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WATER QUALITY ASSESSMENT FOR ITS IMPACT ON CONCRETE DURABILITY – A CASE STUDY

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ABSTRACT
Due to rapid industrialization, the river Yamuna is among the most polluted rivers which originates from Yamunotri glaciers (elevation 6300m) in the Himalayas. The discharge of untreated domestic and industrial effluents has affected the quality of Yamuna River and ruling out the possibility for underwater life and domestic supply. Impurities in the form of sewage, dirt and other floating materials contributed in downgrading water quality. In the same time, due to rapid modernization, a large number of construction projects are upcoming in the catchment area of the river. In this scenario, it is important to evaluate its water quality to envisage its effect on concrete durability. CSMRS has studied the water quality of the Yamuna river, Nallahs and few ground water (hand pump) locations situated in the catchment area of the river flowing at Delhi for three seasons in pre-monsoon, Monsoon and lean seasons. The water samples were analysed in laboratory for the parameters mentioned in IS: 456 – 2000 & CPCB standards. Langelier Index values of the river samples are found negative in majority of river locations indicating the water is aggressive in nature. The high values of suspended solids & alkalinity values in lean and pre-monsoon seasons in majority of locations makes the water unfit for construction as per IS 456 – 2000. The Nallah water quality found polluted as per CPCB norms. Present study highlights the seasonal change in water quality of river, nallah and ground water to evaluate its suitability for use in concrete making. The study indicates that there is an urgent need to check the inflow of pollution loads emanating from different external sources for making the water quality fit for concrete construction.

INTRODUCTION
River Yamuna is one of the major rivers of the Indo-gangetic plain. The rapid industrilisation and urbanization in its catchment area has led to large quantity of discharge of untreated industrial waste and sewage in it. The low perennial flow and dumping of huge quality of partially treated/untreated effluents has made river Yamuna as one of the most polluted rivers in India. For instance, Delhi alone (from Wazirabad to Okhla) contributes more than 3,500 MLD (923.0 MGD) of sewage through major drains falling in it. According to a study made by CPCB, only 45% of sewage and 55% of industrial effluents are treated up to secondary level before discharge into the Yamuna river. Due to complex nature of sewage and industrial effluents, the chemical properties of river water, ground water, top and sub soil in the adjoining areas are severely affected and altered. The parameters like colour, odour, pH, electrical conductivity (EC), total dissolved salts, suspended solids, chloride, sulphate, acidity and alkalinity are found far beyond the permissible limits. It renders the quality of water as unfit for its use in drinking, irrigation and even concrete construction and may cause the durability problems in upcoming civil engineering structures at long run. For the construction of the structures, available ground and river water quality need to be evaluated to protect the geotechnical properties of construction materials. Presence of higher amount of sulphate, chloride, soluble salts, pH, hardness, sodium, potassium, calcium and other ions start deteriorating reactions which ultimately damage the structures, thus causing development of cracks in the structures which become unsafe for human population and causes heavy economic complications.[1][2][3].

FOCUS OF INVESTIGATION
The water quality of various locations of river Yamuna, important nallahs and hand pump locations were evaluated in three different seasons viz. lean, monsoon and pre-monsoon seasons to study the variation in water quality from Wazirabad to Okhla region of Delhi (NCR). The purpose of investigation is to assess ts suitability for concrete making as per guidelines given in IS 456 – 2000 “Code of Practice – Plain & reinforced concrete”. (Table 1). River and ground water (hand pump) samples were specifically analysed for the parameters given in Table 1.

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Table 1: IS 456: 2000 Code of practice for plain and reinforced concrete
Permissible limits for solids (Clause 5.4)

Parameters	Tested as per	Permissible limit, Max
Organic solids	IS 3025 (Part 18): 1988	200 mg/l
Inorganic solids	IS 3025 (Part 18): 1984	3000 mg/l
Sulphates (as SO_4)	IS 3025 (Part 24): 1986	400 mg/l
Chlorides (as Cl)	IS 3025 (Part 32): 1988	2000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work
Suspended matter	IS 3025 (Part 17): 1984	2000 mg/l
pH value	IS 3025 (Part 11): 1983	Not less than 6
Acidity	To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml of 0.02 normal NaOH.	
Alkalinity	To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H_2SO_4.	

SAMPLING LOCATIONS

The total number of sites for drawing the water samples were 18 comprising 11 Nos. of river water samples from right & left bank of the river; 03 Nos. of water samples of the underground water collected from hand pumps and 04 Nallah water samples mixing with the river in Table 2.

Table 2 : Sampling locations

Sample Nos	Locations
RIVER LOCATIONS	
1	River, at Jagatpur Gaon U/S to Wazirabad, R/B
2.	River, below Wazirabad Flyover, D/S, R/B
3.	River, below Wazirabad Flyover, D/S, L/B
6.	River at Surghat, D/S, L/B
9.	River, Below Geeta Colony Flyover, D/S, R/B.
10.	River, Near elephant habitat at U/S of ITO flyover, L/B
13	River, Below ITO Flyover, D/S; R/B.
15.	River, Behind Indraprastha Gas Turbine, D/S, R/B.
16.	River, at Nizamuddin Flyover, U/S, R/B.
17.	River, at Nizammuddin Flyover, D/S, L/B.
18.	River, at Kalindi Kunj, Okhla Barrage, D/S., R/B.
NALLAH LOCATIONS	
4.	Nallah Near Wazirabad fly over, D/S, L/B
7.	Najafgarh Nallah, D/S, R/B,
11.	Nallah Shantivan, Opp. Rajghat Power Station, R/B
14.	Nallah behind Indraprastha Gas Turbine, D/S, R/B.
GROUND WATER LOCATIONS	
5.	Hand Pump at Wazirabad Crematorium, D/S, L/B
8.	Hand Pump, Below Geeta Colony Flyover, D/S, R/B
12.	Hand Pump, Near elephant habitat at U/S of ITO flyover, L/B

MATERIALS AND METHODS

Degree of aggressivity of water along with pollution parameters like pH value, suspended solid value etc. are to be established with relevant national and international codes and practices to ascertain its effect on concrete durability. National & international codes like Central Pollution Control Board Standard : Rule No. 3, March

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1996[9] ; International Commission on Large Dams, ICOLD Bulletin No. 71 "Exposure of Dam Concrete to Special Aggressive Waters – Guidelines and Recommendations, 1989" for assessing aggressivity of soft water[12] and guidelines of suitability of water for construction purpose "IS: 456-2000 - Plain and reinforced concrete - Code of practice (Fourth revision)[8]were consulted.

FIELD & LABORATORY INVESTIGATIONS

In situ parameters like pH, $CaCO_3$ saturated pH, conductivity and temperature were determined immediately after collection of the water samples. Construction parameters like acidity, alkalinity, sulphate, chloride, suspended solids, inorganic solids & organic solids were determined as required in Indian Standard Code No. 456 – 2000.

Insitu Parameters : Ph, Conductivity And Temperature

River locatiions (sample nos. 1,2,3,6,9,10,13,15,16,17,18)

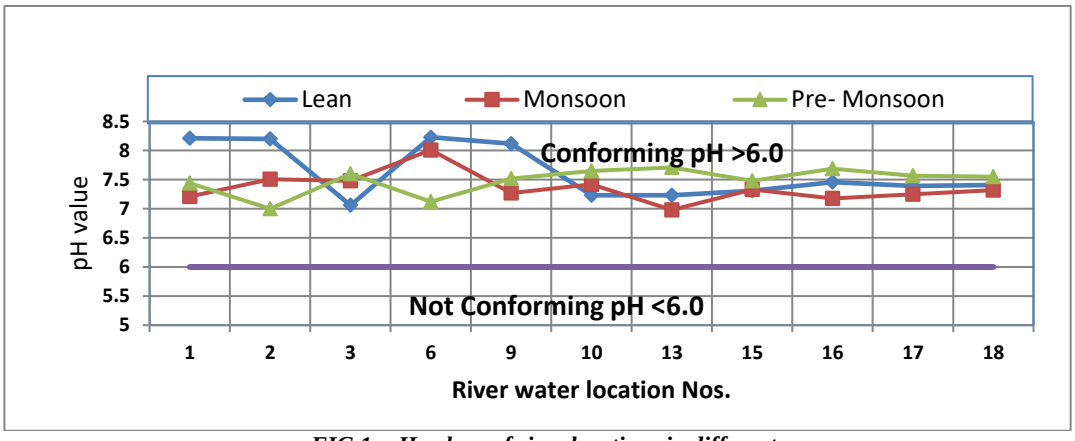

FIG 1: pH values of river locations in different seasons

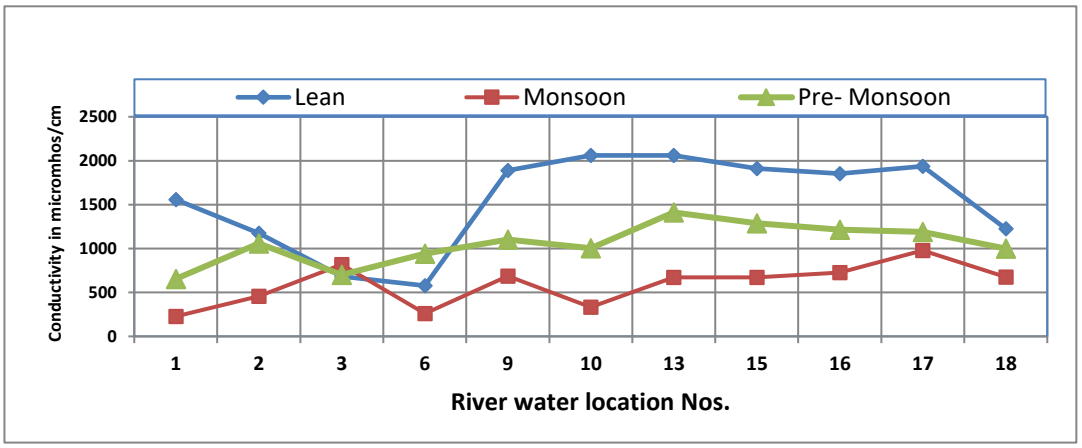

FIG 2: Conductivity values of river locations in different seasons

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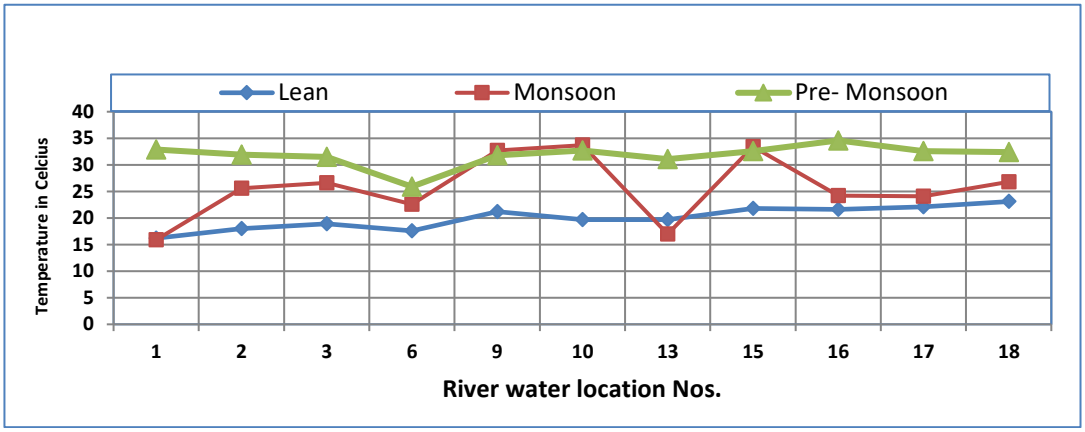

FIG 3: Insitu temperature of river locations in different seasons

HAND PUMP Locations (Sample Nos. 5,8,12)

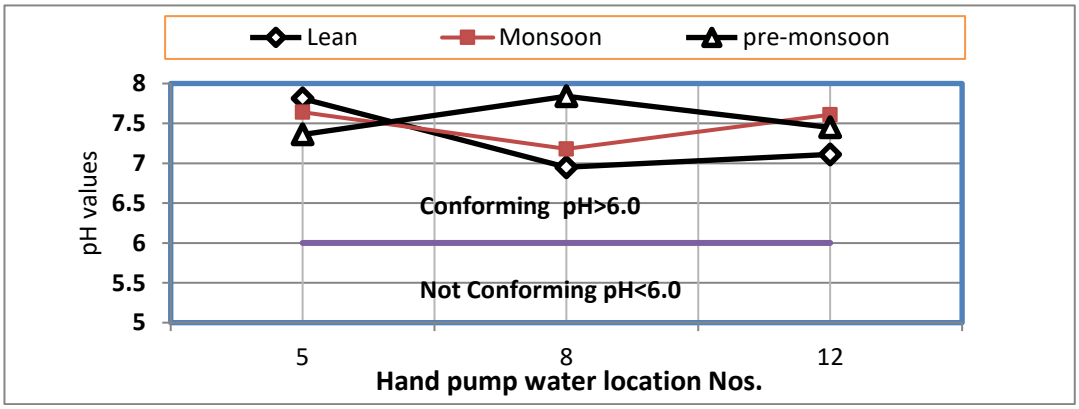

FIG 4: pH values of Hand pump locations in different seasons

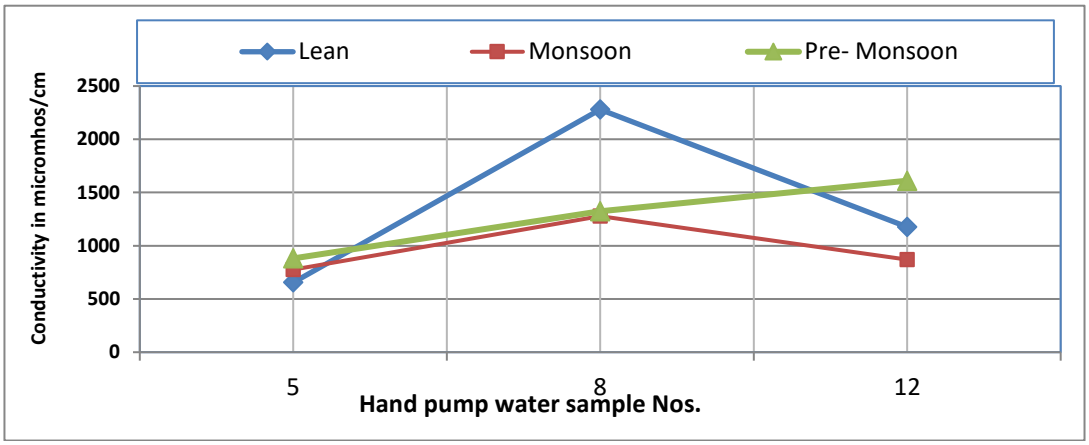

FIG 5: conductivity values of Hand pump locations in different seasons

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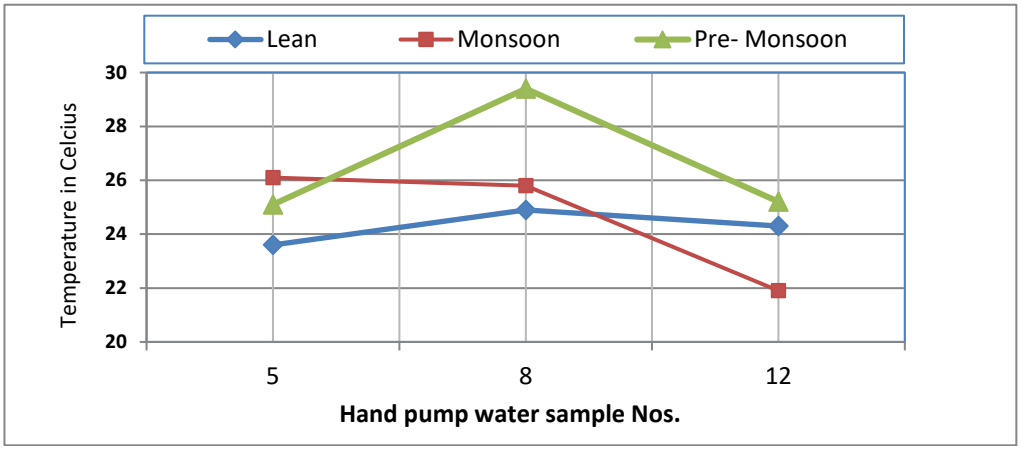

FIG 6 : Insitu temperature of hand pump locations in different seasons

NALLAH Locations (Sample Nos. 4,7,11,14)

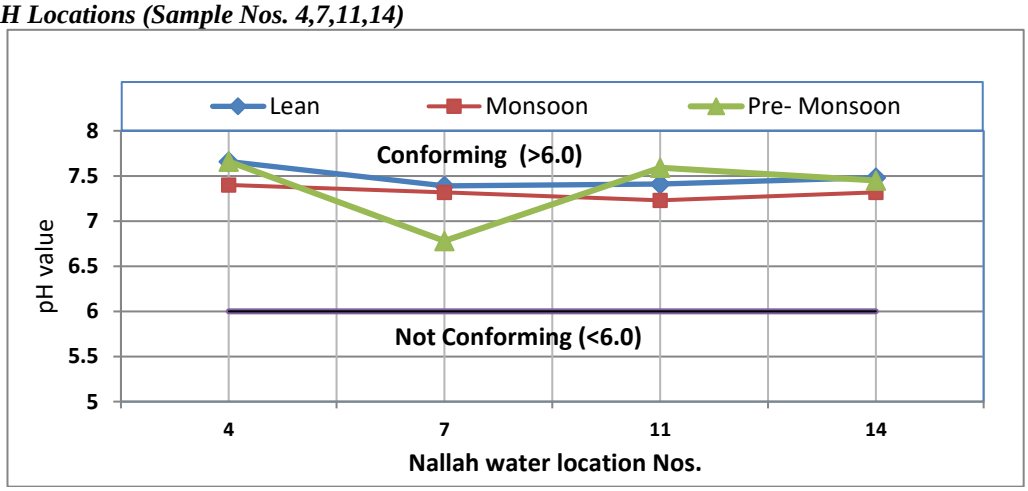

FIG 7 : pH values of Nallah locations in different seasons

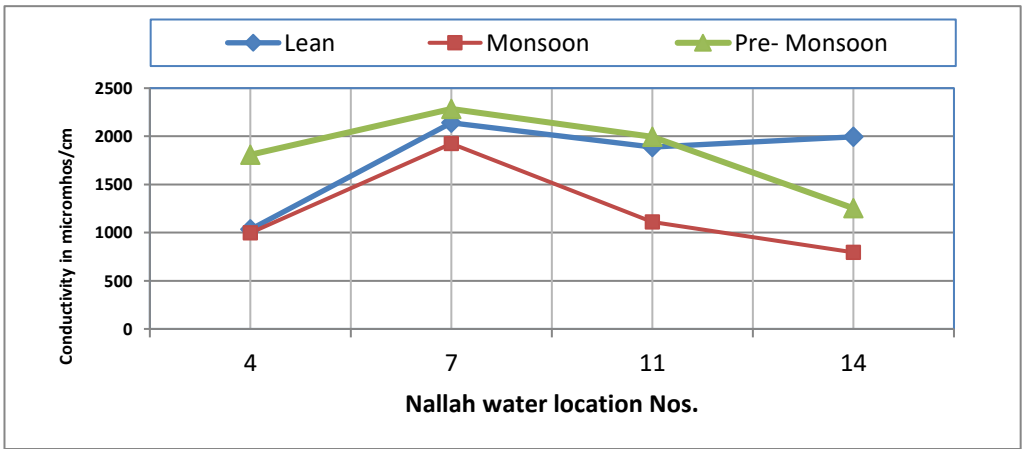

FIG 8: Conductivity values of Nallah locations in different seasons

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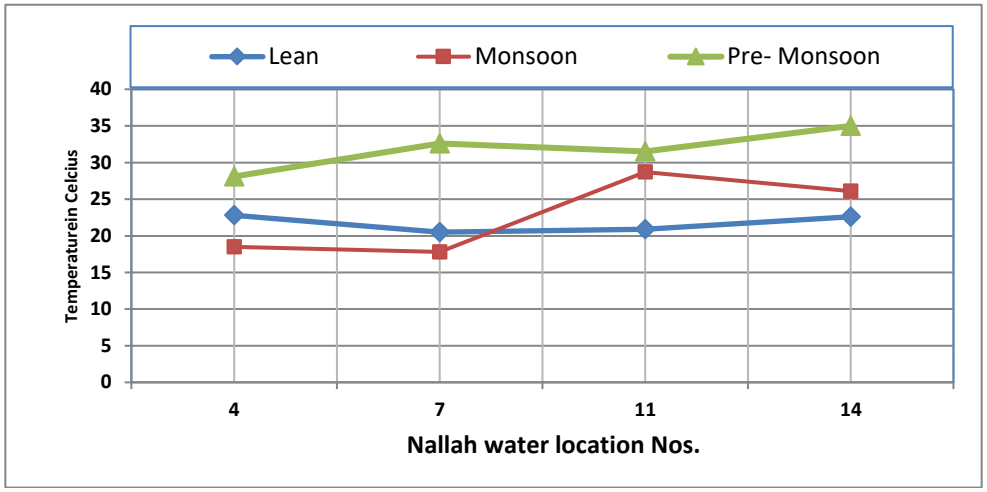

FIG 9: Insitu temperature (°C) of Nallah locations in different seasons

LABORATORY PARAMETERS– River locations

The river water samples were analysed for construction parameters as mentioned in Table 1. The results are given in Table 3.

Table 3 : Laboratory analysis – River locations

Sample Nos.	Sample Locations	**Acidity:** Volume of 0.02N NaOH to neutralize 100 ml of sample using phenolphthalein as an indicator (ml)			**Alkalinity:** Volume of 0.02N H_2SO_4 to neutralize 100 ml of sample using mixed indicator (ml)		
	Seasons →	**Feb 2016**	**Aug 2014**	**May 2014**	**Feb 2016**	**Aug 2014**	**May 20 14**
		Lean Season	**Mon-soon**	**Pre-monsoon**	**Lean Season**	**Mon-soon**	**Pre-monsoon**
1.	River, at Jagatpur Gaon U/S to Wazirabad, R/B	0.8	1.9	2.5	26.25	10	18.4
2.	River, below Wazirabad Flyover, D/S, R/B	0.8	1.8	2.9	22.5	16.3	18.4
3.	River, below Wazirabad Flyover, D/S, L/B	2.8	2.0	1.9	31.25	22.5	14.3
6.	River at Surghat, D/S, L/B	0.8	1.0	3.0	15.0	10.0	21.5
9.	River, Below Geeta Col-ony Flyover, D/S, R/B.	0.9	1.7	1.8	28.75	16.3	24.6

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10.	River, Near elephant habitat at U/S of ITO flyover, L/B	2.4	2.0	1.8	35.0	15.0	21.5
13.	River, Below ITO Flyover, D/S; R/B.	2.6	3.0	1.9	36.25	15.7	23.6
15.	River, Behind Indraprastha Gas Turbine, D/S, R/B.	2.6	2.0	2.5	28.75	15.7	24.6
16.	River, at Nizamuddin Flyover, U/S, R/B.	2.5	2.9	1.8	30	21.3	23.6
17.	River, at Nizammuddin Flyover, D/S, L/B.	2.1	2.0	1.9	32.5	22.5	21.5
18.	River, at Kalindi Kunj, Okhla Barrage, D/S., R/B.	2.0	2.0	1.9	17.5	18.8	31.8

Table : 3 Cont'd..

Sample Nos.	**Sample Locations**	**Chloride, (as Cl^-), mg/l**			**Sulphate, (as SO_4^{--}), mg/l**		
	Seasons →	**Feb 2016**	**Aug 2014**	**May 20 14**	**Feb 2016**	**Aug 2014**	**May 20 14**
		Lean Season	**Mon-soon**	**Pre-monsoon**	**Lean Season**	**Mon-soon**	**Pre-Mon-soon**
1.	River, at Jagatpur Gaon U/S to Wazirabad, R/B	268.5	14.2	25.8	192.5	26.4	30.4
2.	River, below Wazirabad Flyover, D/S, R/B	190.8	28	110.8	156.9	44.8	77.0
3.	River, below Wazirabad Flyover, D/S, L/B	75.4	55.2	75.4	85.7	33.2	45.7
6.	River at Surghat, D/S, L/B	75.4	20	111.2	70.3	26.6	62.5
9.	River, Below Geeta Col- ony Flyover, D/S, R/B.	315.1	65	156.2	187.5	82.1	155.1
10.	River, Near elephant habitat at U/S of ITO flyover, L/B	372.8	64.1	157.8	183.6	57.4	167.1
13.	River, Below ITO Flyover, D/S; R/B.	412.7	81.4	222.1	192.6	86.5	171.2
15.	River, Behind Indraprastha Gas Turbine, D/S, R/B.	195.3	61.3	198.1	158.7	98.9	178

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16.	River, at Nizamuddin Flyover, U/S, R/B.	332.8	116.1	217.7	205.7	132.3	155.1
17.	River, at Nizammuddin Flyover, D/S, L/B.	323.9	98.1	222.1	169.6	121.6	176.6
18.	River, at Kalindi Kunj, Okhla Barrage, D/S., R/B.	230.8	142	187.7	149.9	103.5	222

Table : 3 Cont'd..

Sample Nos.	**Sample Locations**	**Inorganic solids, mg/l**			**Organic solids, mg/l**		
		Feb 2016	**Aug 2014**	**May 2014**	**Feb 2016**	**Aug 2014**	**May 20 14**
	Seasons →	**Lean Season**	**Mon-soon**	**Pre-monsoon**	**Lean Season**	**Mon-soon**	**Pre-monsoon**
1.	River, at Jagatpur Gaon U/S to Wazirabad, R/B	988	112	378	89	67	73
2.	River, below Wazirabad Flyover, D/S, R/B	760	283	637	91	45	56
3.	River, below Wazirabad Flyover, D/S, L/B	539	445	444	61	57	34
6.	River at Surghat, D/S, L/B	383	172	622	44	23	39
9.	River, Below Geeta Col-ony Flyover, D/S, R/B.	1142	433	781	109	47	71
10.	River, Near elephant habitat at U/S of ITO flyover, L/B	1301	326	741	111	35	66
13.	River, Below ITO Flyover, D/S; R/B.	1321	447	930	132	45	79
15.	River, Behind Indraprastha Gas Turbine, D/S, R/B.	1055	453	882	92	31	82
16.	River, at Nizamuddin Flyover, U/S, R/B.	1102	570	837	178	57	87
17.	River, at Nizammuddin Flyover, D/S, L/B.	1179	627	819	109	62	90
18.	River, at Kalindi Kunj, Okhla Barrage, D/S., R/B.	775	547	855	66	44	100

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Table : 3 Cont'd..

Sample Nos.	Sample Locations	pH values			Suspended solids, mg/l		
		Feb 2016	Feb 2016	Aug 2014	Feb 2016	Feb 2016	Aug 2014
	Seasons →	Lean Season	Lean Season	Mon-soon	Lean Season	Lean Season	Mon-soon
1.	River, at Jagatpur Gaon U/S to Wazirabad, R/B	8.21	7.21	7.44	32.4	866.5	133
2.	River, below Wazirabad Flyover, D/S, R/B	8.20	7.51	7.00	54.1	567.3	82.1
3.	River, below Wazirabad Flyover, D/S, L/B	7.06	7.48	7.60	174.1	345.1	111
6.	River at Surghat, D/S, L/B	8.23	8.01	7.12	57.1	233.6	92.1
9.	River, Below Geeta Col-ony Flyover, D/S, R/B.	8.12	7.27	7.52	64.9	344.4	344
10.	River, Near elephant habitat at U/S of ITO flyover, L/B	7.23	7.42	7.65	182.7	387.9	238
13.	River, Below ITO Flyover, D/S; R/B.	7.23	6.98	7.71	109	467.1	211
15.	River, Behind Indraprastha Gas Turbine, D/S, R/B.	7.31	7.33	7.48	76.6	333.2	164
16.	River, at Nizamuddin Flyover, U/S, R/B.	7.46	7.18	7.69	282.6	299.8	224
17.	River, at Nizammuddin Flyover, D/S, L/B.	7.39	7.25	7.57	22.7	455.2	109
18.	River, at Kalindi Kunj, Okhla Barrage, D/S., R/B.	7.41	7.32	7.55	41.1	269.3	215

The interpretation w.r.t. conformity of the river water samples as per IS : 456-2000 is given in Table 4.

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Table 4 : Interpretation of river water quality as per IS : 456 – 2000

Sample Nos.	↓Locations	IS : 456 – 2000 Conformity remarks		
	Seasons→	Lean	Monsoon	Pre-monsoon
1	Jagatpur Gaon U/S to Wazirabad, R/B	Not Conforming	Conforming	Conforming
2	Below Wazirabad Flyover, D/S, R/B	Conforming	Conforming	Conforming
3	Below Wazirabad Flyover, D/S, L/B	Not Conforming	Conforming	Conforming
6	River at Surghat, D/S, L/B	Conforming	Conforming	Not Conforming
9	Below Geeta Colony Flyover, D/S, R/B.	Not Conforming	Conforming	Not Conforming
10	Near elephant habitat at U/S of ITO flyover, L/B	Not Conforming	Conforming	Not Conforming
13	River below ITO flyover, D/S, R/B.	Not Conforming	Conforming	Not Conforming
15	Behind Indraprastha Gas Turbine, D/S, R/B.	Not Conforming	Conforming	Not Conforming
16	Nizamuddin Flyover, U/S, R/B.	Not Conforming	Conforming	Not Conforming
17	Nizammuddin Flyover, D/S, L/B.	Not Conforming	Conforming	Not Conforming
18	Kalindi Kunj, Okhla Barrage, D/S., R/B.	Conforming	Conforming	Not Conforming

Evaluation of aggressivity of river water – Langelier Index

International Commission on Large Dams (ICOLD) Bulletin No. 71 – "Exposure of Dam Concrete to Special Aggressive Waters – Guidelines and Recommendations, 1989" measures the aggressivity of water based on the Langelier Index value calculated using given formula for water having temperature less than 25°C. The Langelier Saturation Index (LI), a measure of a solution's ability to dissolve or deposit calcium carbonate, is often used as an indicator of the corrosivity of water. When no protective scale is formed, water is considered to be aggressive and corrosion can occur. In developing the LI, Langelier derived an equation for the pH at which water is saturated with calcium carbonate (pHs). This equation is based on the equilibrium expressions for calcium carbonate solubility and bicarbonate dissociation. To approximate actual conditions more closely, pHs calculations were modified to include the effects of temperature and ionic strength. The magnitude and sign of the LI value show water's tendency to form or dissolve scale and thus to inhibit or encourage corrosion. The information obtained from LI is a general indicator of the corrosivity of water. [12]

FIG. 10 illustrates the calculated LI values during investigation. Out of three seasons, LI calculation for pre-monsoon period not calculated for all river samples as the temperature of the water exceeded 25°C. LI values calculated for lean (February) and monsoon (August) seasons only. Out of two seasons, It is seen that from Table 9 that the river water locations from Wazirabad to Okhala tends to be aggressive as the Langelier index value falls in negative category consistently. Monsoon season Langelier Index value much arithmetically lesser than lean season indicating more aggressivity. However, none of the river locations measured the LI value more negative than -1.50 indicating moderately aggressivity. It indicates the remedial measures applicable for moderate aggressive conditions during concrete construction as per IS 456 – 2000 (fourth revision).[8]

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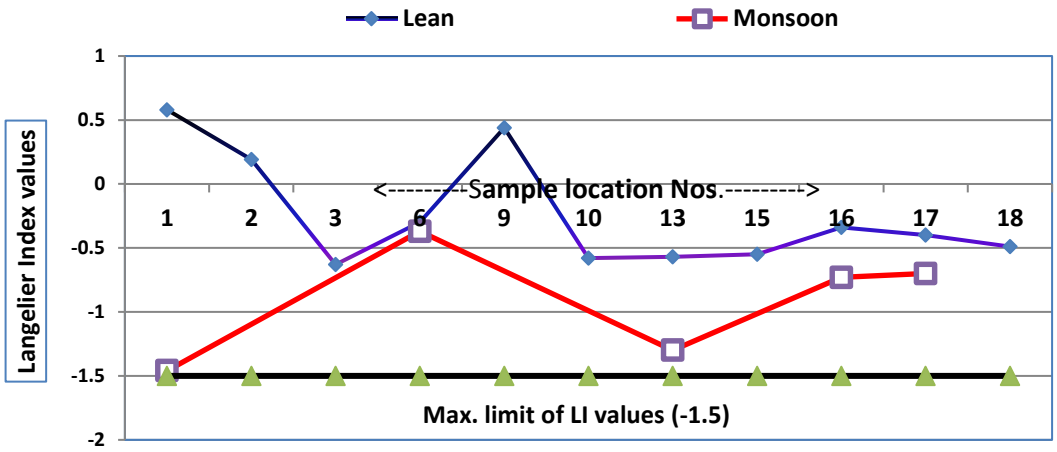

FIG 10 : Variation in Langelier Index values in river locations

EVALUATION OF NALLAH WATER QUALITY DATA AS PER CPCB NORMS

The Central Pollution Control Board (CPCB) have mentioned certain established norms for evaluating effluent/nallah water quality with reference to the environmental pollution aspect. The main parameters are pH and suspended solid content.

Table 5 : pH & Suspended solids of Nallah locations as per CPCB norms

Nallah locations	pH value			Suspended solid, mg/lit			Remarks – Limits of parameter as per CPCB Norms
	Lean	Mons-oon	Pre-mons-oon	Lean	Mons-oon	Pre-mon-soon	
Near Wazirabad flyover, D/S, L/B (Sample No 4)	7.66	7.40	7.66	284.9	112.5	236	As per CPCB norms, pH value should be between 6.5 to 8.5 and suspended. Solid content should not exceed 100 mg/lit.
Najafgarh Nallah (Sample No. 7);	7.39	7.32	6.78	364.6	456.5	1054	
Nallah Shantivan (Sample No. 11)	7.41	7.23	7.59	117.5	200	398	
Nallah behind Indraprastha power station (Sample No. 14)	7.48	7.32	7.45	131.1	256.8	376	

It is seen from the above data that all the nallah water locations fail to conform the CPCB standard throughout the period of water quality observations w.r.t. suspended solid content. All the Nallah sewage water contain high amount of suspended solid in the range 112.5– 1054 mg/lit. which is beyond the permissible limit of 100 mg/lit.

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GROUND WATER – HAND PUMP WATER QUALITY

Table 6 : Laboratory analysis – Hand Pump Water (Ground Water)

Parameters	Hand Pump, Wazirabad Crematorium, D/S, L/B (Sample No. 5)			Hand Pump, Wazira-bad Crematorium, D/S, L/B, (sample No. 8)			Hand Pump, Wazira-bad Crematorium,D/S, L/B, (Sample No. 12)		
	Feb 2016	Aug 2014	May 20 14	Feb 2016	Aug 2014	May 20 14	Feb 2016	Aug 2014	May 20 14
	Lean Season	Mon-soon	Pre-monsoon	Lean Season	Mon-soon	Pre-monsoon	Lean Season	Mon-soon	Pre-monsoon
Acidity: Volume of 0.02N NaOH to neutralize 100 ml of sample using phenolphthalein as an indicator (ml)	1.4	1.9	2.0	2.9	1.8	1.6	2.8	1.9	2.5
Alkalinity: Volume of 0.02N H_2SO_4 to neutralize 100 ml of sample using mixed indicator (ml)	20	22.5	18.4	37.5	35.0	18.4	22.5	17.5	18.4
Chloride, (as Cl^-), mg/l	82.1	66	96.4	330.8	170.7	224.7	199.7	170	323.9
Sulphate, (as SO_4^{--}), mg/l	65.4	55.9	81.7	248.3	111.9	208.8	104.2	88.7	126
Inorganic solids, mg/l	448	473	556	1371	1050	868	750	600	982
Organic solids, mg/l	43	50	50	135	98	77	63	62	89
pH values	7.81	7.64	7.36	6.95	7.18	7.84	7.11	7.61	7.45
Suspended solids, mg/l	10	0	3.1	13	0	0	37.5	0.8	10.2

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Interpretation of ground water quality w.r.t. IS : 456 – 2000 (Table 7)

Table 7 : Conformity w.r.t. IS : 456 – 2000

Sample Nos.	↓Locations Seasons→	IS : 456 – 2000 Conformity remarks		
		Lean	Monsoon	Pre-monsoon
5	Near Wazirabad Cremation Ground	Conforming	Conforming	Conforming
8	Below Geeta Colony Flyover, D/S, R/B	Not Conforming	Not Conforming	Conforming
12	Near elephant habitat at U/S of ITO flyover, L/B	Conforming	Conforming	Conforming

CHLORIDES IN CONCRETE

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimize the chances of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete coming from concrete materials, that is, cement, aggregates water and admixtures, as well as by diffusion from the environment should be limited. The total amount of chloride content (as Cl) in the concrete at the time of placing shall comply with the requirements given in Table 8. The total acid soluble chloride content should be calculated from the mix proportions and the measured chloride contents of each of the constituents. Wherever possible, the total chloride content of the concrete should be determined.

The effect of chloride, sulfate and chloride-sulfate solutions on corrosion of steel embedded in cement paste has been investigated. The reinforcement corrosion was evaluated by measuring corrosion potentials and corrosion current density using D.C. linear polarization resistance technique. Results indicate that the corrosion activity was very minimal in specimens immersed in pure sulfate solution. The reinforcement corrosion activity was found to be higher in specimens immersed in chloride-sulfate solutions as compared to those immersed in pure chloride solution. [11]

Table 8 : Limits of Chloride content of Concrete as per IS: 456-2000[8]
(Table 7. Clause 8.2.5.2)

Sl. No.	Type or use of concrete	Max. total Acid soluble Chloride content expressed as Kg/m^3 of concrete
1.	Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete.	0.4
2.	Reinforced concrete or plain concrete containing embedded metal	0.6
3.	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

CONCLUSION

River Locations

- Majority of river water locations are not fit for construction as per IS 456: 2000 guidelines in lean and pre-monsoon seasons and are fit for construction in monsoon season.
- Langelier Index which is the measure to determine water aggressivity, calculated for lean (February) and monsoon (August) seasons for river locations as the temperature of the water remain below 25°C.The river water locations from Wazirabad to Okhala tends to be aggressive as the Langelier index

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value falls in negative category consistently. However, none of the river locations measured the LI value more negative than -1.50 indicating overall water quality as **"Moderately aggressive".** (FIG. 10)

- The environment of river water locations can be concluded as **"moderately aggressive".**
- Hand pump water samples conforms to the criteria laid down in IS 456 – 2000 for its use in construction purpose barring hand pump location situated below Geeta colony flyover, which is not conforming in lean and monsoon observations.
- High values of conductivity in ground water samples may be attributed to the seepage of river water flowing around the vicinity of hand pump locations due to having high values of dissolved salts as seen in **Table 6.**

RECOMMENDATIONS

- As far as corrosion of reinforcement of concrete due to chloride ions is concerned, minimum concrete cover as per design/codal requirement may be provided. Furthermore, limit of chloride ion within concrete should be restricted to acceptable limit given in IS: 456 – 2000**.**
- Under Para 1.2 (Table 3 of IS: 456-2000) important aspects about environmental conditions of water with respect to its attack on concrete has been dealt with at ordinary temperature only.
- Three seasonal water quality data suggests the exposed conditions is **"moderate**" condition. In that case following remedial measures may be considered:

	Plain concrete	**Reinforced concrete**
Minimum cement content, Kg/M^3	240	300
Maximum free water-cement ratio	0.60	0.50
Minimum grade of concrete	M15	M25

Note: Under this condition, it would be preferable to use blended cement such as Portland blast furnace slag cement/Portland Pozzolana cement etc. W/C ratio may be kept much below the values prescribed above to get a good dense and impermeable concrete. Keeping the cementitious content much above the minimum prescribed value is advisable. However, if potentially reactive aggregates are encountered, optimum cement content may have to be considered.[8]

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