Vol. 10. No.4. 2021

Contents available at:

www.crdeepjournal.org

International Journal of Environmental Sciences (ISSN: 2277-1948) (CIF: 3.654)
A Peer Reviewed Quarterly Journal

Full Length Research Paper

Assessment of Effects of Solid Waste from the Municipal Solid Waste Dumping Yards on Ground Water using GIS tool: A Case Study of Southern part of Bengaluru, Karnataka, India

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ARTICLE INFORMATION

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Article history:
Received: 05-12-2021
Revised: 08-12-2021
Accepted: 11-12-2021
Published: 13-12-2021

Key words:
Groundwater, Water Parameters, Bangalore, Karnataka, India.

ABSTRACT

Water is an essential and basic requirement for all living species.The availability of water is a major fact or in the planning and growth of any activity in a city. The analyses of ground water quality due to the impact of municipal solid waste dumping yards were studied in Bangalore southern part of the city. In this research work an attempt has been made to assess the effect of municipal solid waste dumping yard on groundwater quality. For this work a study area has been chosen and four municipal dumping yards sites were chosen. The groundwater samples were collected nearer the selected Solid waste landfill-sites in southwest part of the Bengaluru to study the possible impact of solid waste effect on ground water quality. The physical and chemical parameters such as temperature, pH, hardness, electrical conductivity, total dissolved solids, total suspended solids, alkalinity, calcium, magnesium, chloride, nitrate, sulphate, phosphate and the metals like sodium, potassium, iron, lead and zinc were studied using various analytical techniques. It has been found that most of the parameters of water are not in the acceptable limit in accordance with the IS 10500 Drinking Water Quality Standards. It is concluded that the contamination is due to the solid waste materials that are dumped in the area. The most significant observation was in pre monsoon 78% of samples were having less than BIS standards and 25% of samples in post monsoon were having less than 6mg/L DO. All the samples were having high BOD in PRM but in POM 43% of samples were out of permissible limits. Results of concentration of lead shows 37% of samples of PRM & 15% of the samples of POM are out of the permissible limit. Thus, our results indicate the urgent requirement of remedial efforts in management of solid wastes dumping yards to protect the ground water of Bengaluru city and their adjoining areas.

Introduction

Groundwater is part of the Hydrological cycle. It is water that is located beneath the earth's surface in pores and crevices of rocks and soil. It moves much more slowly than surface water. Water can move down a river in hours, days or perhaps weeks. Groundwater in an aquifer may take ten, one hundred or many thousand years to flow through an aquifer (2).

Management of groundwater needs to consider the amount of water going into the aquifer. Groundwater is an important resource all over the world. The term groundwater is *usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formation that are fully saturated. It supports drinking water supply; livestock needs irrigation, industrial and many commercial activities*. Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies (5).

In India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water based human activities are causing pollution of this precious resource .In Bangalore city fractured granitic- gneisses and gneisses are the main water bearing formations. Ground water occurs within the weathered and fractured rocks under water-table conditions and semi-confined conditions (9). Bengaluru is the largest city in Karnataka and commonly known as City of Gardens. In recent years the city has grown extensively and the growth rate is considerably high over past decades.

The Bengaluru water supply and sewerage board (BWSSB) which supplies water in the city pumps in 900 million liters of water every day to the city but the demand is more than 1450 million liters per day(4) .

Type of water supplied	**Distribution area covered in %**	**% of population using water**	**Amount of Water pumping in MLD**
Cauvery water	67	77%	900
Bore well water	33	23%	124

Source: Bengaluru water supply and sewerage board (2016)

Solid waste refers to *the range of garbage arising from animal and human activities that are discarded as unwanted and useless.* Solid waste is generated from industrial, residential and commercial activities in a given area, and may be handled in a variety of ways. Regardless of the origin, content or hazard potential, solid waste must be managed systematically to ensure environmental best practices. The term Solid Waste Management is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental considerations.

Solid waste landfills are a necessity in modern-day society, because the collection and disposal of waste materials into centralized locations helps minimize risks to public health and safety. Solid waste landfills, which are regulated differently than hazardous waste landfills, may accept a variety of solid, semi-solid, and small quantities of liquid wastes (Yusuf, 2007). Municipal solid waste (MSW) landfills accept nonhazardous wastes from a variety of sources such as households, businesses, restaurants, medical facilities and schools. Many MSW landfills also can accept, conditionally exempted hazardous waste from businesses, small quantities of hazardous waste from households and other toxic wastes. Industrial facilities may utilize their own captive landfill (i.e., a solid waste landfill for their exclusive use) to dispose of nonhazardous waste from their processes such as sludge from paper mills and wood waste from wood processing facilities.

The main objective of this research work is to analyze some physico-chemical parameters of the ground water of Bangalore city, Karnataka Generally, the analyses of Physiochemical and biological parameters lead to assess the quality of groundwater. Hydro chemical characteristics of groundwater can also be analyzed for the groundwater assessment. Geographic Information System (GIS) mapping technique is the best representative tool in the assessment of groundwater quality and its utilization for irrigation, drinking and constructional needs (Ravikumar et al., 2013; Srinivasamoorthy et al., 2011) The better understanding of groundwater quality can be achieved by representing the data by ArcGIS Software . There is a possibility of changes in groundwater quality due to hydrology and geologic conditions over a period of time.

The groundwater samples were collected nearer to selected Solid waste landfill-sites in southwestern parts of the Bengaluru to study the possible impact of solid waste effect on soil and ground water quality. The physical and chemical parameters such as temperature, pH, hardness, electrical conductivity, total dissolved solids, total suspended solids, alkalinity, calcium, magnesium, chloride, nitrate, sulphate, phosphate were studied using various analytical techniques. It has been found that most of the parameters of water are not in the acceptable limit in accordance with the BIS (2009) Drinking Water Quality Standards. It is concluded that the contamination is due to the solid waste materials that are dumped in the area.

Materials and methods

Study Area

Bangalore officially known as Bengaluru is the capital and the largest city of the Indian state of Karnataka. It has a population of more than 8 million and a metropolitan population of around 11 million, making it the third most populous city and fifth most populous urban agglomeration in India. Located in southern India on the Deccan Plateau, at a height of over 900 m (3,000 ft) above sea level, Bangalore is known for its pleasant climate throughout the year. Its elevation is the highest among the major cities of India. Bangalore lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Cretaceous Deccan Plateau) at an average elevation of 900 m (2,953 ft). It is located at 12°58′44″N 77°35′30″E and covers an area of 741 km2 (286 sq mi). Bangalore is a district headquarters located 260km from the state capital Bangalore Karnataka India, at 13°.5' and 14°50'N and 75°30' and 76°30'E geographically. Bangalore district receives average annual rainfall of 644 mm (25.4 inch). The district enjoys semi-arid climate, dryness in the major part of the year and hot summer. In general, southwest monsoon contributes 58 % of total rainfall and northeast monsoon contributes 22 % rainfall. The remaining 20 % rainfall is received as sporadic rains in summer months. It receives low to moderate rainfall. The groundwater quality is degrading in Bangalore city is due to increases human habitation and commercial practice. Therefore, we have decided to analyze its groundwater so that some remedies for the improvement could be possible.

Sample collection method

Groundwater samples were collected from the surroundings near to the four solid waste dumping yards namely Kannahalli, Lingaderranahalli, Chikkanagamanagala and Subbarayanapalya which is selected and located at southern parts of Bangalore city. Eight ground water samples from each dumping yard are collected during the pre-monsoon (April and May 2017) and post monsoon (November and December 2017). The collected water samples were transferred into pre cleaned plastic water bottles for analysis of chemical characters. Samples collected in black colored bottles of 3 liters capacity bottle at the study sites were properly labeled and a recorded. The various physiochemical parameters were analyzed and health impacts of chemical parameters are reported (Table 2 and 3). Total alkalinities of the water samples were determined by titrating with N/50 H_2SO_4 using phenolphthalein and methyl orange as indicators. The chloride ions were generally determined by titrating the water samples against a standard solution of Ag No3 using potassium chromate as an indicator. The conductivity of the water samples were measured using the conductometric method.

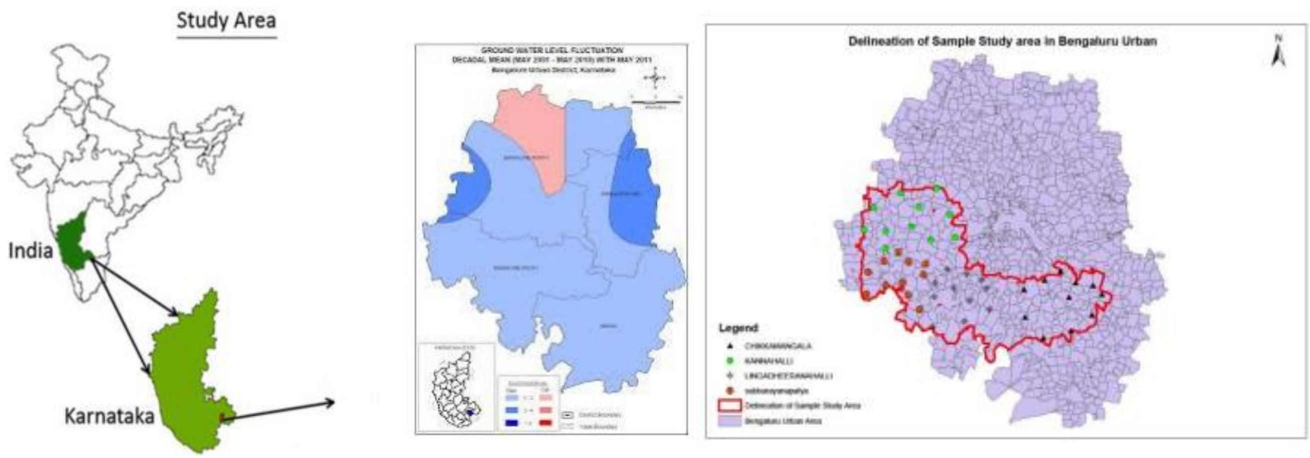

Fig. 1 Study area

The total hardness of the water samples were determined by complex metric titration with EDTA using Erichrome black-T as an indicator. Sulphate and fluoride of the water samples were estimated by UV-visible spectrophotometer. TDS of water sample were measured using gravimetric method. Heavy metals concentration like Iron, Zinc, Nickel and Lead were analyzed by acid digestion method using atomic absorption spectrophotometer. Kannahalli common municipal solid waste management facility (CMSWMF) is located at Survey No. 85, Kannahalli Village, Yeshwanthpura Hobli, Seegehalli Cross, Magadi Road, Bangalore – 560 091. The site is located towards West of Bangalore city, next to the Seegehalli bus depot. The site has an average elevation of 16 meters. The coordinates are 12.98° N 80.18° E. Chikkanagamanagala CMSWMF is situated on an area of 15.3 acres with design capacity to handle 500 TPD of municipal waste. The yard is located at village Chikkanagamangala, Sarjapur Hobli, Anekal Taluk in the Bangalore Urban district of State of Karnataka at an average elevation of 916m. The coordinates of the site are 12°51'40.36"N, 77°41'10.16"E . The Ligadeeranahalli CMSWMF municipal dumping yard is situated at Lingadheeranahalli village Kengeri Hobli, Bangalore South taluk in the Bangalore Urban district of State of Karnataka. The geographical coordinates of the site are Point Coordinates 12°52'36.02"N, 77°30'22.76"E. The Subarayanapalya CMSWMF municipal dumping yard is located at an elevation of 775 meters and is sloping from West to East towards the natural nallah adjacent to the site. The Subbarayanapalya CMSWMF is situated at Survey. No. 143, Kumbalgood village, Kengeri Hobli, Bangalore South Taluk, Bengaluru. It has an area of 3.8 hectares and handles about 200 TPD of municipal waste, which is collected from areas within the RR Nagar and Bangalore South Zone. The Geographical Coordinates of Site is 12°53'0.18"N 77°25'50.23"E.

Table 1. GPS coordinates of the water samples points

Kannahalli			subbarayanapalya			Lingadeeranahalli			Chikkamangala		
Sample	X	Y	sample	X	Y	sample	Y	X	sample	X	Y
KG1	77.45529	12.99889907	SG1	77.46277	12.89384	LG1	12.85372	77.53359	CG1	77.7231	12.87701
KG2	77.38572	12.99798934	SG2	77.46595	12.91087	LG2	12.90355	77.49891	CG2	77.69665	12.88256
KG3	77.47324	12.94743798	SG3	77.42389	12.92905	LG3	12.86057	77.47902	CG3	77.67277	12.90132
KG4	77.51102	12.95154189	SG4	77.4018	12.91555	LG4	12.81389	77.47609	CG4	77.64802	12.88554
KG5	77.50293	12.98657431	SG5	77.3747	12.86449	LG5	12.82328	77.52548	CG5	77.61859	12.82987
KG6	77.42701	13.01991109	SG6	77.37722	12.89822	LG6	12.84176	77.564	CG6	77.64674	12.79724
KG7	77.3705	12.96398174	SG7	77.40451	12.87711	LG7	12.87382	77.55924	CG7	77.68897	12.80791
KG8	77.40433	12.96088526	SG8	77.43863	12.86319	LG8	12.887	77.55248	CG8	77.72075	12.83307

Result and discussion

Currently carried research investigation should give more precise answer on influence of anthropogenic activities in the examined groundwater samples of the study area.

The study area shows the moderately contaminated with total dissolved solids and hardness in samples. Ground water Parameters in sampling sites have varied due to anthropogenic activities, but this value does not have any harmful impact for the water to use for drinking purpose. Hence the ground water in Bangalore city area is suitable for drinking, commercial, Industrial, and agriculture purposes.

pH of water samples varies in the range of 6.17 to 8.66 and 7.5 to 8.7 during PRM (pre monsoon) and POM(post monsoon) season respectively. Most of the samples showed high pH that is greater than 7 which might due to the presence of carbonate and bicarbonate salts. The acceptable limit for the drinking water standard is 6.5 to 8.5. Since CG5 & CG6 does not lie in the limit, it is not suitable for drinking.

TDS is generally considered not as a primary pollutant, but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants. The total hardness of 201.6 to 1209 ranges in PRM and 205 to 1179 ranges in POM were recorded. 65.62 % of samples were out of permissible limits in PRM and 43.75 % in POM season according to BIS standards. BIS (2012) permissible limit for TDS is 500. The samples in PRM and in POM which are out of permissible limits show the action of sewage and urban runoff in the study area.

The calcium concentration varies from 28 to 148 mg/L to 29.1 to 60.1 mg/L and the magnesium concentration varies from 25 to 105 mg/L and 16 to 94 ranges in PRM and POM respectively. The BIS limit for calcium is 200 mg/L and the permissible limit in the absence of alternate source is 200 mg/L. The desirable limit for magnesium is 100 mg/L. Calcium & Magnesium are within permissible limits in both seasons of ground water samples of PRM and POM.

Total alkalinity values vary from 101 mg/L to 692.8 mg/L. The desirable limit for total alkalinity is 200 mg/L. The total alkalinity value of water sample is very higher as compared to the standard. Carbonated and bi carbonates are responsible for causing alkalinity in water bodies. Anthropogenic activity which includes alkalinity (bicarbonates and carbonates) is from cleaning agents and food residues. In the present study carbonates fell in the range 20.0 to 60.00 and 0 to 100 in PRM and POM respectively. Bi carbonates were in the range of 165 to 840 and 51 to 400 in PRM and POM respectively.

Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L; however, calcium or magnesium chlorides are not usually detected by taste until levels of 1000 mg/L are reached. The desirable limit for chloride is 250 mg/L and the permissible limit in the absence of alternate source is 1000 mg/L. All the water samples fall within the limit. In the study area the presence of chloride may be due to urban runoff and sewage water intrusion. The chloride content observed were as follows PRM 58 to 302 mg/L and POM 46.8 to 195.5 mg/L.

The values for the present water samples vary from 1622 mg/L to 1809 mg/L. The desirable limit for TDS is 500 mg/L and the permissible limit in the absence of alternate source is 2000 mg/L. The TDS levels of the water come within the limit. Total Suspended Solids (TSS) (measure of the mass of fine inorganic particles suspended in the water values) is in between 24 and 42 mg/L.

Nitrate is one of the most common groundwater contaminant. The excess levels can cause methemoglobinemia, or "blue baby" disease. Although nitrate levels that affect infants do not pose a direct threat to older children and adults, they do indicate the possible presence of other more serious residential or agricultural contaminants, such as bacteria or pesticides. Nitrate in groundwater originates primarily from fertilizers, septic systems, and manure storage or spreading operations. The permissible limit for the nitrate is 45 mg/L. The water samples are in the range of 0 to 70.0 mg/L and 0 to 195.4 mg/L in PRM and POM respectively. 15% of Samples & 25% of samples are out of the permissible limit in PRM and POM respectively.

Phosphate varied from 0.04 to 2.05 in PRM and 0.04 to 1.5 in POM. Superphosphates applied to the fields as fertilizer and alkali phosphate used in house hold as detergents can be the sources of inorganic phosphate. SiO2 varied from 2.21 to 83.65 mg/L and 0 to 67.68 mg/L in PRM and POM respectively.

BIS permissible limit for fluoride is 1.5mgl if present in low concentration up to 1 mg/lt are generally considered as beneficial in water. Such water consumption improves dental health and prevents the formation of dental caries. Excessive fluoride it is greater than 1.5 mg /lt in drinking water may cause molting of teeth of dental caries. 9% of PRM samples are out of the permissible limit.

Sulfate can be found in almost all natural water. The origin of most sulfate compounds is the oxidation of sulfite ores, the presence of shales, or the industrial wastes. Sulfate is one of the major dissolved components of rain. High concentrations of sulfate in the water we drink can have a laxative effect when combined with calcium and magnesium, the two most common constituents of hardness. The sample contains the sulphate concentration in the range of 0.56 to 68.70 mg/L and 0 to 15.3 mg/L in PRM and POM respectively. The desirable limit for sulphate is 200 mg/L and the permissible limit in the absence of alternate source is 400 mg/L.

Sodium salts (exact limits have not been prescribing concerning the sodium in drinking water and the occurrence of hypertension). Threshold limit for sodium has not been assigned by BIS. However concentration in excess of 200mg/l may give rise to unacceptable tasted. The present study reveals the ranges of sodium from 3.60 to 116.30 mg/L and 0 to 74 mg/L in PRM and POM respectively. High concentration of was recorded in PRM. All samples showed acceptable condition concerning sodium content. Sodium is an essential nutrient. The Food and Nutrition Board of the National Research Council recommends that most healthy adults need to consume at least 500 mg/day, and that sodium intake be limited to no more than 2400 mg/day. *Potassium* occurs widely in environment including all natural water sources. Potassium ranges observed were as follows PRM 0.30 to 9.21 mg/L and POM 1.5 to 48.5 mg/L. The presence of potassium in ground waste supports daily requirement for humans.

Phosphorus is usually present in natural water as Phosphates (orthophosphates, polyphosphates, and organically bound phosphates). Sources of phosphorus include human and animal wastes (i.e., sewage), industrial wastes, soil erosion, and fertilizers. Excess phosphorus causes extensive algal growth called "blooms," which are a classic symptom of cultural eutrophication and lead to decreased oxygen levels in creek water. The water samples contain 0.04 to 2.05 mg/L & 0.04 to 1.5 mg/L of Phosphate in PRM & POM samples respectively.

Heavy Metals

Under heavy metals category the ground water samples were analyzed for Iron, Lead, Zinc and Nickel in PRM and POM seasons. It was observed that Iron, Lead, Zn and Nickel metals were present in low quantity or below the detection level. The presence of iron, lead zinc and nickel indicate the origin of these wastes perhaps from disposed battery cells, used aerosol cans and other materials with certain degree of toxicity.

Iron

Iron concentration varies from 0 to 1.20 mg/L and 0.01 to 0.8 mg/L in PRM and POM respectively. 18% of samples of PRM & 6 % of Samples of POM are out of the Permissible limit.

Zinc

Its concentration varies from 0 to 0.52 mg/L and 0 to 0.25 mg/L in PRM and POM respectively. All the samples from both PRM & POM are within the permissible limit.

Lead

The permissible limit for lead is 0.05 mg/L. Some of the water sample has no appreciable concentration of lead and it is found to be below the detection level. The detection level is 0.01 mg/L. Concentration varies from 0 to 0.78 mg/L and 0 to 0.62 mg/L in PRM and POM respectively. 37% of samples of PRM & 15% of the samples of POM are out of the permissible limit. This indicates that the lead origin is because of the discharged battery cells.

Nickel

The desirable limit for nickel is 0.07 mg/L as per the WHO guidelines for drinking water quality, 2006. Concentration varies from 0 to 0.58 mg/L and 0.05 to 0.09 mg/L in PRM and POM respectively. 28% samples of PRM & 53% of POM samples are out of the permissible limit.

Dissolved oxygen

It is a fundamental requirement for the maintenance of life of all living organisms in water. BIS has indicated the value of DO drinking water as 6mg/L.

DO in PRM ranged from 2.18 to 7.89 and 4.9 to 8. In POM 78% of samples in PRM were having less than BIS standards. 25% of samples in POM were having less than 6mg/L DO, this shows the presence of high organic pollutants in the ground water. at the end of the monsoon season due to to the addition of new water to the aquifer has reduced the organic matter by dissolution . Hence in POM season have lesser percentage of samples were having less do compared to PRM.

Biological oxygen demand:

BOD can be defined as a measure of the pollution organic matte present in a given sample of water. BOD can be defined as the amount of the oxygen used during oxidation of oxygen demanding waste when a sample of water is incubated for 5 days at $20^{o}c$ with DO measured before and after.

In the present study BOD varied from 4.19 to 6.88 and 2 to 3 in PRM and POM respectively. BIS put permissible limit of BOD for drinking purpose is 2mg/L, all the samples were having high BOD in PRM but in POM 43% of samples were out of permissible limits.

Chemical oxygen demand is a measure of oxygen equivalent of the organic matter of the water which is susceptible to oxidation by a strong chemical. COD ranges from 2.50 to 7.10 and 12.1 to 20.2 in PRM and POM respectively. COD values indicated the intrusion of chemicals to ground water through percolation, the origination of chemicals on the land surface with anthropogenic activities.

Preventive measures:

Proper methods of solid waste disposal have to be undertaken to ensure that it does not affect the environment around the area or cause health hazards to the people living there. At the source of the solid wastes (household-level) proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizers .the e wastes which is an important sources for the heavy metals should be strictly avoided in the dumping yard and it should be segregated and sent to recycle plant for recycle.

Table 2. Physico-chemical and heavy metals Characteristics of ground water samples in pre monsoon season 2017

Kannahalli (Ground Water of Pre-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
KG1	7.3	1102	295.9	804	40.1	57	98.3	7.21	60	420	58	55.6	0.16	26.23	33.2	0.2	0.07	0.1	0.08	0.15	5.2	6.1	4.2
KG2	7.85	1203	469.2	868	72.2	84	77.5	2.89	60	480	125.9	45.57	1.23	16.02	40.12	0.89	0.22	0.77	0.34	0.32	4.22	5.93	5
KG3	7.19	1145	464	945	98.6	85	116.3	1.55	60	650	157.25	53.1	1.56	68.24	52.13	0.91	1.1	0.46	0.25	0.23	6.82	6.19	4.2
KG4	7.45	1298	493.5	828	122.6	53	89.6	7.29	20	440	185.9	35.2	1.87	33.89	62.15	1.59	0.98	0.56	0.29	0.41	3.23	6.87	4.6
KG5	7.22	1345	445.3	779	148.4	25	102.8	0.52	40	600	246.2	55.2	0.98	10.01	83.65	1.64	0.71	0.34	BDL	0.38	5.97	5.73	4.8
KG6	6.89	1411	459.8	859	72.8	44	112.5	8.24	20	720	195.2	68.7	2.05	52.69	10.98	0.75	1.2	0.21	0.58	0.16	4.76	6.48	7.1
KG7	7.55	1506	559.45	942	56.9	68	79.1	9.21	60	810	245.5	38.5	BDL	13.56	19.5	0.98	1	0.36	0.28	0.18	5.24	6.26	6.5
KG8	6.98	1831	615.6	915	50.59	89	80.25	8.24	60	840	187.9	63.8	1.99	43.25	55.87	1.79	1.11	0.58	0.31	0.52	6.18	5.59	6.1
Lingadheeranahalli (Ground Water of Pre-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	**4.34**	**6.894**	
LG1	6.9	669	396	460.1	72.7	101	6.7	0.8	40	400	136	2.5	0.16	0.9	3.45	0.25	0	0.77	0.02	0.015	2.18	4.595	5.6
LG2	7.62	896	320.3	420.5	52.1	105	7.4	1.2	60	220	148	4.4	0.1	22	10.34	0.5	0.09	0	0.03	0.07	4.33	6.1	5.6
LG3	7	604	450.5	501.5	111.2	64	6.2	1.35	20	555	206	3.6	0.12	32	2.21	0.18	0	0.46	0.02	0.06	7.82	5.38	5.6
LG4	7.34	1050	408.6	534	99.23	84	8.2	0.98	40	625	302	6.3	0.14	70	4.28	0.12	0.04	0	0	0.04	2.89	4.468	4.2
LG5	6.98	890	561.24	692.12	122.54	71	7.5	0.56	40	428	250	6.5	0.12	40	29.89	0.27	0	0	0	0.14	3.98	6.612	2.5
LG6	6.9	777	582.07	384.2	125.8	48	8	0.74	60	656	116	7.2	0.07	0	22.6	0.64	0	0	0	0.05	5.32	6.415	3.2
LG7	6.7	689	692.8	543	70.98	44	7.56	0.68	40	524	132	1.3	0.06	42	51.2	0.42	0.05	0	0.02	0.06	2.94	5.889	4.8
LG8	7.2	962	689.23	794	82.2	57	6.87	0.32	40	448	301	0.56	0.04	55	16.2	0.17	0.06	0	0.02	0.07	4.76	5.907	3.2
ChikkaNagamangala (Ground Water of Pre-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
CG1	8.31	778	235	597	87	84	6	0.3	40	460	138	6.3	0.18	0	21.3	0.2	0	0.78	0.02	0.04	7.4	5.64	4.8
CG2	8.19	662	262	207	94	94	7.5	0.6	60	500	171	9	0.17	0	25.4	0.15	0	0.41	0.03	0.06	2.26	6.03	3.1
CG3	7.88	845	299	327	65	101	8.4	0.4	60	360	260	8.7	0.17	0	8.7	0.19	0	0	0.02	0	5.21	6.17	3.2
CG4	8.35	482	235	291	73	86	6.2	0.5	40	580	227	7.9	0.18	32.54	5.2	0.12	0.04	0	0	0.14	4.36	6.28	3.2
CG5	8.66	608	272	765	35	67	8.12	0.1	20	440	250	4	0.16	55.65	64.8	0.28	0.09	0	0	0.06	5.31	6.30	5.8
CG6	8.25	1121	190	497	51	69	7.8	0.2	40	600	109	0.9	0.15	0	15.9	0.3	0	0	0	0	4.21	5.32	5.4
CG7	8.37	1224	217	500	29	79	6.9	0.3	40	380	136	2.8	0.18	18.34	29.6	0.26	0	0	0	0	2.98	4.47	5.4
CG8	8.31	784	199	202	116	82	8.3	0.3	20	400	77	5.4	0.18	18.34	10.4	0.64	0.06	0	0	0.03	7.24	6.58	6.2
Subbarayanapalya (Ground Water of Pre-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
SG1	6.98	1049	162	690	28	70	4.2	0.2	40	350	147	15	0.18	0	15.49	0.28	0	0	0	0	5.12	5.089	6.2
SG2	6.29	945	119	345	36	76	6.2	0.2	20	380	144	15	0.18	0	33.54	0.29	0	0	0	0	3.74	4.785	4.9
SG3	6.17	1207	101	697	54	82	8.1	0.3	20	165	106	12	0.16	0	39.75	0.42	0	0	0	0.08	4.31	4.845	4.8
SG4	7.21	1325	198	632	72	84	9.8	0.5	40	460	215	7.9	0.16	0	63.04	0.32	0.06	0	0	0	7.89	5.124	4.8
SG5	6.18	1024	294	345	124	91	10.5	0.5	40	540	123	11.7	0.17	15.45	65	0.42	0.08	0	0	0	6.6	4.189	3.4
SG6	6.57	1781	218	741	108	105	3.6	0.4	60	225	151	16.8	0.18	0	12	0.14	0	0	0	0	3.34	5.708	3.5
SG7	7.15	1941	164	1209	38	68	4.5	0.2	20	320	203	30	0.15	19.89	15	0.15	0	0	0	0	7.15	4.546	3.5
SG8	6.5	1251	245	1051	87	58	5.7	0.2	20	440	186	8.2	0.15	0	40.5	0.42	0	0	0	0	5.03	6.877	4

Table 3. Physico-chemical and heavy metals characteristics of ground water samples in post monsoon season 2017

Kannalli (Ground Water of Post-monsoon)																								
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	CO_3^{2-}	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
KG1	8.1	1103	462.7	807	50.1	62	13.8	2	50	244.1	75.4	0	0	0.49	0	10.31	0.8	0.3	0.26	BDL	0.25	6.5	2	12.4
KG2	8.3	1251	483.8	764	60.1	69	51	2.1	20	250	125.5	0	0.4	1.35	18.5	6.14	0.3	0.8	0.49	0.08	BDL	5.5	2	12.2
KG3	8.2	1409	458.9	968	48.1	54	70	2.1	30	145.2	174	50	4.4	1.4	0	22.14	0.5	0.29	BDL	0.09	BDL	6.9	3	12.6
KG4	8	1771	612.5	879	32.1	62	37	2.1	20	250	175	50	5	0.16	0	20.2	0.19	0.4	BDL	0.06	0.09	6.6	3	15.2
KG5	7.8	1832	432	772	32.1	28	74	3	30	300	114	50	1.6	0.29	36.8	39.96	0.2	0.12	BDL	0.05	0.08	6.8	2	14.6
KG6	8.3	1141	455	1158	56.1	94	42	4	20	200	121.4	50	4.8	0.04	27.6	3.42	0.14	0.14	BDL	0.08	0.19	7.7	2	14.6
KG7	8.3	1405	620.9	1179	32.1	54	64	3	20	400	148.9	60	4.2	0.1	0	7.56	0.12	0.18	BDL	BDL	BDL	6.5	3	16.3
KG8	8.4	1295	484.5	941	38.1	53	0	5	60	201	195.5	100	15.3	0.1	18.4	39.7	0.18	0.11	BDL	BDL	0.06	6.9	2	20.2

Lingadheeranahalli (Ground Water of Post-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	CO_3^{2-}	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
LG1	8.3	264	80	205	40.1	52	5.2	1.5	40	51	48.6	0	0	0.8	124.5	11.25	0.15	0.01	BDL	BDL	BDL	6.1	2	12.5
LG2	8.3	278	90	345	40.1	58	45.5	2.5	40	142.5	54.32	39	5.2	1.3	124.5	42.5	0.28	0.12	BDL	BDL	BDL	5.2	2	12.8
LG3	8.2	489	120	495	45.2	64	34.8	39.1	40	150.9	69.7	50	2.5	1.3	145.2	57.45	0.34	0.01	BDL	BDL	BDL	5.2	3	12.2
LG4	8.2	546	140	924	29.1	75	50	39.1	60	205.1	70.9	50	2.8	1.4	165.4	42.3	0.4	0.01	BDL	0.09	BDL	5.8	2	12.2
LG5	8.5	798	190	435	48.1	43	54.5	4.5	20	305	85.5	50	9.2	1.4	34.5	44.5	0.45	0.12	0	0.08	BDL	6.4	2	14.5
LG6	8.4	1204	210	479	48.2	72	57.5	6	40	280	105.4	60	3.4	1.5	136.5	65.5	0.6	0.01	0	BDL	BDL	6.2	3	14.5
LG7	7.9	618	180	645	40	41	23	6	20	187.9	117.5	30	1	1.5	195.4	13.5	0.16	0.01	BDL	BDL	BDL	5.5	3	16.5
LG8	8	718	160	924	50.1	61	24	48.5	40	125.5	110.4	50	0	0.8	174.8	12	0.15	0.01	BDL	0.05	BDL	4.9	3	16.5
ChikkaNagamangala (Ground Water of Post-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	CO_3^{2-}	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
CG1	7.5	345	105	250	48.1	58	22	38.1	20	240	46.8	0	0	0.39	0	15.93	0.3	0.1	0.28	0.08	0.25	7	2	12.4
CG2	7.8	355	140	245	50.1	42	15.8	2.2	20	244.1	77.1	0	0	0.23	0	9.95	0.9	0.02	BDL	BDL	0.09	8	2	12.8
CG3	8	659	170	420	60.1	61	45.5	2	60	145	135.8	50	4.4	1.35	0	10.15	0.4	0.03	0.49	BDL	0.08	7.5	2	12.9
CG4	8.2	680	140	450	60.1	81	58	2.1	40	260	147.5	50	0.2	0.42	15.8	7.45	0.36	0.12	BDL	0.08	BDL	5.5	3	16.2
CG5	8.3	848	170	510	60.1	64	65	3.1	40	250	174	50	5	0.22	29.6	20.54	0.6	0.01	BDL	0.08	0.05	7.9	3	12.1
CG6	8.7	746	190	598	48.1	16	50	4	20	300	117.8	60	1.6	0.64	35.4	67.68	0.19	0.08	BDL	0.09	0.19	6.6	3	16.4
CG7	8.4	842	280	438	40.1	48	37	3	40	250	131.4	100	4.8	1.4	0	50.54	0.2	0.01	BDL	BDL	BDL	6.8	2	16.3
CG8	8.5	1125	340	460	32.1	86	74	4	40	200	165.9	100	4.2	0.5	0	22.25	0.14	0.01	BDL	BDL	0.09	7.7	3	20.2
Subbarayanapalya (Ground Water of Post-monsoon)																							
Parameters	pH	EC	TH	TDS	Ca^{2+}	Mg+	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	CO_3^{2-}	SO_4^{2-}	PO_4^-	NO_3^-	SiO_2^-	F	Fe	Pb	Ni	Zn	DO	BOD	COD
Unit		µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L			
SG1	8.2	365	110	240	47.1	58	22	38.1	40	245	58.6	0	0	0.29	0	0	0.39	0.1	0.025	0.08	0.24	7	2	12.1
SG2	8.2	325	160	235	48.1	64	15.8	2	40	244.8	87.1	0	0	0.12	0	0	0.9	0.02	BDL	0.09	0.08	7.5	2	12.2
SG3	8	439	130	260	50.1	48	45.5	2	20	250	183.5	40	0	0.32	15.8	0.1	0.4	0.03	0.62	0.08	0.09	7.5	2	12.4
SG4	8.1	585	170	360	55.1	58	51	2.1	20	145.3	147	40	0.2	1.45	0	0.2	0.21	0.12	BDL	0.09	BDL	6.5	2	12.6
SG5	8.1	650	190	470	60.1	61	41	3	20	250	174	55	0.2	0.24	0	3.5	0.56	0.01	BDL	BDL	BDL	6	3	17.6
SG6	8.3	687	190	490	60.1	84	41	4	40	250	118.3	55	4.5	0.25	18.5	3.5	0.19	0.08	BDL	BDL	0.19	6.5	3	15.4
SG7	7.9	616	340	585	50.1	75	54	4	60	350	169.6	55	4.5	0.18	26.8	4.5	0.4	0.01	BDL	BDL	0.08	6.6	3	12.8
SG8	7.8	1002	170	438	50.1	84	60.5	7	60	300	138.5	50	5	0.05	45.2	4	0.2	0.01	BDL	0.09	0.09	6.8	2	12.1

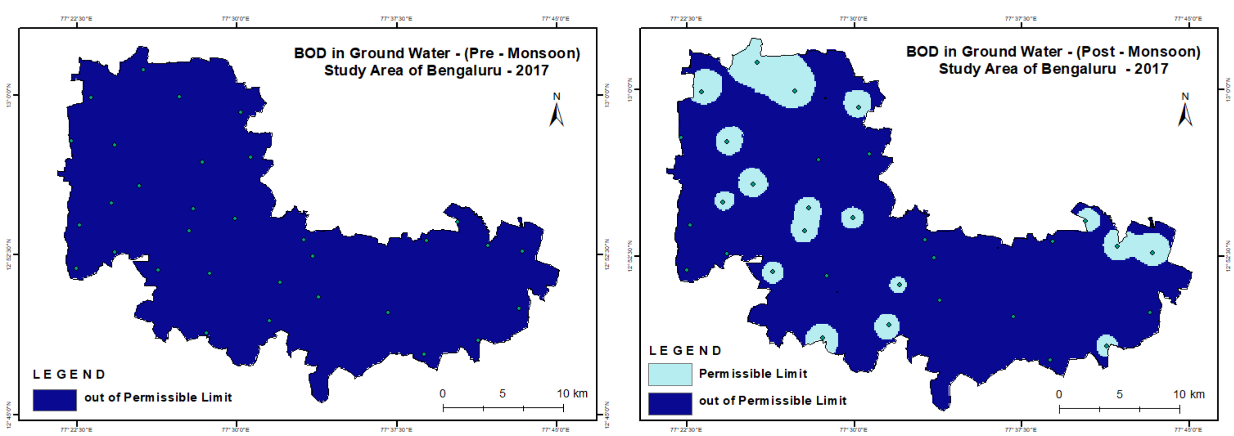

Fig 2. Spatial distribution of BOD in groundwater samples collected during pre and post monsoon of 2017

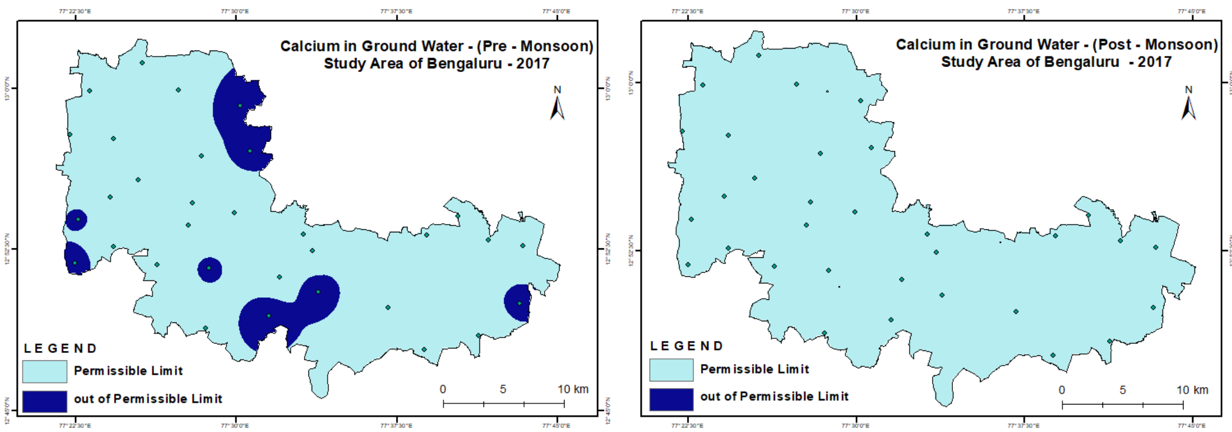

Fig 3. Spatial distribution of Calcium in groundwater samples collected during pre and post monsoon of 2017

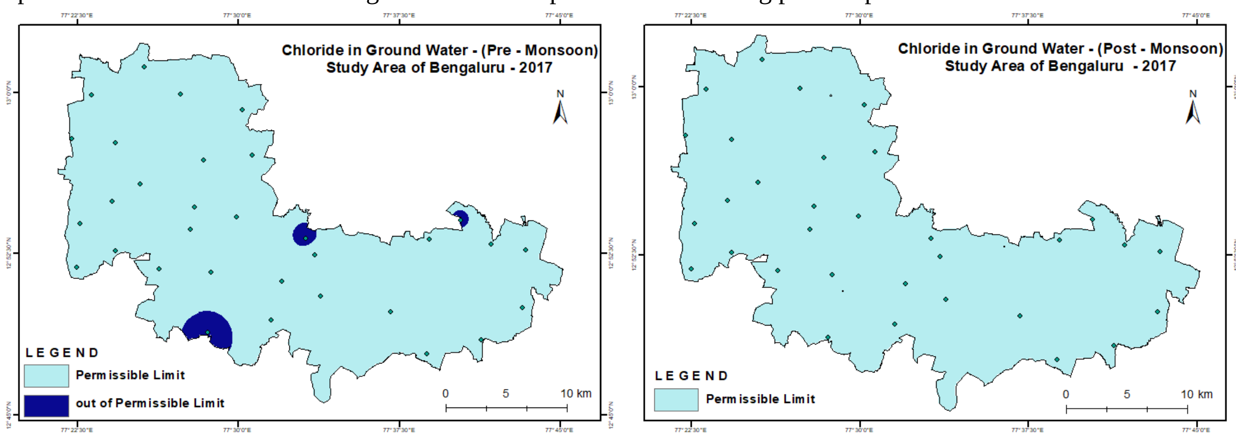

Fig 4. Spatial distribution of Chloride in groundwater samples collected during pre and post monsoon of 2017

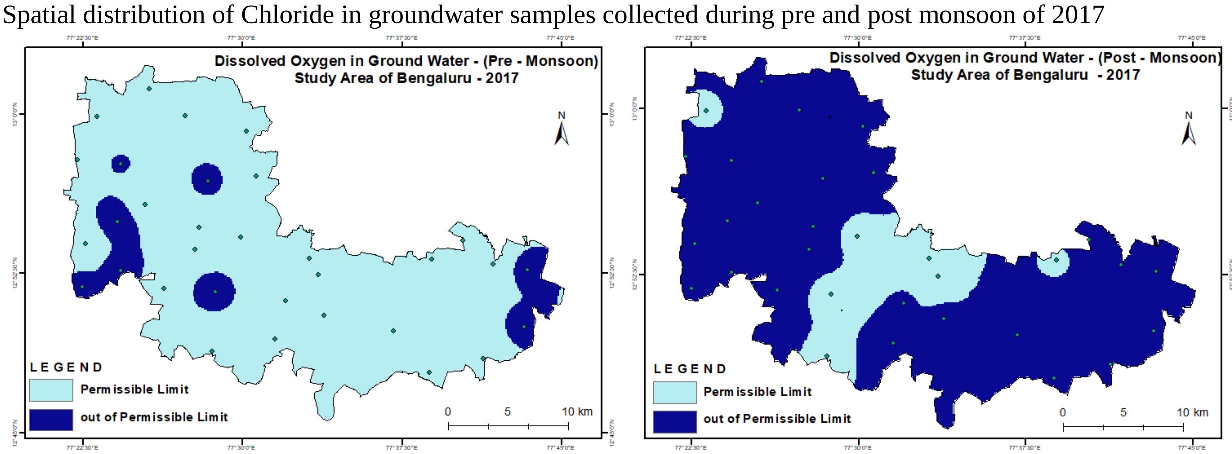

Fig 5. Spatial distribution of Dissolved Oxygen in groundwater samples collected during pre and post monsoon of 2017

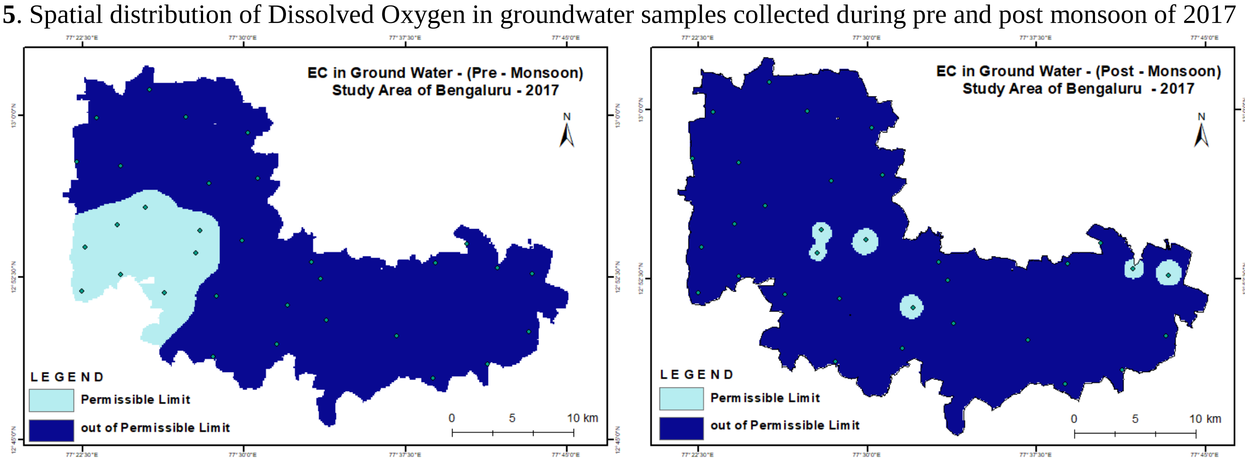

Fig 6. Spatial distribution of EC in groundwater samples collected during pre and post monsoon of 2017

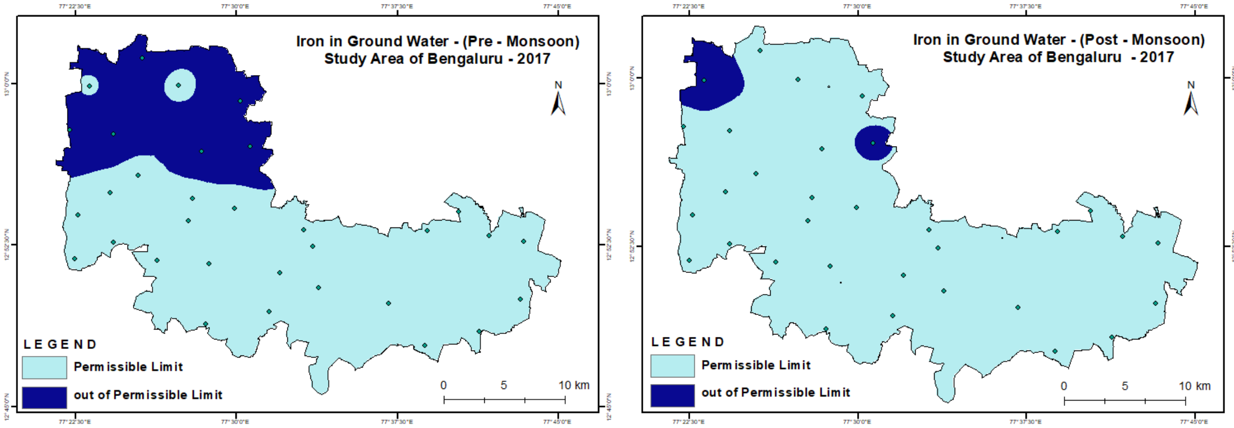

Fig 7. Spatial distribution of Iron in groundwater samples collected during pre and post monsoon of 2017

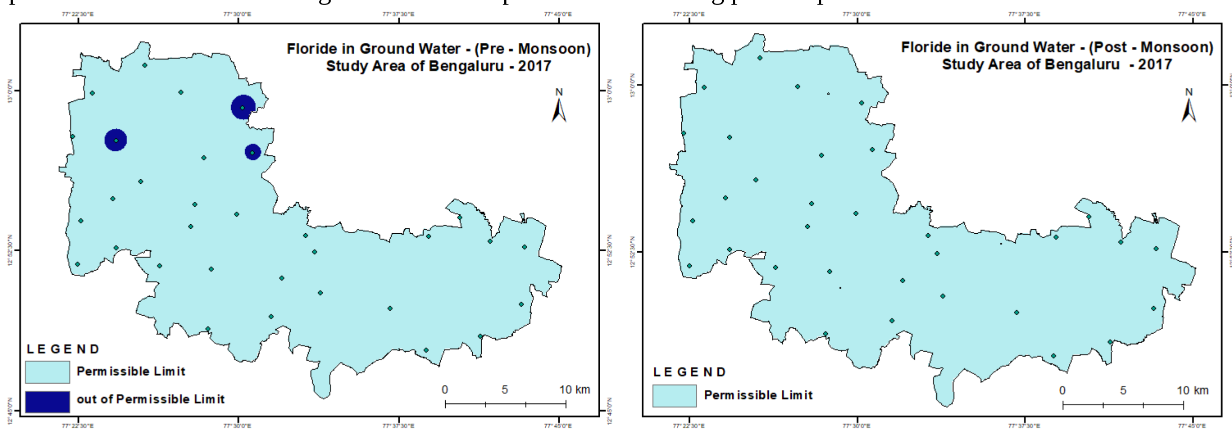

Fig 8. Spatial distribution of Fluoride in groundwater samples collected during pre and post monsoon of 2017

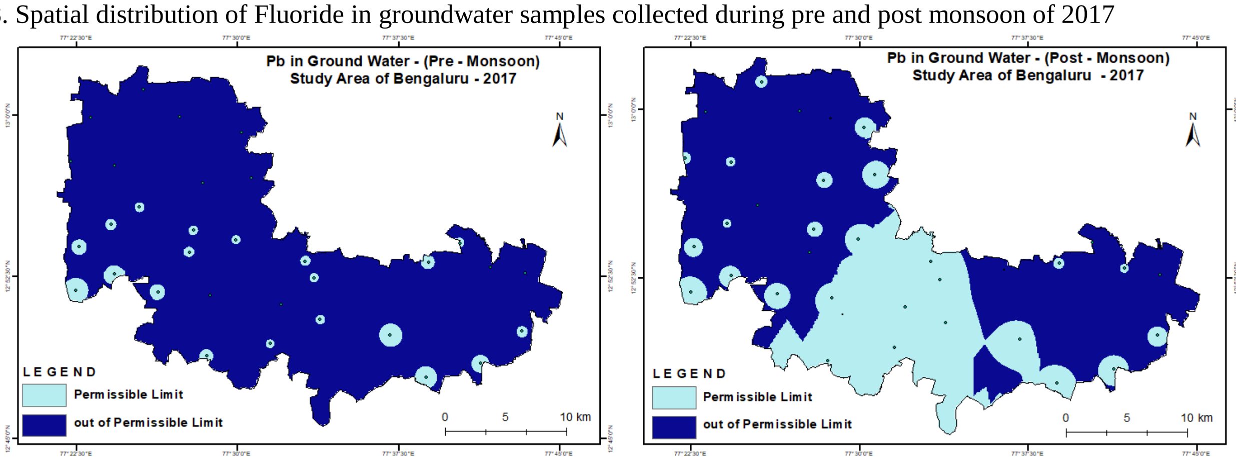

Fig 9. Spatial distribution of Pb in groundwater samples collected during pre and post monsoon of 2017

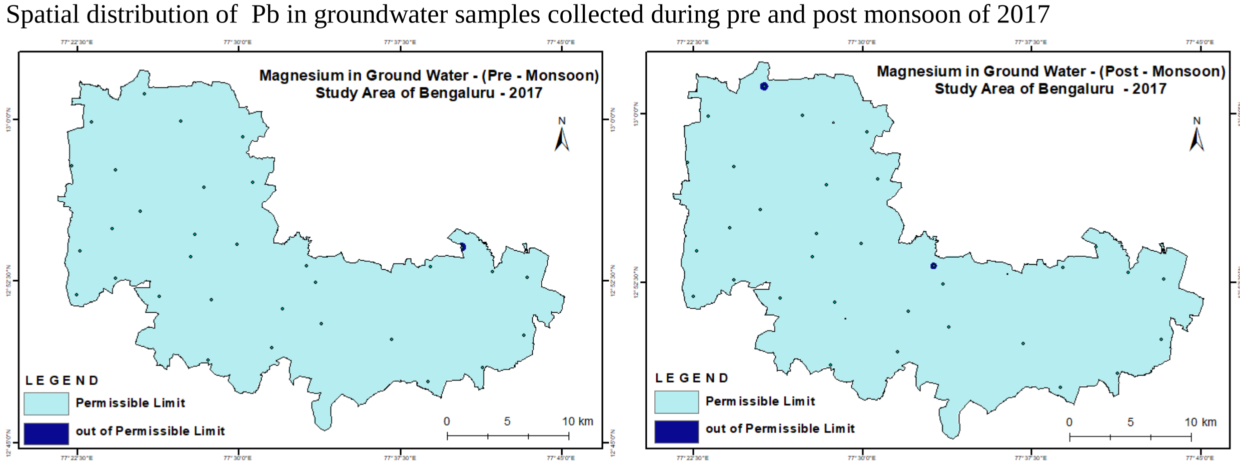

Fig 10. Spatial distribution of Megnissium in groundwater samples collected during pre and post monsoon of 2017

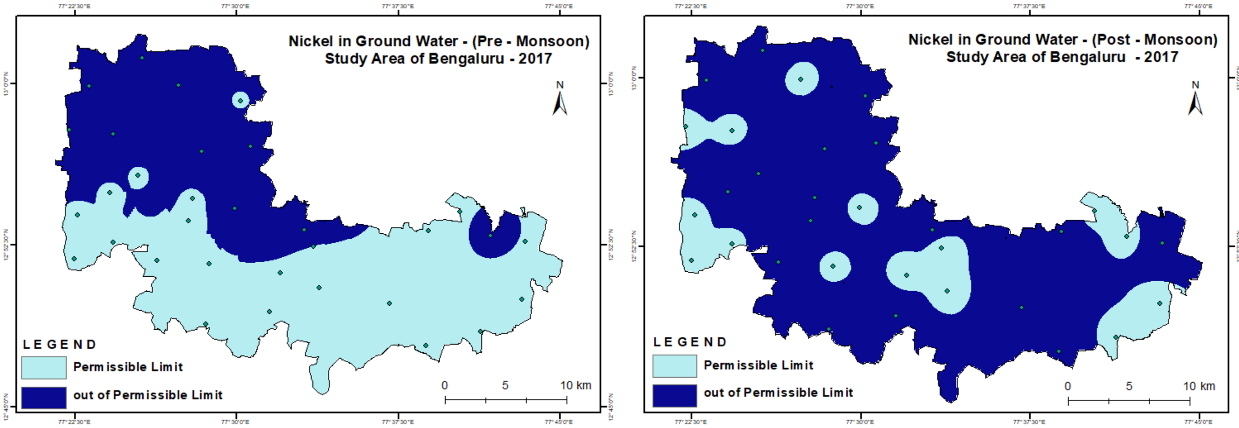

Fig 11. Spatial distribution of Nickel in groundwater samples collected during pre and post monsoon of 2017

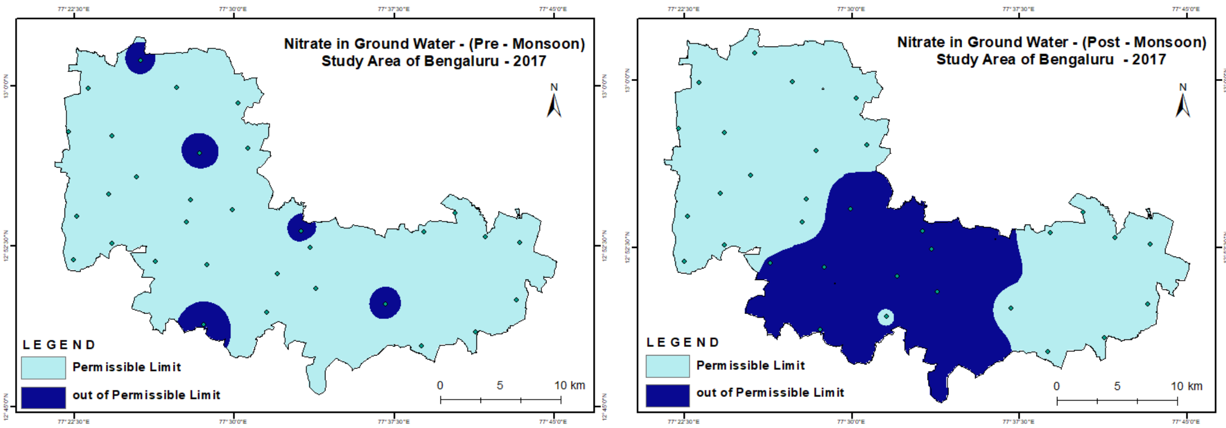

Fig 12. Spatial distribution of Nitrate in groundwater samples collected during pre and post monsoon of 2017

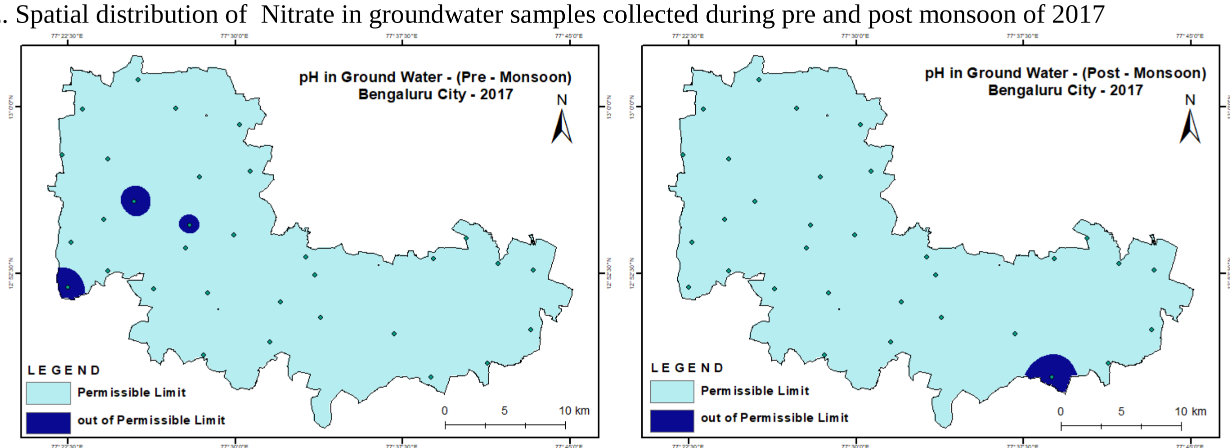

Fig 13. Spatial distribution of pH in groundwater samples collected during pre and post monsoon of 2017

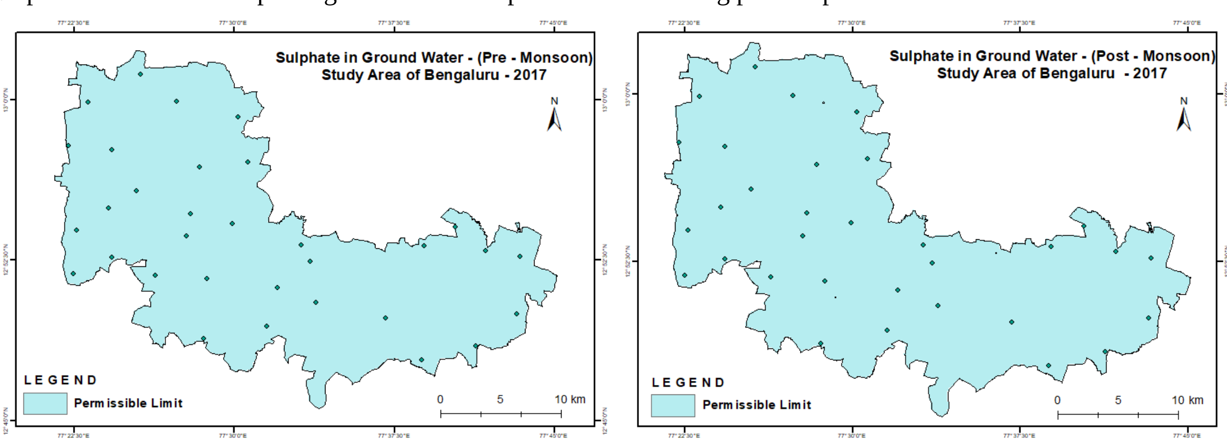

Fig 14. Spatial distribution of Sulphate in groundwater samples collected during pre and post monsoon of 2017

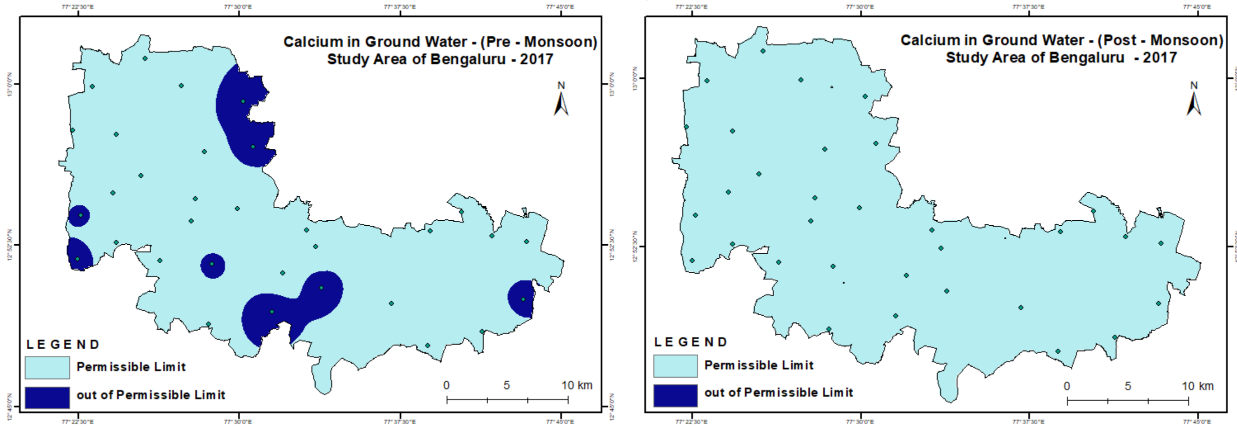

Fig 15. Spatial distribution of Calcium in groundwater samples collected during pre and post monsoon of 2017

Conclusion

Modernization and progress has had its own way of causing environmental degradation and it is one of the main aspects for causing pollution. It is creating pollution to the earth – be it land, air, and water. With increase in the global population and changing the living styles there is a rising demand for food and other essentials. This has been a rise in the amount of waste being generated daily by each household. This waste is ultimately thrown into municipal waste collection centers from where it is collected by the area municipalities to be further thrown into the landfills and dumps. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported to the final dumpsites. If at this stage the management and disposal is improperly done, it can cause serious impacts on health and problems to the surrounding environment. Waste that is not properly managed, especially excreta, e wastes and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease. Normally it is the wet waste that decomposes and releases a bad odour. This leads to unhygienic conditions and thereby to a rise in the health problems. The plague outbreaks in Surat is a good example of a city suffering due to the callous attitude of the local body in maintaining cleanliness in the city. Plastic waste is another cause for ill health. Thus, excessive solid waste that is generated should be controlled by taking certain preventive measures.

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