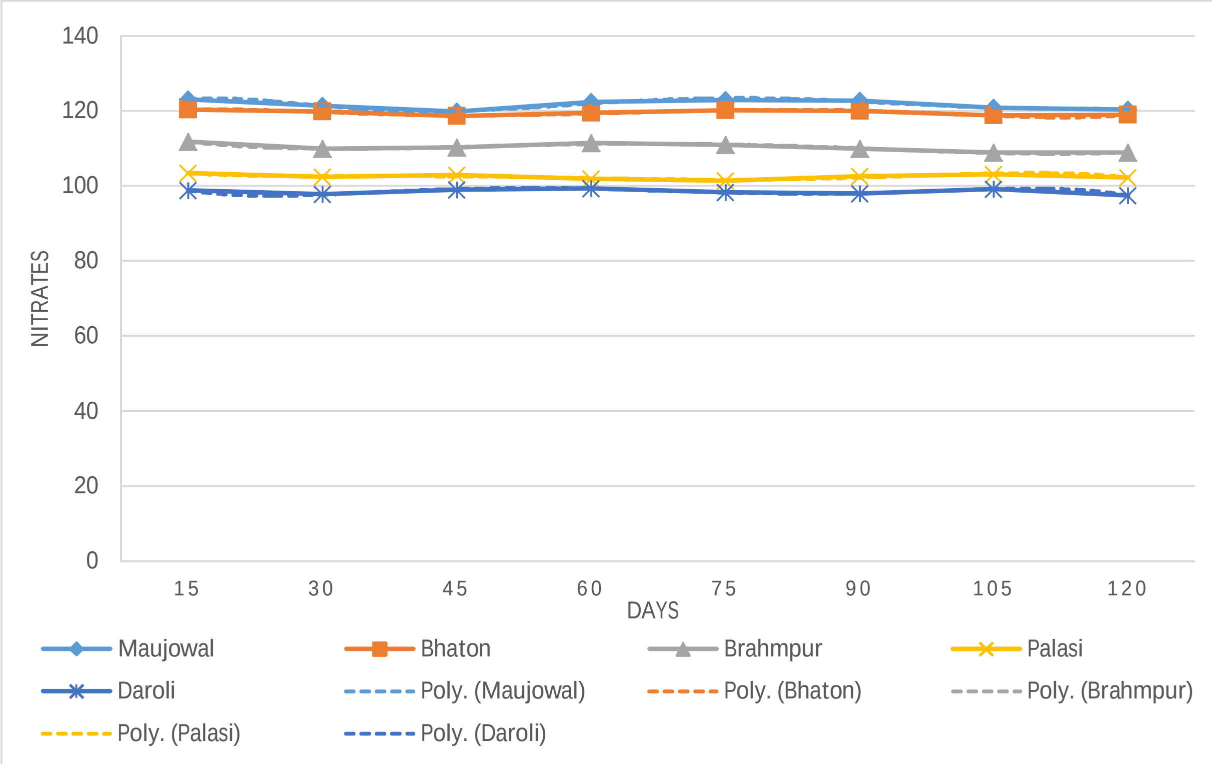

Fig. 5.5(a). Spatial and Temporal variation chart of Nitrates of Groundwater Sampling stations during the sampling period

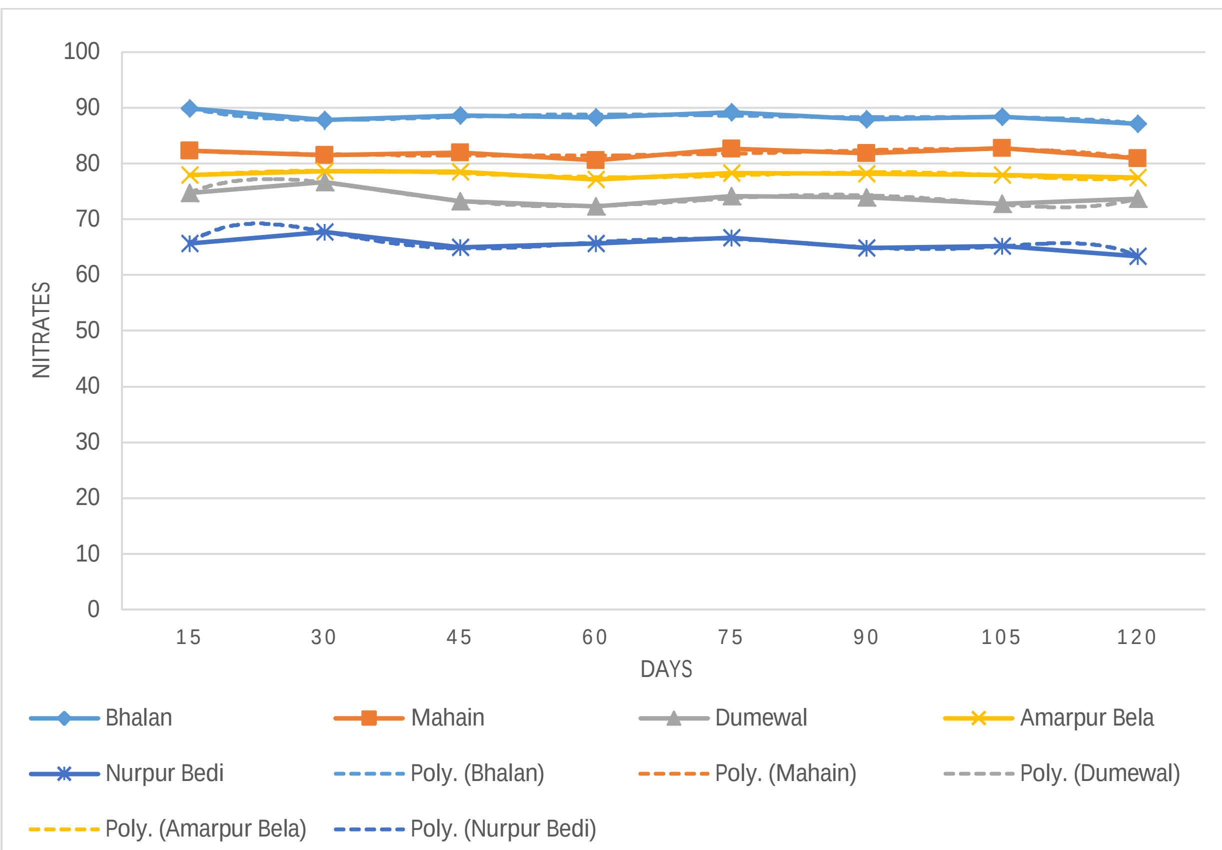

Fig. 5.5(b). Spatial and Temporal variation chart of Nitrates of Groundwater Sampling stations during the sampling period

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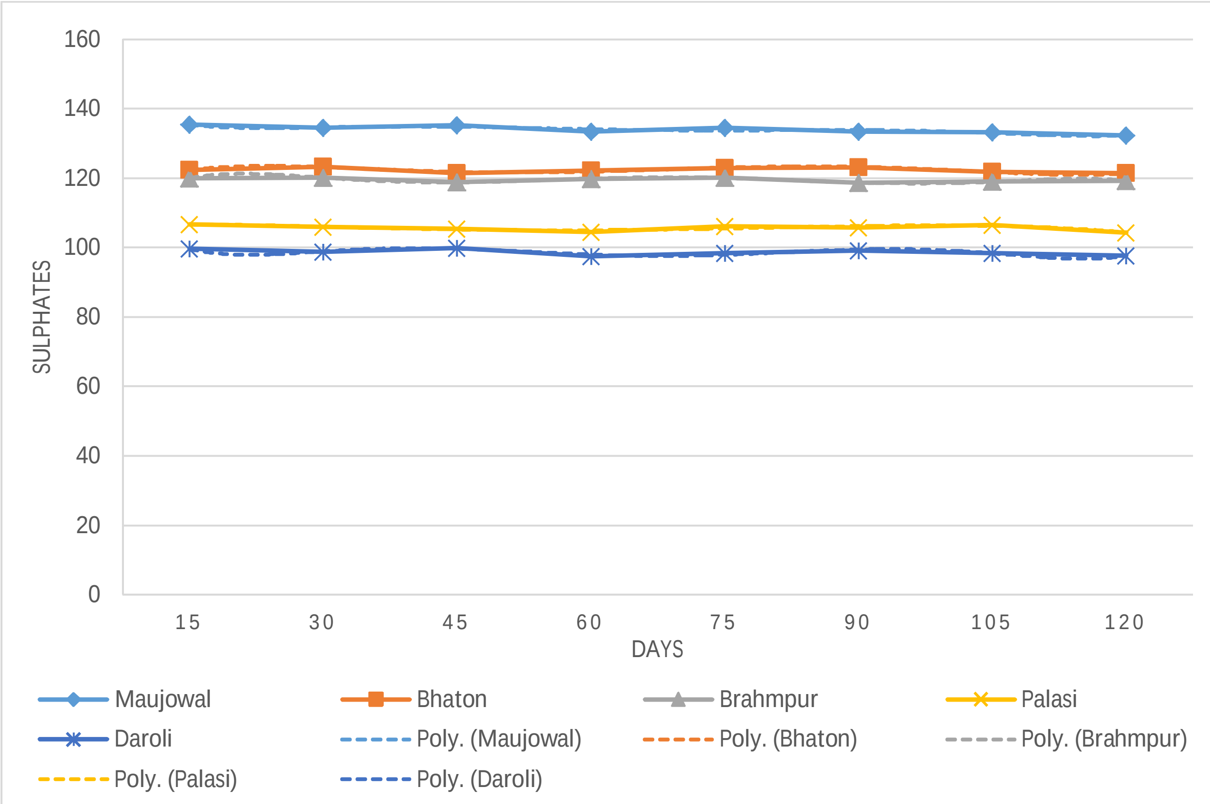

Fig. 5.6(a). Spatial and Temporal variation chart of Sulphates of Groundwater Sampling stations during the sampling period

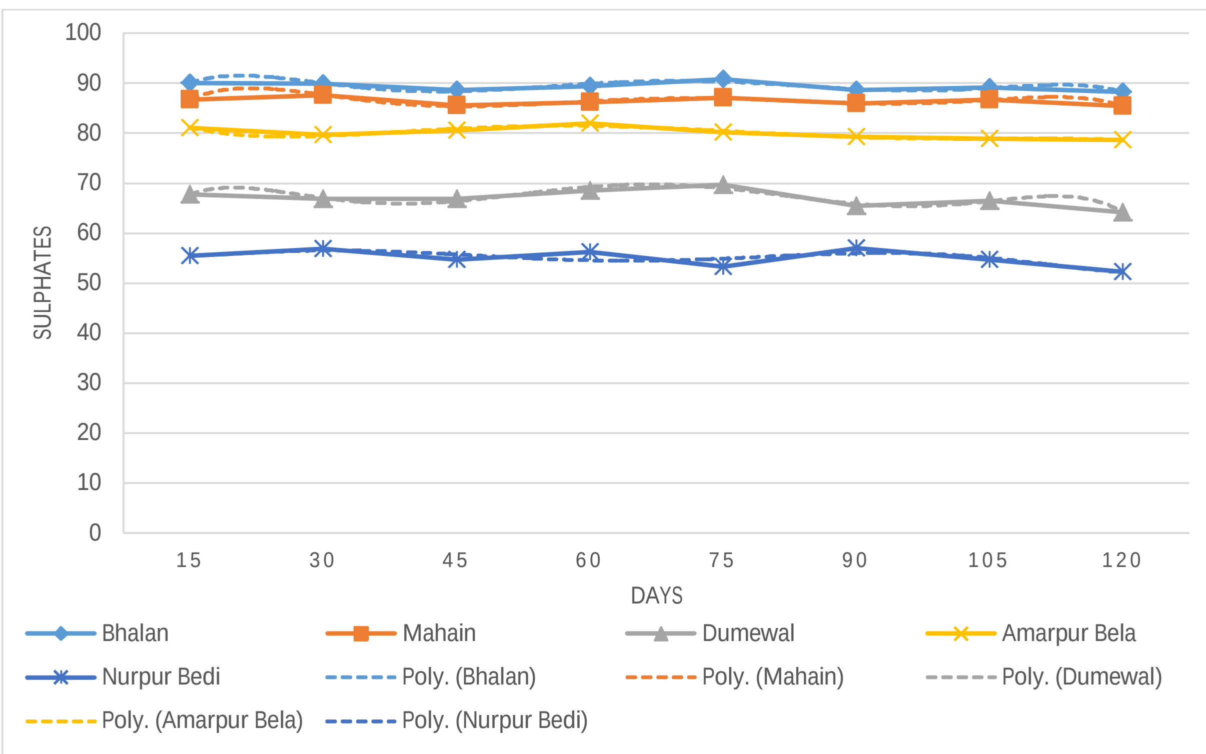

Fig. 5.6(b). Spatial and Temporal variation chart of Sulphates of Groundwater Sampling stations during the sampling period

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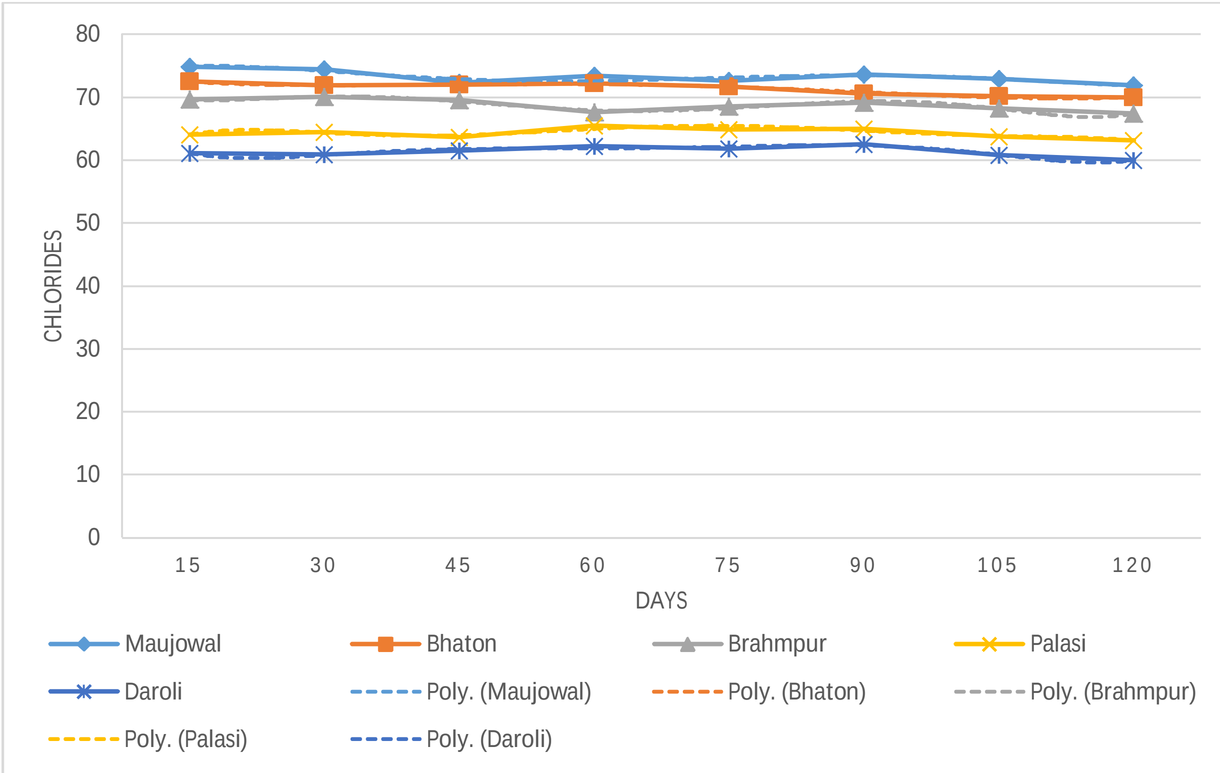

Fig. 5.7(a). Spatial and Temporal variation chart of Chlorides of Groundwater Sampling stations during the sampling period

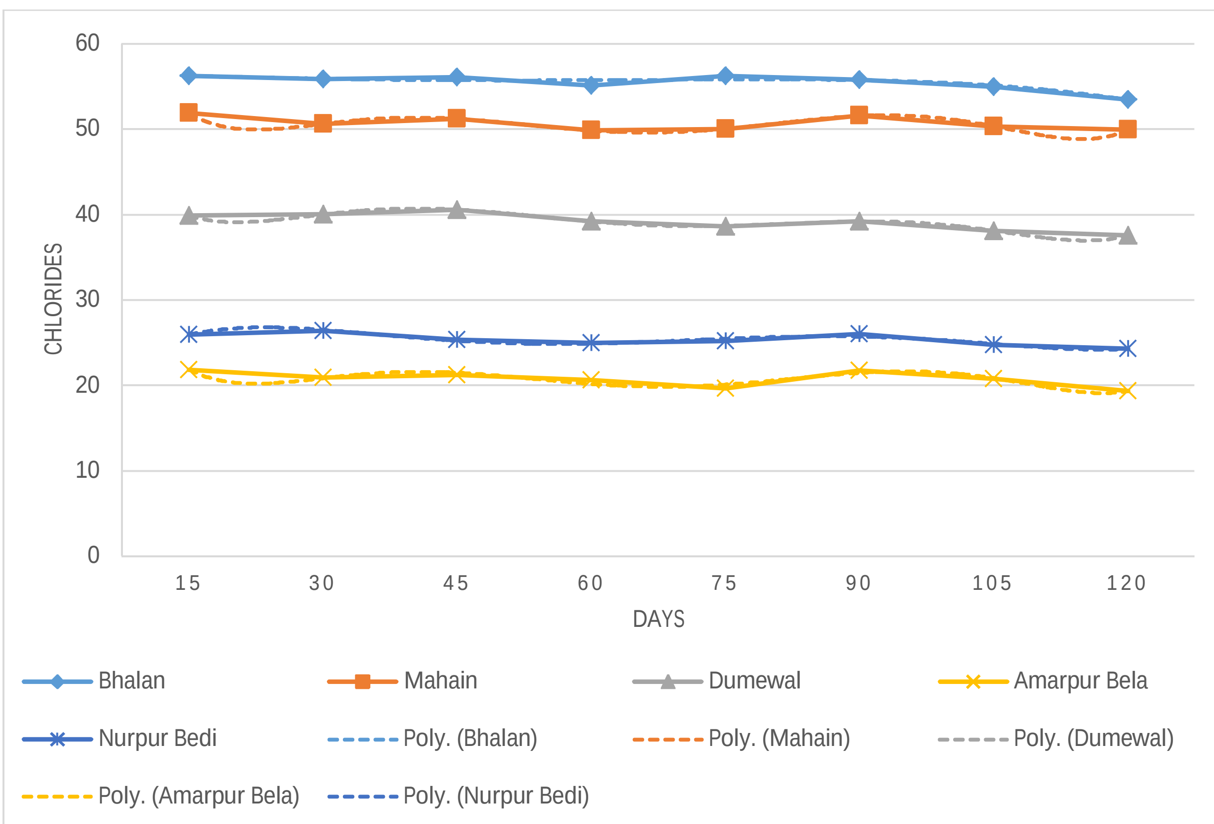

Fig. 5.7(b). Spatial and Temporal variation chart of Chlorides of Groundwater Sampling stations during the sampling period

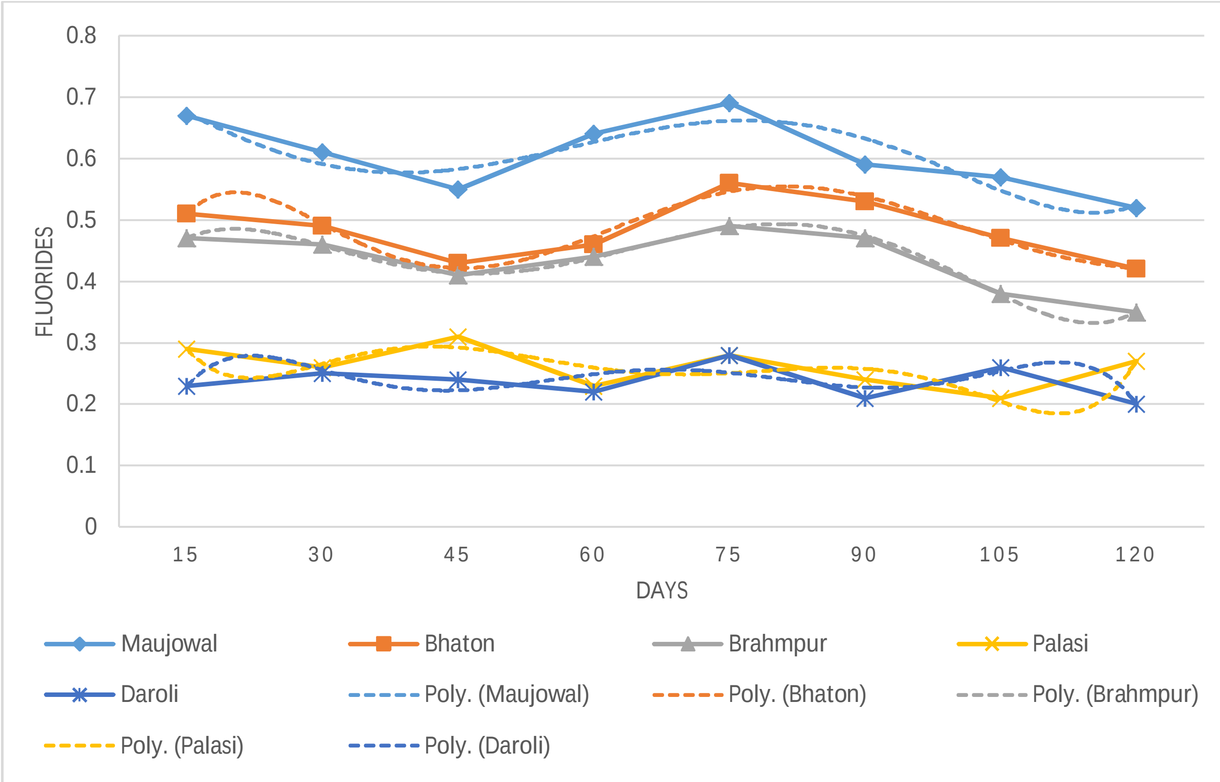

Fig. 5.8(a). Spatial and Temporal variation chart of Fluorides of Groundwater Sampling stations during the sampling period

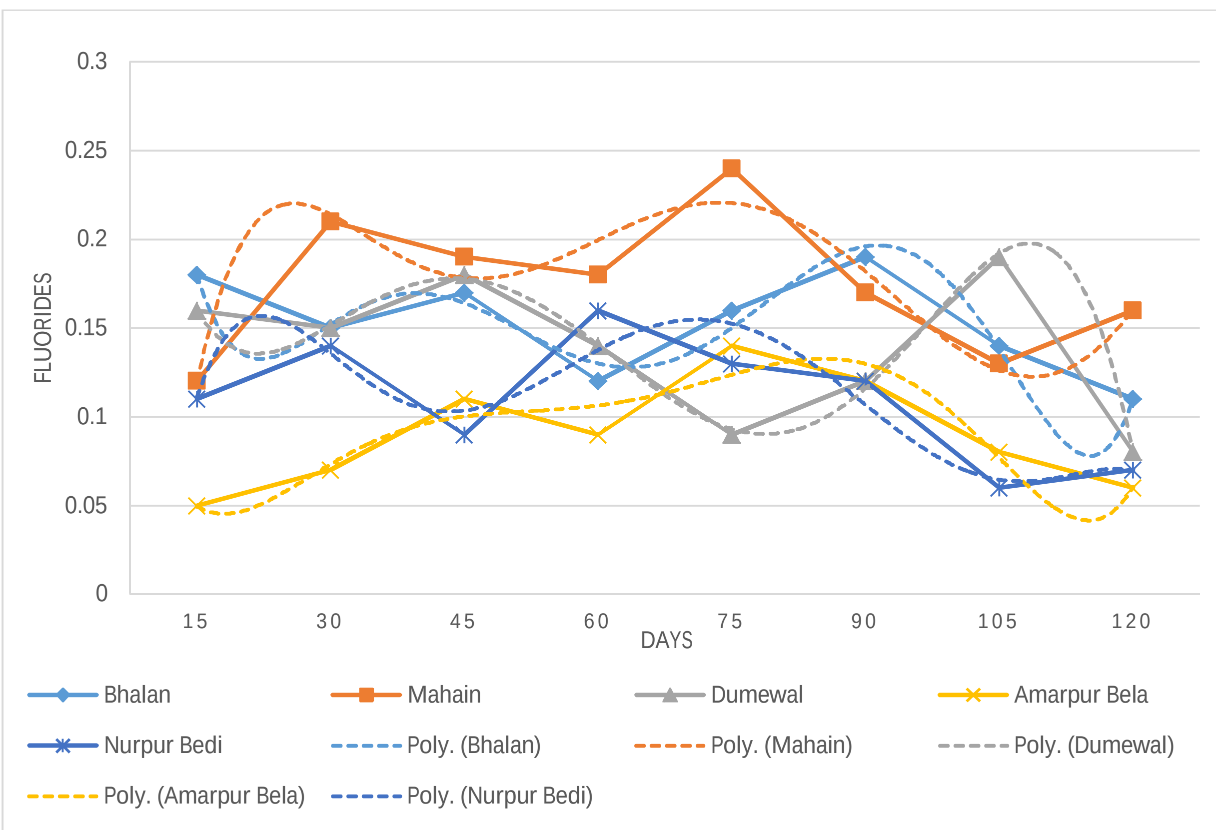

Fig. 5.8(b). Spatial and Temporal variation chart of Fluorides of Groundwater Sampling stations during the sampling period

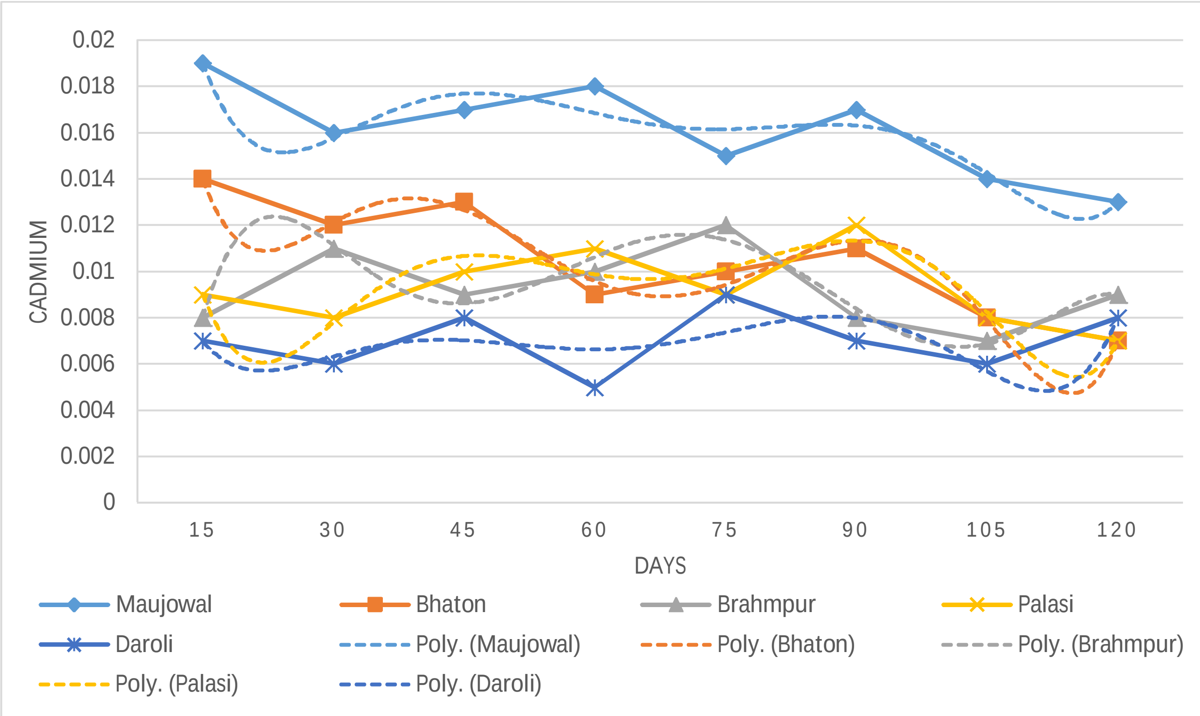

Fig. 5.9(a). Spatial and Temporal variation chart of Cadmium of Groundwater Sampling stations during the sampling period

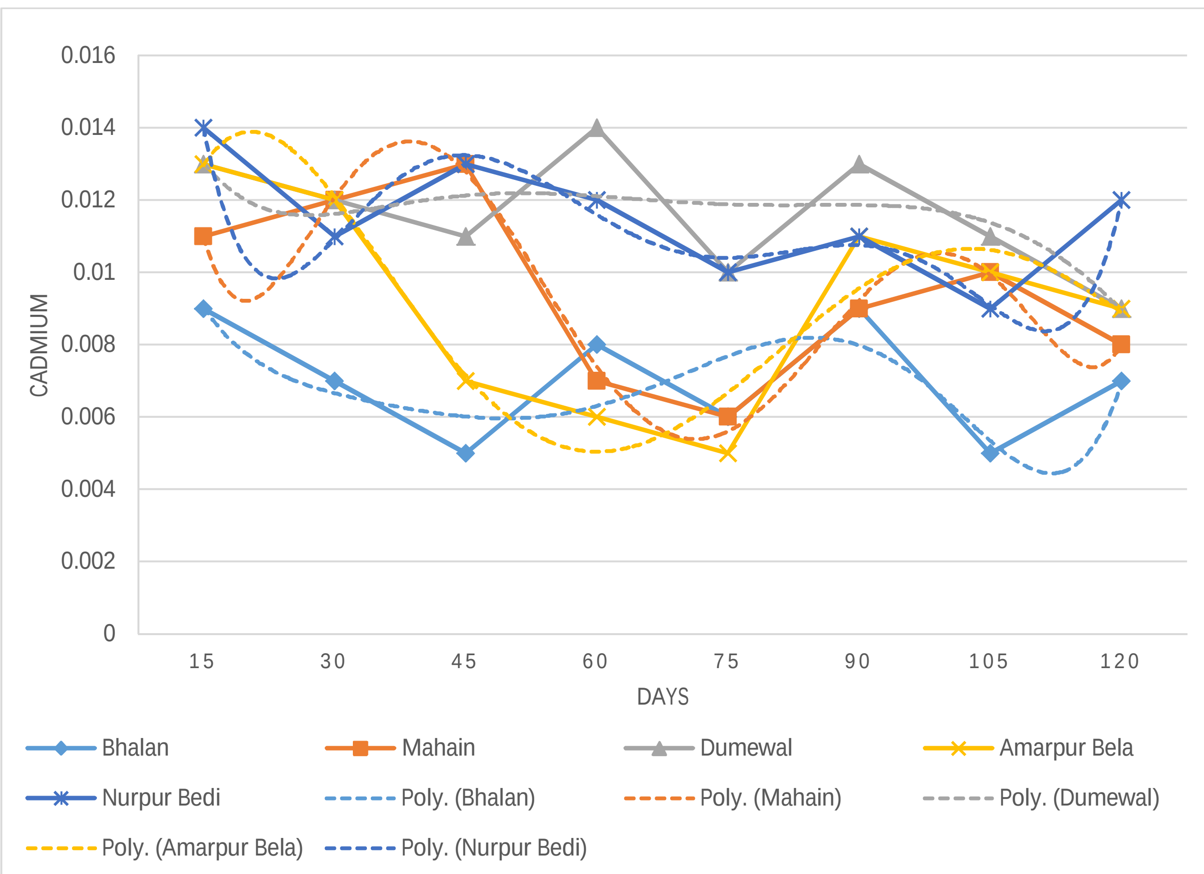

Fig. 5.9(b). Spatial and Temporal variation chart of Cadmium of Groundwater Sampling stations during the sampling period

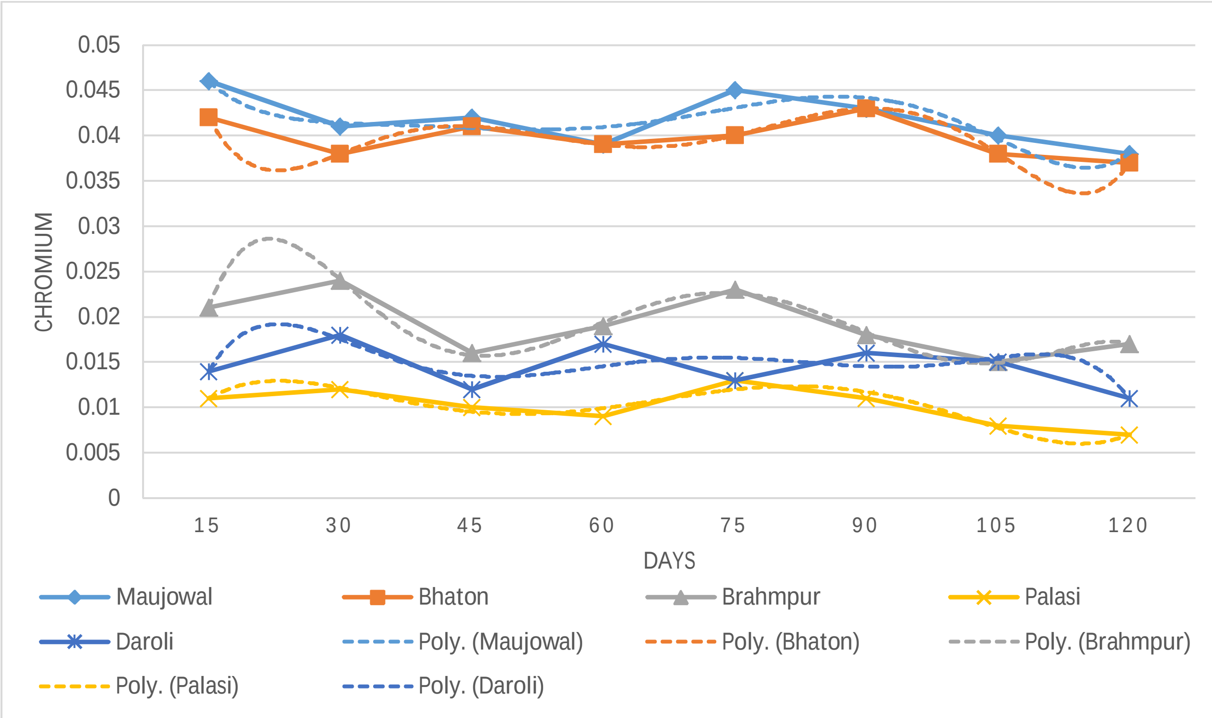

Fig. 5.10(a). Spatial and Temporal variation chart of Chromium of Groundwater Sampling stations during the sampling period

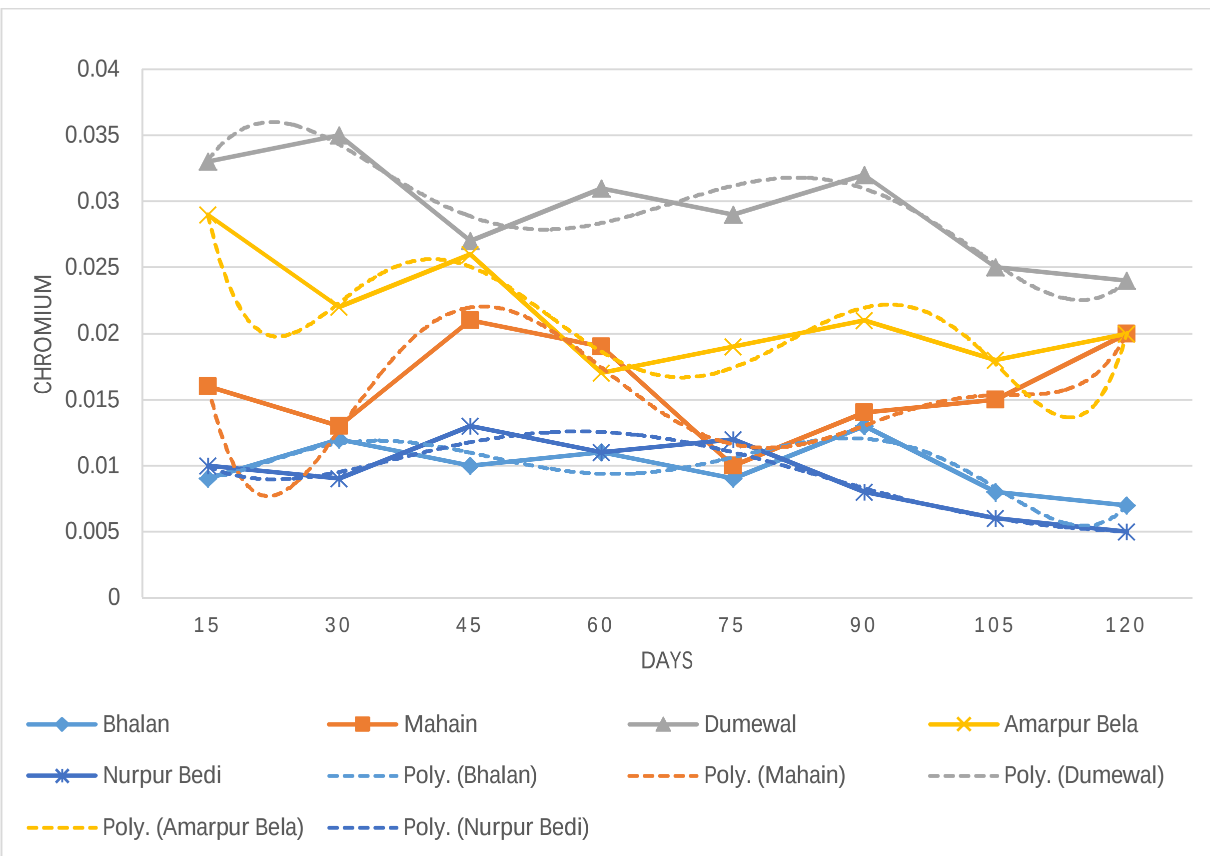

Fig. 5.10(b). Spatial and Temporal variation chart of Chromium of Groundwater Sampling stations during the sampling period

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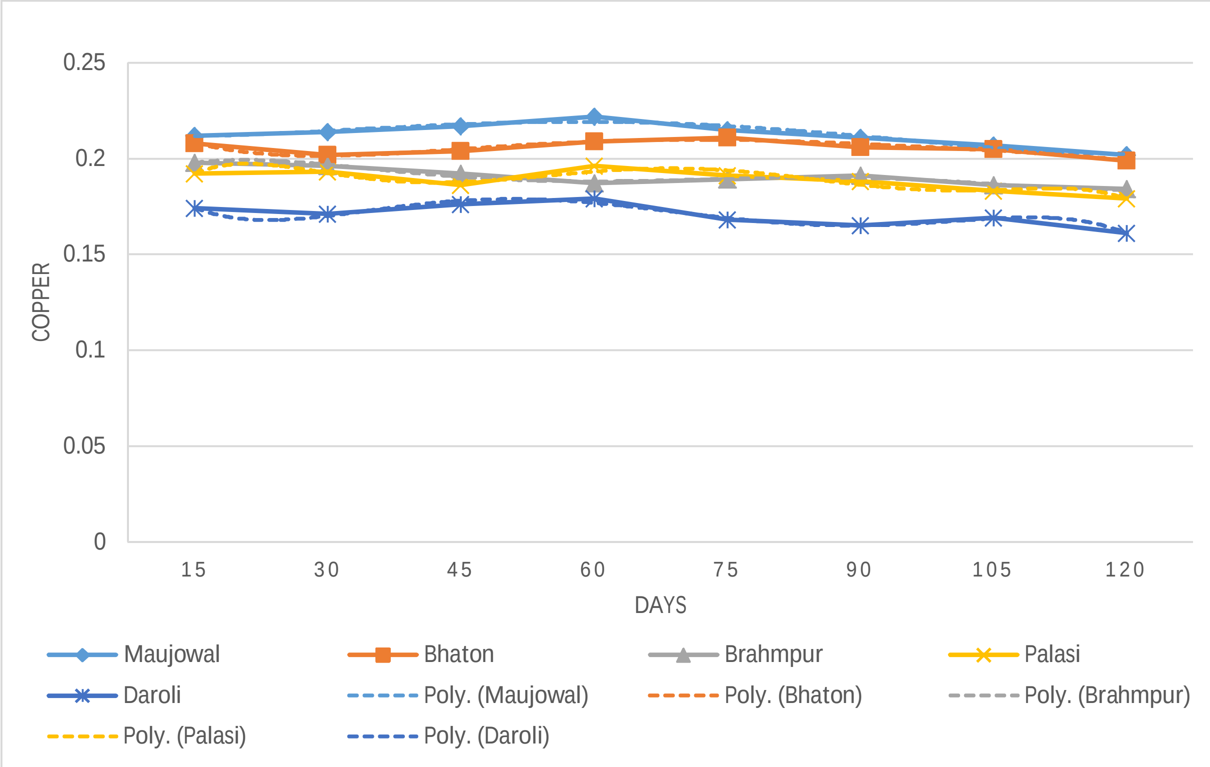

Fig. 5.11(a). Spatial and Temporal variation chart of Copper of Groundwater Sampling stations during the sampling period

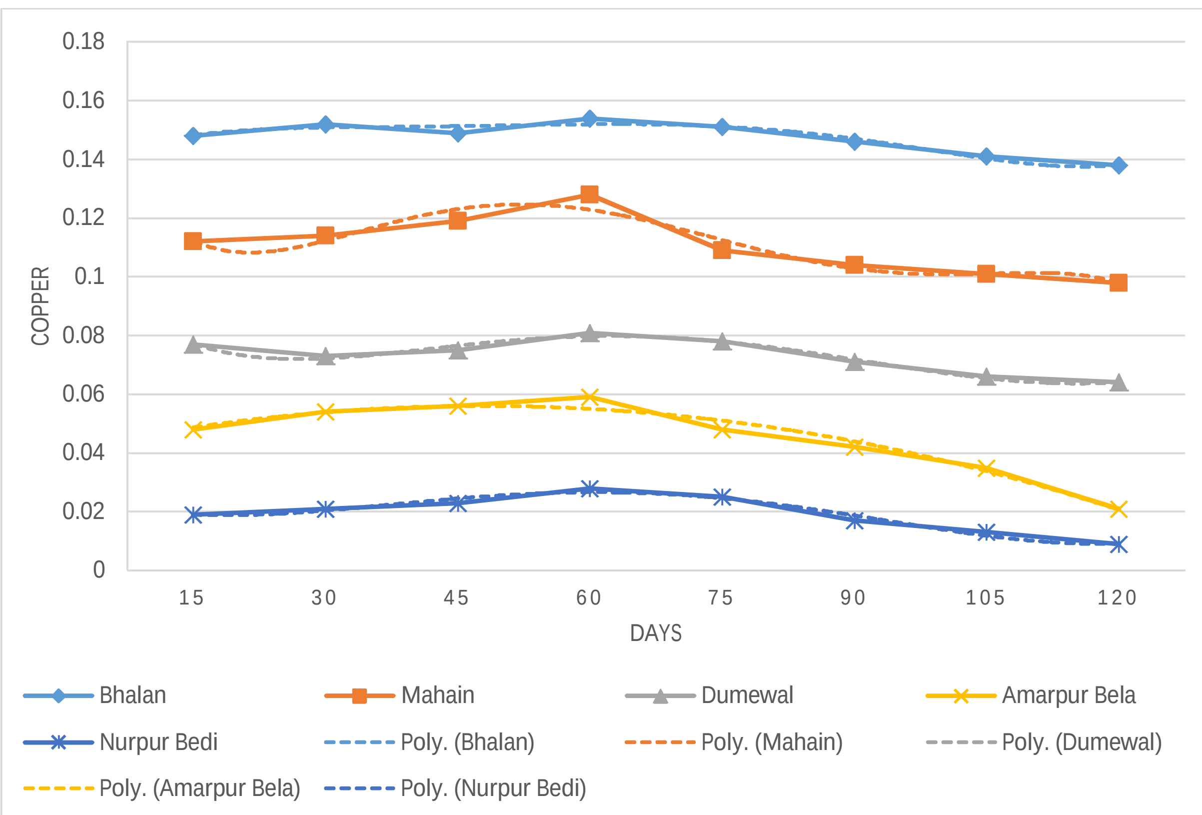

Fig. 5.11(b). Spatial and Temporal variation chart of Copper of Groundwater Sampling stations during the sampling period

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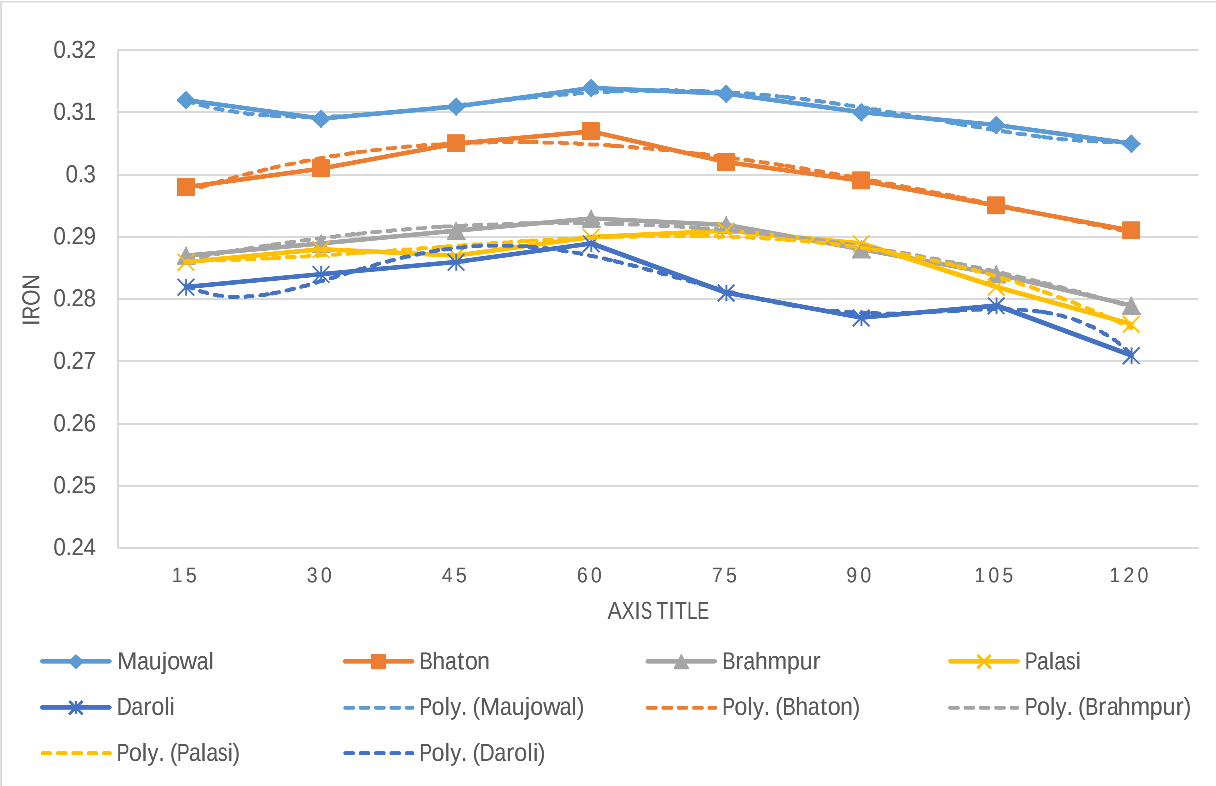

Fig. 5.12(a). Spatial and Temporal variation chart of Iron of Groundwater Sampling stations during the sampling period

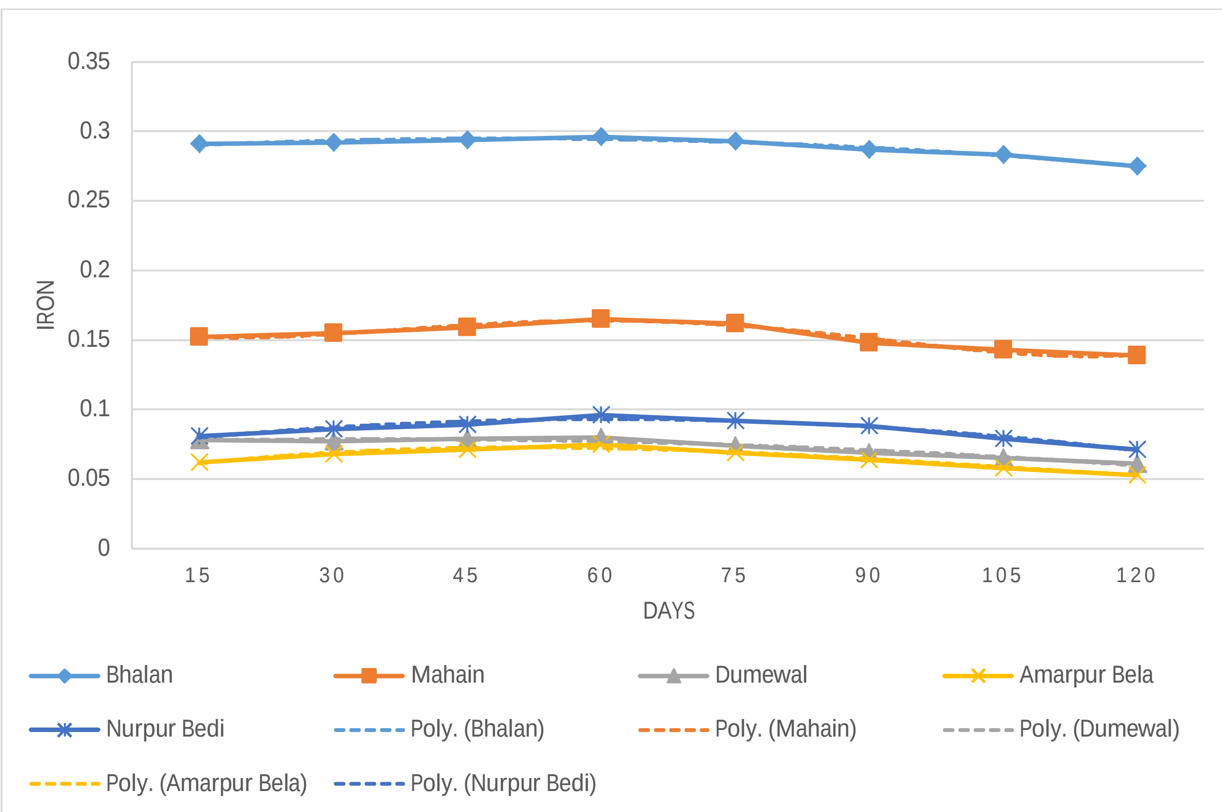

Fig. 5.12(b). Spatial and Temporal variation chart of Iron of Groundwater Sampling stations during the sampling period

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

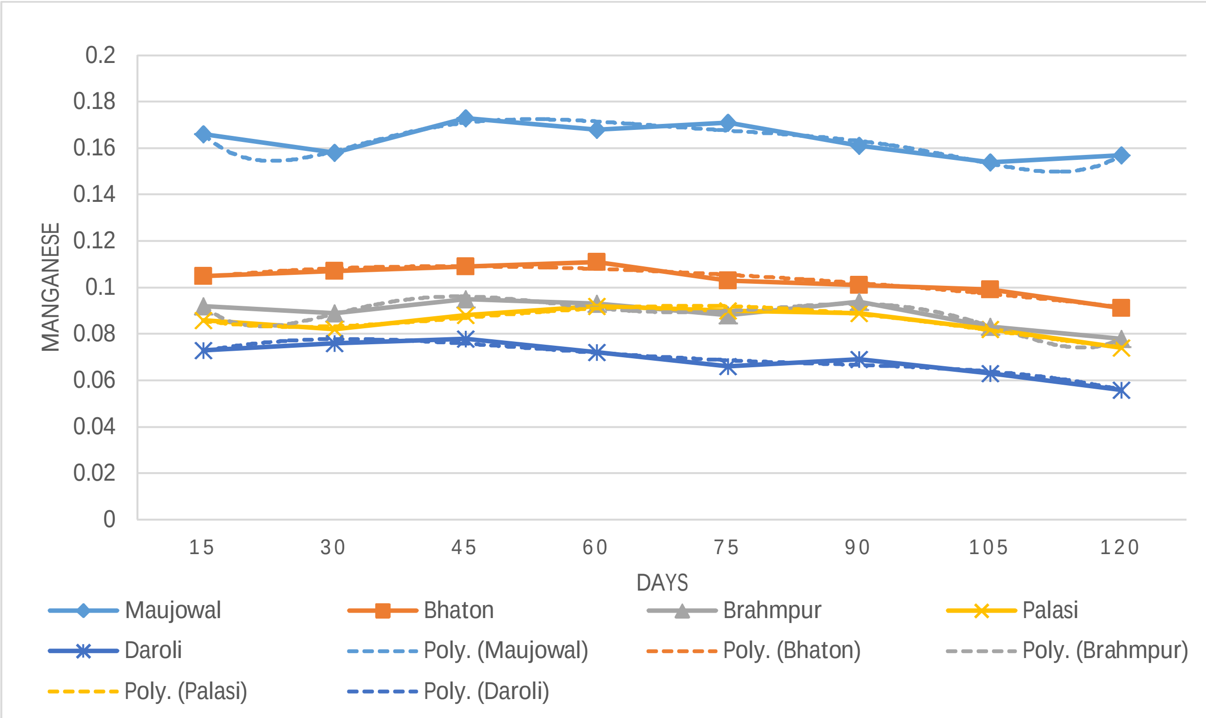

Fig. 5.13(a). Spatial and Temporal variation chart of Manganese of Groundwater Sampling stations during the sampling period

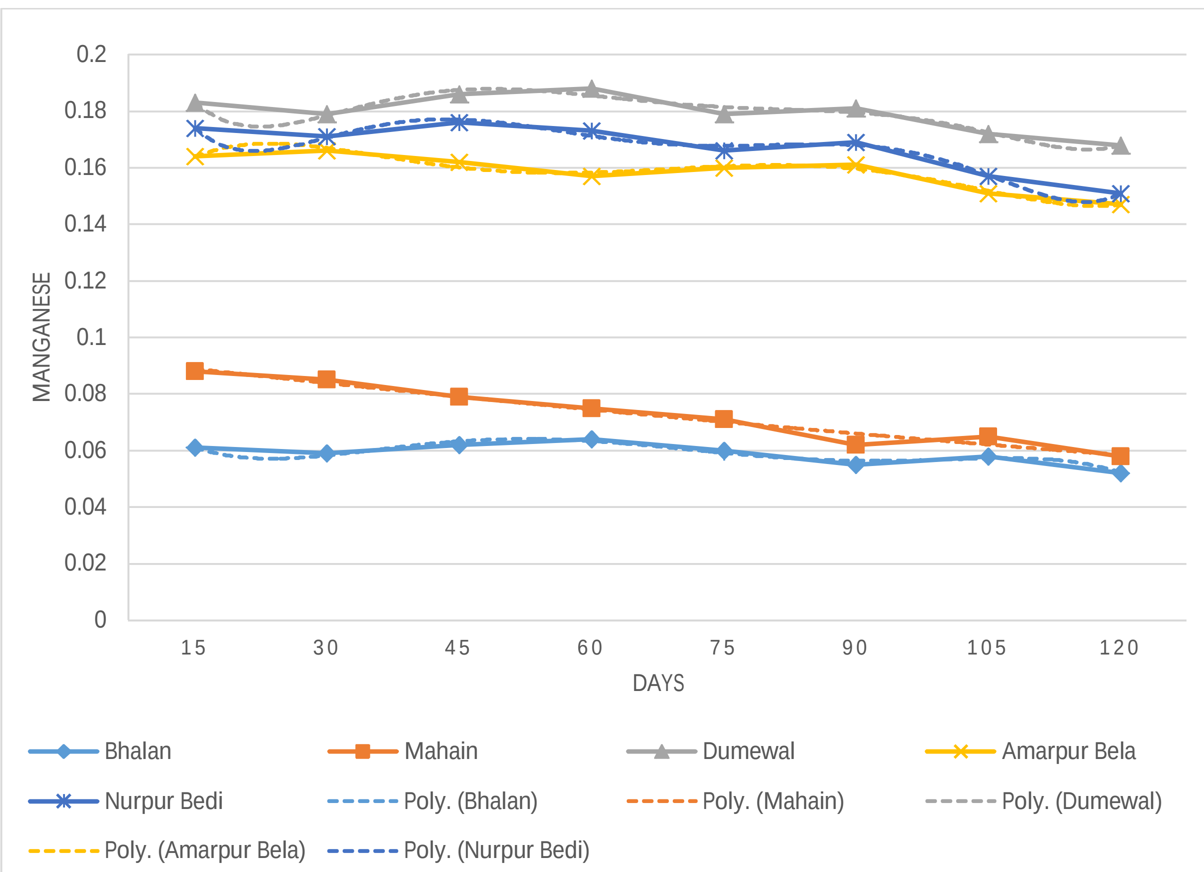

Fig. 5.13(b). Spatial and Temporal variation chart of Manganese of Groundwater Sampling stations during the sampling period

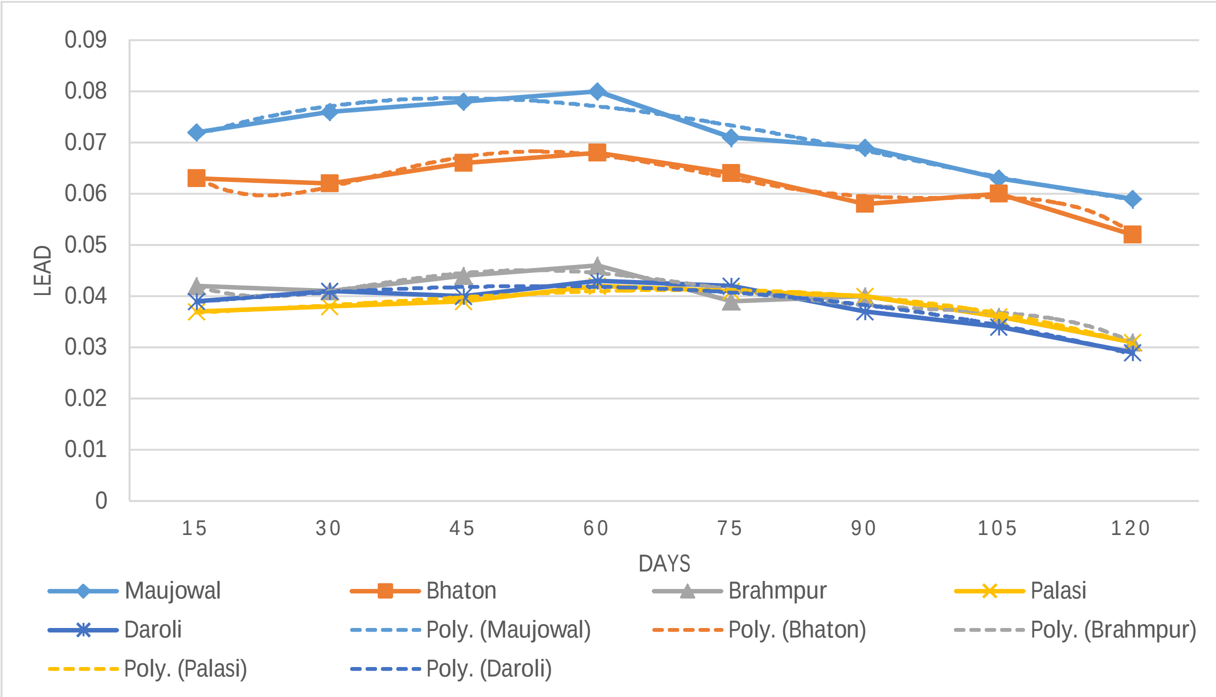

Fig. 5.14(a). Spatial and Temporal variation chart of Lead of Groundwater Sampling stations during the sampling period

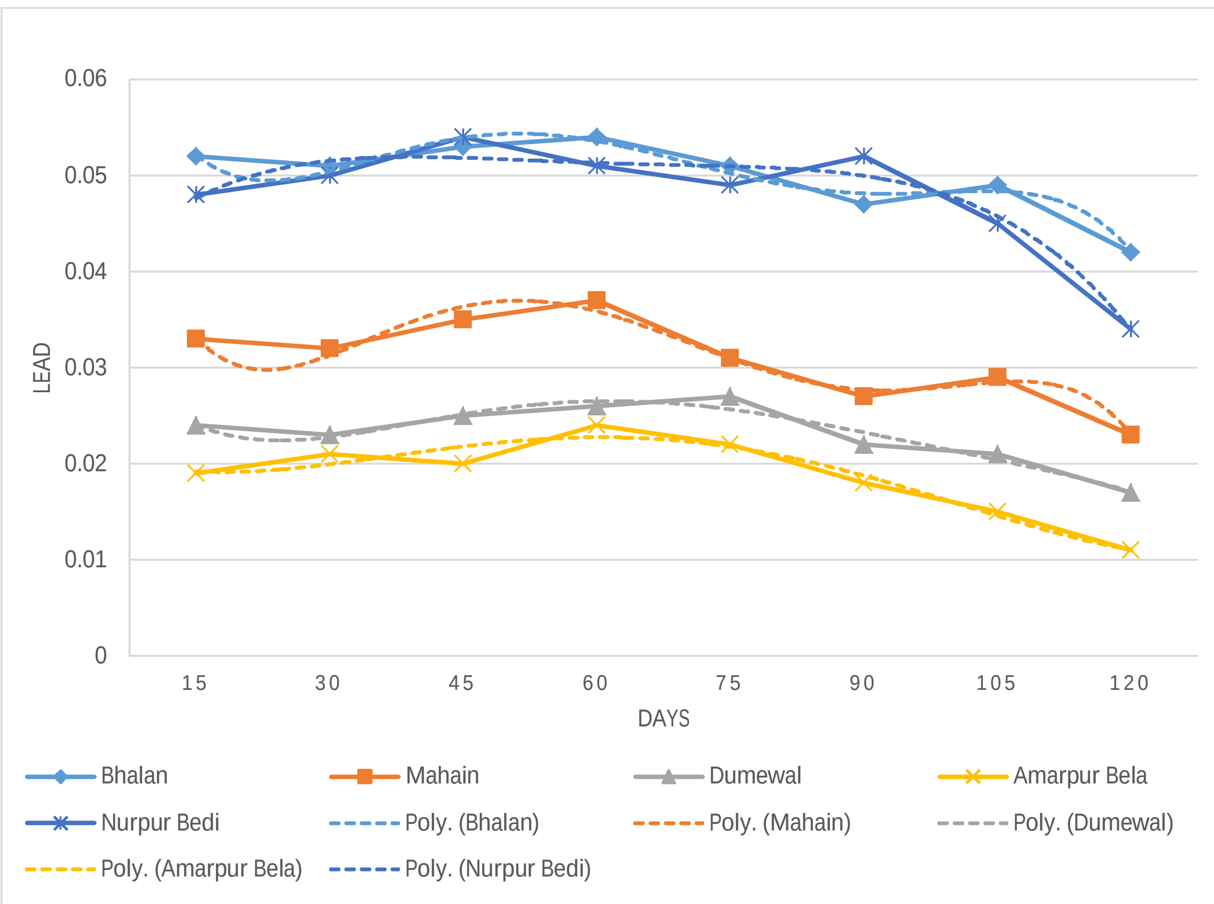

Fig. 5.14(b). Spatial and Temporal variation chart of Lead of Groundwater Sampling stations during the sampling period

Sr. No.	Parameters	A	B	C	D	E
1	pH value	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.0-8.5
2	Total Dissolved Solids mg/L, Max	500	-	1500	-	2100
3	Total Hardness (as $CaCO_3$), mg/L, Max	200	-	-	-	-
4	Dissolved Oxygen (DO)mg/l, Min	6	5	4	4	-
5	Biochemical Oxygen demand (BOD)mg/l, Max	2	3	3	-	-
6	Nitrate (as NO_3), mg/l, Max	20	-	50	-	-
7	Sulphate (as SO_4) mg/l, Max	400	-	400	-	1000
8	Chloride (as Cl), mg/l, Max	250	-	600	-	600

Table -2.1
Surface Water Quality Standards in India (Source IS 2296:1992)

Designated best use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20^0C, 2mg/l or less
Outdoor bathing (Organised)	B	1.Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20^0C, 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20^0C, 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20 □C, 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 □C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below - E	Not meeting any of the A, B, C, D & E criteria

Table - 2.2
Designated best use classification of surface water, Source: CPCB

Sr. No.	Parameters	Acceptable Limit	Permissible Limit in absence of alternate source
1	pH value	6.5 – 8.5	No Relaxation
2	Total Dissolved Solids mg/L, Max	500	2000
3	Total Hardness (as $CaCO_3$), mg/L, Max	200	600
4	Total Alkalinity (as $CaCO_3$), mg/L, Max	200	600
5	Nitrate (as NO_3), mg/l, Max	45	No Relaxation
6	Sulphate (as SO_4) mg/l, Max	200	400
7	Chloride (as Cl), mg/l, Max	250	1000
8	Fluoride (as F) mg/l, Max	1	1.5
9	Cadmium (as Cd), mg/l, Max	0.003	No Relaxation
10	Total chromium (as Cr), mg/l, Max	0.05	No Relaxation
11	Copper (as Cu), mg/l, Max	0.05	1.5
12	Iron (as Fe), mg/l, Max	0.3	No Relaxation
13	Manganese (as Mn), mg/l, Max	0.1	0.3
14	Lead (as Pb), mg/l, Max	0.01	No Relaxation

Table - 3

IS 10500: 2012, Drinking Water – Specification

IV. RESULTS AND DISCUSSIONS

A. Groundwater Analysis

1) *Ph:* In our study we found out that the pH of Maujowal and Bhaton Villages have crossed the upper limit of pH value range i.e., (6.5-8.5) seven times and six times respectively out of the total eight times of sample collection during the sampling period. The pH of all the other village's samples were found out to be in the acceptable range according to IS 10500:2012. We got a maximum pH value of 8.82 at Maujowal sampling station and a minimum pH value of 7.45 at Nurpur Bedi.
2) *Total Dissolved Solids:* The TDS values of all the sampling stations are found out way greater than the acceptable limit of 200 mg/L (as $CaCO_3$) according to IS 10500:2012 as we got a maximum value during the analysis of Total Dissolved Solids as 1326 mg/L (as $CaCO_3$) at Maujowal and a minimum value of 597 mg/L (as $CaCO_3$) at Nurpur Bedi.
3) *Total Hardness:* The Total Hardness values of all the sampling stations were found out to be greater than the acceptable limit of 200 mg/L (as $CaCO_3$) according to IS 10500:2012 except Nurpur Bedi for three samples out of a total of eight samples collected during the sampling period. Total Hardness value ranges from 187 mg/L (as $CaCO_3$) to 423 mg/L (as $CaCO_3$) having maximum value at Maujowal and minimum at Nurpur Bedi. Calcium and magnesium salts are common constituents of rocks present in earth's crust. Therefore, whenever surface water percolates through the crust, it dissolves salts of Ca^{2+} and Mg^{2+} with it, leading to their enhanced concentration in the groundwater (Ravindra et al., 2019).
4) *Total Alkalinity:* The Total Alkalinity of each sample for all the sampling stations were found out to be greater than the acceptable limit of 200 mg/L (as $CaCO_3$) according to IS 10500:2012. Maximum value of total alkalinity is found out to be at Maujowal having a value of 535 mg/L (as $CaCO_3$) and minimum value of total alkalinity is 356 mg/L (as $CaCO_3$) found out to be at Nurpur Bedi.
5) *Nitrates:* In our study we found out that each and every sample have Nitrate concentration greater than the acceptable limit of 45 mg/L for Nitrate (as NO_3) given in IS 10500:2012. Also according to IS 10500:2012 there should not be any relaxation given to this value of 45 mg/L for Nitrate (as NO_3) which tells us that this should be strictly followed. But in our study we found out that the Nitrate values of all the sampling stations for each sample collected during the sampling period are greater than the prescribed acceptable limit which gives us a clear understanding of the level of pollution status in the groundwater of Nangal nearby NFL Drain region. Maximum value which we got is 123.03 mg/L at Maujowal village's groundwater sample and a minimum value of 63.39 mg/L which we got at Nurpur Bedi village's groundwater sample.
6) *Sulphates:* According to IS 10500:2012, the acceptable limit for Sulphate (as SO_4) mg/l is 200 mg/L and the permissible limit in absence of alternate source is 400 mg/L. But in our study we found out that none of the village's groundwater sample collected during sampling period have Sulphate concentration greater than the acceptable limit. Sulphate concentration values ranges from 52.27 mg/L at Nurpur Bedi to 135.36 mg/L at Maujowal.

7) *Chlorides:* The Chloride values of each and every sample collected during the sampling period from every sampling station are found out to be way lower than the given acceptable limit of 250 mg/L in IS 10500:2012. The maximum value of chloride is found out to be 74.88 mg/L at Maujowal and a minimum value of 19.35 mg/L is found out to be at Amarpur Bela. Therefore the chloride content of Nangal's groundwater near to NFL Drain region is under permissible limits.
8) *Fluorides:* In our study we got the maximum value of Fluoride (as F) as 0.69 mg/L at Maujowal and a minimum value of 0.05 mg/L at Amarpur Bela. So this means that the range which we got for fluorides is lesser than the acceptable limit of 1 mg/L according to IS 10500:2012. Infact almost all the samples collected during sampling period have fluoride value even less than 0.6 mg/L except just for four samples of Maujowal's groundwater sample.
9) *Cadmium:* According to IS 10500:2012, the acceptable limit for Cadmium (as Cd) is 0.003 mg/L. And during our analysis of Cadmium we found out that values of Cadmium for every sample collected from all the sampling stations during the sampling period are greater than the prescribed limit of 1 mg/L. We got the maximum value of Cadmium as 0.019 mg/L at Maujowal and the minimum value which we got at Daroli, Bhalan and Amarpur Bela is 0.005 mg/L.
10) *Total Chromium:* In our study we found out that the range of Total Chromium (as Cr) values varies from 0.005 mg/L to 0.046 mg/L. Minimum value is found to be at Nurpur Bedi and maximum value is found to be at Maujowal. Now as according to IS 10500:2012, the acceptable limit for Total Chromium (as Cr) is 0.05 mg/L, so in our analysis for Total Chromium we found out that the each and every sample collected from every sampling station during the sampling period is having a value less than the prescribed value of 0.05 mg/L by IS 10500:2012. So the groundwater of Nangal near NFL Drain's region is within the permissible limits of Total Chromium.
11) *Copper:* According to IS 10500:2012, the acceptable limit for Copper (as Cu) is 0.05 mg/L and the permissible limit in absence of alternate source is 1.5 mg/L. Now in our study during the analysis of Copper we found out that all the samples collected from Nurpur Bedi are having values lesser than the maximum acceptable limit for Copper according to IS 10500:2012 and five samples collected from Amarpur Bela during the sampling period are having values less than the maximum acceptable limit. Except than these samples, all the other samples analysed for Copper are having greater values than the maximum acceptable limit. In our study, Copper values ranges from 0.009 mg/L at Nurpur Bedi to 0.222 mg/L at Maujowal.
12) *Iron:* All the eight samples collected from Maujowal and four out of eight samples collected from Bhaton are having values greater than the maximum acceptable limit of 0.3 mg/L according to IS 10500:2012 for Iron (as Fe). All the other samples except than these 12 samples are having values of Iron lesser than the maximum acceptable limit of 0.3 mg/L. The maximum value in the analysis of Iron is found out to be 0.314 mg/L in Maujowal sampling station's groundwater sample and a minimum value of 0.053 mg/L is found to be at Nurpur Bedi.
13) *Manganese:* According to IS 10500:2012, the acceptable limit for Manganese (as Mn) is 0.1 mg/L. In our study during the analysis of Manganese we found out that all the samples collected from Brahmpur, Palasi, Daroli, Bhalan and Mahain have values of Manganese lower than the maximum acceptable limit of 0.1 mg/L. On the contrary all the samples collected from Maujowal, Dumewal, Amarpur Bela and Nurpur Bedi have the values of Manganese greater than the maximum acceptable limit of 0.1 mg/L. Out of the total ten sampling stations from where the samples have been collected during the sampling period, Five stations have lesser value than the maximum acceptable limit and four stations have greater values than the maximum acceptable limit of 0.1 mg/L. Now for the remaining one station i.e., Bhaton, we found out that two samples out of the total eight samples collected during the sampling period have values lower than the maximum acceptable limit and the other six samples have greater value than the maximum acceptable limit. Range of Manganese values varies from 0.052 mg/L at Bhalan to 0.188 mg/L at Dumewal sampling station.
14) *Lead:* In our study during the analysis of Lead we found out that all the 80 samples collected from ten different sampling stations during our sampling period of four months are having values of Lead (as Pb) greater than the maximum acceptable limit of 0.01 mg/L according to IS 10500:2012. The maximum value of 0.08 mg/L was found to be at Maujowal sampling station and a minimum value of 0.011 mg/L was found to be at Amarpur Bela sampling station.

B. *Sutlej River Water Analysis*

1) *pH:* According to IS 2296:1992, Surface Water Quality Standards in India, the pH value range given for Class A is 6.5 – 8.5. Now in our study during the analysis of pH in the Sutlej River water near NFL Drain region, we found that at the U/S of Drain sampling location the values of pH are within the range given according to IS 2296:1992, Surface Water Quality Standards in India as we got a mean pH value of 8.02 at the U/S of Drain sampling location. But after mixing with the polluted wastewater discharge from NFL Drain there is a spike in the pH values in the downstream side of Sutlej River water as we got a mean pH

value of 8.69 at D/S of Drain sampling location and a mean pH value of 8.62 at 2 Km D/S of Drain sampling location. At 5 Km D/S of Drain sampling location, the mean pH value is not within the range of 6.5 – 8.5 as we got a mean pH value of 8.53. But as we further on the downstream side of Sutlej River water we got a mean pH value of 8.4 at 10 Km D/S of Drain sampling location which completely comes within the range of 6.5 – 8.5 according to IS 2296:1992, Surface Water Quality Standards in India, for Class A.

2) *Total Dissolved Solids:* At U/S of Drain, TDS values are found to be lower with a mean of 126.25 mg/L. But after mixing with the polluted wastewater discharge from NFL Drain, all of a sudden there is a rise in the TDS values at the downstream side of Sutlej River water. At about 1 Km downstream from NFL Drain, we got a mean concentration of Total Dissolved Solids of 467.13 mg/L. Now as we move away from NFL Drain on the downstream side of the Sutlej River, the concentrations of Total Dissolved Solids are decreasing with a mean value of 428.13 at 2 Km D/S of Drain and a mean value of TDS concentration of 326.25 mg/L at 10 Km D/S of NFL Drain. But all of the total five sampling stations of Sutlej River at Nangal near NFL Drain region are having TDS concentrations lower than the value of 500 mg/L according to IS 2296:1992, Surface Water Quality Standards in India for Class A as stated in Table 1.1, which means that this region of Sutlej River water does not need any conventional treatment for lowering Total Dissolved Solid concentrations in river water.
3) *Total Hardness:* In our study during Sutlej river water analysis, we found out that the Total Hardness (as $CaCO_3$) values are considerably lower than the maximum limit of 200 mg/L (as $CaCO_3$) according to IS 2296:1992 for Class A. At U/S of Drain we got a mean of 65.875 mg/L (as $CaCO_3$) which increased to a value of 91.125 at D/S of Drain (about 1 Km from NFL Drain) after mixing with the polluted wastewater discharge from NFL Drain. Now as we move on the downstream side of Sutlej River, we see a decrease in the concentration of TDS with a mean value of 81.5 mg/L (as $CaCO_3$) at 5 Km D/S of Drain and a mean value of 74.875 mg/L (as $CaCO_3$) at 10 Km D/S of Drain sampling station which is about 10 Km from the NFL Drain at the downstream side of Sutlej River. All the sampling stations have Total Hardness values lower than the maximum limit of 200 mg/L (as $CaCO_3$) according to IS 2296:1992, Surface Water Quality Standards in India for Class A as stated in Table 1.1.
4) *Alkalinity:* During the analysis of Alkalinity in Sutlej River water samples, we found out that the alkalinity values got increased after mixing with the NFL Drain's polluted wastewater as compared to the values on upstream side of NFL Drain i.e., before mixing. At U/S of Drain we got a mean value of Alkalinity concentration in Sutlej river water samples as 108.125 mg/L (as $CaCO_3$) which increased to a mean value of 150 mg/L (as $CaCO_3$). After this sampling station there is a decrease in Alkalinity Values with a mean value of 143 mg/L (as $CaCO_3$) at 2 Km D/S, 135.625 mg/L (as $CaCO_3$) at 5 Km D/S of Drain and 128.5 mg/L (as $CaCO_3$) at 10 Km D/S of Drain sampling station.
5) *Dissolved Oxygen:* In our study we found out that the concentration of Dissolved Oxygen in Sutlej River water samples collected is maximum at U/S of Drain sampling station with a mean value of 9.35 mg/L and minimum at D/S of Drain sampling station with a mean value of 8.38 mg/L. But we found that that the concentration of Dissolved Oxygen started increasing as we move on the downstream side of Sutlej River with a mean value of 8.56 mg/L at 2 Km D/S of Drain and a mean value of 8.91 mg/L at 10 Km D/S of Drain sampling station. According to IS 2296:1992, Surface Water Quality Standards in India, for Class A, Dissolved Oxygen concentration should have a minimum value of 6.0 mg/L which is totally being followed in our analysis of Dissolved Oxygen.
6) *Biochemical Oxygen Demand:* During the analysis of BOD, we found out that at U/S of Drain, there is a mean value of 2.02 mg/L which is almost same as the maximum limit of 2 mg/L according to IS 2296:1992, Surface Water Quality Standards in India, for Class A. But after mixing with the polluted wastewater discharge from NFL Drain, all of a sudden there is a rise in the BOD values at the downstream side of Sutlej River water. At D/S of Drain (about 1 Km from NFL Drain) we got a mean value of 22.83 mg/L and mean values of 20.56 mg/L, 16.23 mg/L and 13.36 mg/L at 2 Km D/S of drain, 5 Km D/S of drain and 10 Km D/S of drain respectively.
7) *Nitrates:* According to IS 2296:1992, Surface Water Quality Standards in India, the maximum value for Nitrates (as NO_3) for Class A is 20 mg/L. Now in our study during the analysis of Nitrates in Sutlej River water we found out that at U/S of Drain sampling station, the mean value of Nitrates concentration is 1.9 mg/L which is way lesser than the maximum limit of 20 mg/L for Class A according to IS 2296:1992, Surface Water Quality Standards in India. But after mixing with the polluted wastewater discharge from NFL Drain there is a huge spike in the Concentration of Nitrates on the downstream side of Sutlej River from NFL Drain as we got a mean value of 119.6 mg/L at D/S of Drain (about 1 Km from NFL Drain) sampling station. Mean values of Nitrates Concentration in Sutlej River water are 106.8 mg/L, 83.6 mg/L and 59.5 mg/L at 2 Km D/S of Drain, 5 Km D/S of Drain and 10 Km D/S of Drain respectively. So all the sampling stations on the downstream side of NFL Drain of

Sutlej River exceeds the maximum limit for Nitrates (as NO_3) for Class A of 20 mg/L according to IS 2296:1992, Surface Water Quality Standards in India.

8) *Sulphates:* According to IS 2296:1992, Surface Water Quality Standards in India, the maximum value for Sulphates (as SO_4) for Class A is 400 mg/L. In our study during the analysis of Sulphates in Sutlej River water we found out that none of the total 40 samples collected during sampling period for Sutlej River water analysis exceeds this maximum value of 400 mg/L for Class A as prescribed by IS 2296:1992, Surface Water Quality Standards in India. Infact the values are way lower than this maximum limit for Class A as the mean value of Sulphates Concentration in Sutlej River water at U/S of Drain sampling station is 7.31 mg/L. But after mixing with the polluted wastewater discharge from NFL Drain there is a bit of increase in the concentration of Sulphates on the downstream side of Sutlej River as we got a mean value of 24.73 mg/L at D/S of Drain (about 1 Km from NFL Drain) sampling station. Mean values of Sulphates Concentration in Sutlej River water at 2 Km D/S of Drain, 5 Km D/S of Drain and 10 Km D/S of Drain sampling stations are 21.85 mg/L, 18.42 mg/L and 14.66 mg/L respectively.
9) *Chlorides:* According to IS 2296:1992, Surface Water Quality Standards in India, the maximum value for Chlorides (as Cl) for Class A is 250 mg/L. In our study during the analysis of Chlorides in Sutlej River water we found out that none of the total 40 samples collected during sampling period for Sutlej River water analysis exceeds this maximum value of 250 mg/L for Class A as prescribed by IS 2296:1992, Surface Water Quality Standards in India. The mean value of Chlorides Concentration in Sutlej River water at U/S of Drain sampling station is 29.51 mg/L. After mixing with the polluted wastewater discharge from NFL Drain there is a slight increase in the concentration of Chlorides on the downstream side of Sutlej River as we got a mean value of 52.61 mg/L at D/S of Drain (about 1 Km from NFL Drain) sampling station. Mean values of Chlorides Concentration in Sutlej River water at 2 Km D/S of Drain, 5 Km D/S of Drain and 10 Km D/S of Drain sampling stations are 47.97 mg/L, 42.04 mg/L and 36.78 mg/L respectively.
10) *Calcium and Magnesium:* During the analysis of Calcium and Magnesium in our study we found out that both of these Calcium and Magnesium ions are relatively lower in concentration in the Sutlej River water near NFL Drain region. As the mean concentration of Calcium at U/S of Drain sampling location is 26.48 mg/L and at the downstream side of the Sutlej River from NFL Drain we got a mean concentration of Calcium as 31.50 mg/L. So from this we can analyse that the Calcium ion concentrations are quite lower. Also the concentration of Magnesium ions are also pretty much lower as we found that the mean concentration of Magnesium in the Sutlej River water at U/S of Drain sampling location is 9.30 mg/L and at the downstream side of the Sutlej River from NFL Drain we got a mean concentration of Magnesium as 12.86 mg/L. Therefore the Magnesium ion concentration is also quite lower in the Sutlej River water near NFL Drain region.

V. CONCLUSION

In the present study, the effect of polluted discharge from NFL Drain into the Sutlej River was analysed and due to this polluted Sutlej River water, its further impact on Groundwater of the nearby region was also analysed as the residents of those villages directly consume the groundwater and use the Sutlej River water and groundwater for all their basic activities.

Sutlej River water contamination can be easily seen from the Spatial and Temporal variation charts as the parameters such as pH value and Biochemical Oxygen Demand are having greater values than their respective permissible values/ranges as according to IS 2296:1992, Surface Water Quality Standards in India for almost all the samples at all the locations which comes on the downstream side of NFL Drain i.e., the sampling locations which comes after the confluence of NFL Drain discharge with Sutlej River water. Now according to IS 2296:1992, Surface Water Quality Standards in India, the maximum value for Nitrates (as NO_3) for Class A is 20 mg/L and it comes as no surprise to us that at all the sampling locations which comes on the downstream side of NFL Drain i.e., the sampling locations which comes after the confluence of NFL Drain discharge with Sutlej River water are having concentration of Nitrates seriously higher than this maximum limit. Infact the maximum Nitrate concentration which we got during its analysis is 125.76 mg/L which is even greater than six times the maximum limit for Class A according to IS 2296:1992, Surface Water Quality Standards in India. So from this we get to know the level of Sutlej River water pollution particularly near NFL Drain's region. Due to the high level of Nitrates concentration in Sutlej River water, the groundwater is also getting polluted due to the obvious reasons of river water seeping through soil to join groundwater table. On the other hand the parameters such as Total Dissolved Solids, Total Hardness, Total Alkalinity, Dissolved Oxygen, Sulphates, Chlorides, Calcium and Magnesium are well within their permissible limits as according to IS 2296:1992, Surface Water Quality Standards in India.

Groundwater is seriously contaminated as the concentrations of Total Dissolved Solids, Total Hardness, Total Alkalinity, Nitrates, Cadmium, Copper and Lead at almost all the sampling locations are highly greater than the their respective acceptable limits according to IS 10500:2012, Drinking Water – Specification by CPCB. The pH value is not under the acceptable range for

Maujowal and Bhaton village's groundwater. The concentrations of Sulphates, Chlorides, Fluorides and Total Chromium are under their respective permissible limits according to IS 10500:2012, Drinking Water – Specification by CPCB at almost all the sampling locations. And finally the concentration of Iron is greater than its acceptable limit at only Maujowal and Bhaton village's groundwater but Manganese concentration is greater than its acceptable limit at Maujowal, Bhaton, Dumewal, Amarpur Bela and Nurpur Bedi village's groundwater. So basically groundwater is quite contaminated with a very high concentration of Nitrates (a prime effluent in the polluted discharge from NFL Drain), Total Dissolved Solids, Total Hardness, Total Alkalinity and heavy metals such as Cadmium, Copper, Iron, Manganese and Lead.

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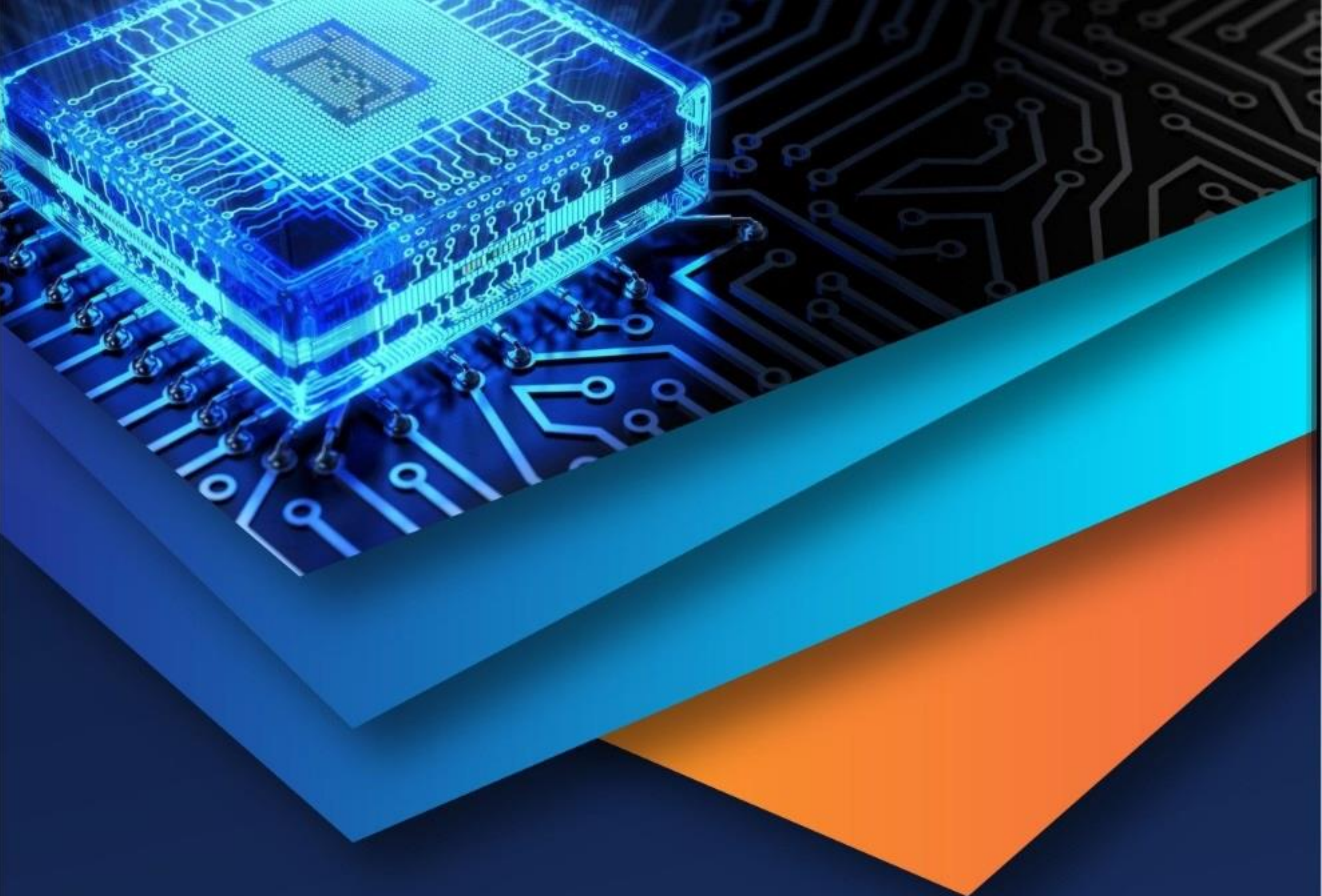

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