एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

NTPC/KGN/EMG/EC-MOEF/2022-23 **Date: 02/05/2023**

To
Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest and Climate Change,
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3,
Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in

Sub: Submission of 16th Half Yearly Environmental Clearance Compliance Report of Khargone Super Thermal Power Project (2x660 MW) at Village Selda & Dalchi, Khargone, Madhya Pradesh by NTPC Ltd.

EC Ref: J-13012/54/2010-1A. II (T), Dated-31.03.2015

Dear Sir,

With reference to the above-mentioned subject, we are submitting the half yearly compliance status report to the stipulated conditions of Environmental Clearance vide email for the period (**Oct'2022-Mar'2023**) for your kind perusal & records please.

It is also submitted that we are unable to upload the six-monthly EC compliance status at Parivesh Portal as per an error encountered while new registration. Compliant already lodged at Parivesh portal and Monitoring Cell, is under process. Therefore, to meet the timely compliance we are submitting the subject matter report vide email.

Submitted for your kind information and perusal please

Thanking you,

Yours sincerely,

(Ashish Kumar Agarwal)
AGM (Ash & Envt. Mgmt.)

Encl. as above

Copy to:

1. The Member Secretary,
   Central Pollution Control Board,
   Email-mscb.cpcb@nic.in

2. The Member Secretary,
   Madhya Pradesh Pollution Control Board,
   Email- ms-mppcb@mp.gov.in

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Encl. as above

Copy to:

1. The Member Secretary,
   Central Pollution Control Board,
   Email-mscb.cpcb@nic.in

2. The Member Secretary,
   Madhya Pradesh Pollution Control Board,
   Email- ms-mppcb@mp.gov.in

KHARGONE SUPER THERMAL POWER PROJECT (2X660 MW)
HALF YEARLY COMPLIANCE REPORT OF
ENVIRONMENTAL CLEARANCE CONDITIONS
(For the period October'2022 - March'2023)

(Vide Letter No. J- 13012/54/2010-IA. II (T) Dated 31st March 2015)

	MOEF & CC Stipulations	NTPC Response
A	**Specific Conditions:**	**Status as on 31.03.2023**
i	Coal transportation shall be by Rail only. An additional EIA shall be carried out and an EMP shall be prepared for laying down the rail line and alternate mode of transportation, in case rail line gets delayed. The EIA/EMP shall be submitted to the Ministry within one year of issuing the EC.	Complied Rail network for NTPC-Khargone has been established and entire coal is being transported by railway route only.
ii	The Sulphur and Ash content of coal shall not exceed 0.5% and 43% respectively. In case of variation of quality at any point of time, fresh reference shall be made to the Ministry for suitable amendments in the environmental clearance.	Compliance assured MOEF&CC Vide Office Memorandum dated 11.11.2020 has modified this condition. The project proponent has to only inform to the Regional Office of MOEF&CC regarding the change in coal source and quality.
iii	Latest authenticated satellite imagery shall be submitted to the Regional Office of the Ministry on an annual basis to monitor the environmental alterations of the area.	Complied Satellite imagery of NTPC-Khargone and its vicinity land area is regularly submitted to the Regional Office of the MOEF&CC annually. Latest satellite imagery for 2022-23 already submitted with Half-yearly compliance report dated 26.11.2022
iv	Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within six months.	Complied Vision document specifying prospective plan of the project was already submitted to the Regional Office of the MOEF&CC vide NTPC letter dated 07.09.2015.
v	Harnessing solar power within the premises of the plant particularly at available roof tops shall be carried out and status of implementation including actual generation of solar power shall be submitted along with half yearly monitoring report.	Complied For harnessing solar power, roof-top and land mounted solar power plants installed within plant & township premises Actual generation of solar power during the FY 2022-23 is 0.6233 million units (MU)
vi	One twin flue stack of 275 m height shall be provided with continuous on-line monitoring system of SO_x, NO_x and **PM2.5 & *PM10.* Exit velocity of flue gases shall not be less than 22 m/sec. In addition to the regular parameters, Mercury	Complied One twin-flue stack of 275-meter height provided for both units. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO2, NOx and PM.

	emission form stack shall also be monitored of six-monthly basis. *As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as "*PM in stack emission" in place of PM2.5 & PM10*	Exit velocity of flue gases being maintained above 22 m/sec. Mercury emission form stack also being monitored periodically. Please refer **Annexure-1**, for Mercury emission report from stack.
vii	High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 50 mg/Nm^3. Adequate dust extraction system such as cyclones/bag filters and water spray system to control fugitive emissions in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided.	Complied High Efficiency Electrostatic Precipitators (ESPs) designed for a guaranteed efficiency of 99.97% provided. The particulate emissions being controlled and maintained below 30 mg/Nm^3 in compliance to MOEF&CC emission norms for TPPs dated 07.12.2015. Adequate dust extraction system and water spray system also provided to control fugitive emissions at coal handling, coal stockyard, ash handling area, transfer points and other vulnerable dusty areas. Please refer **Annexure-1**, for Particulate emission from stack
viii	COC of at least 5.0 shall be adopted.	Compliance assured Closed cycle cooling water re-circulation system is implemented to meet prescribed COC, for the conservation/optimization of water requirement.
ix	Monitoring of surface water quantity and quality shall be conducted regularly and records shall be maintained. The monitoring points shall be located between the plant and drainage in the direction of flow of ground water and records shall be maintained. The monitored data shall be submitted to the Ministry every six months.	Complied Regular monitoring of surface water being carried out through MOEF&CC accredited and NABL certified third party laboratory. Records are being maintained and monitoring reports regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer **Annexure-1** for Surface water reports.
x	Monitoring for heavy metals in ground water in the vicinity of plant shall also be undertaken and monitoring report shall be submitted to the ministry every six months.	Complied Regular monitoring of heavy metals in ground water are being carried out through MOEF&CC accredited and NABL certified third party laboratory. Monitoring reports regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer **Annexure-1** for Heavy metals in ground water reports.
xi	A well-designed rainwater harvesting system shall be put in place within six months, which shall comprise of rainwater collection from the built up and open area in the plant premises and	Complied Well-designed, CGWA approved rainwater harvesting system implemented at plant premises. Records for the harvested quantities of water every year being

	records shall be kept for the quantity of water harvested every year and its use.	maintained. Rainwater harvested is used to recharge the ground water as per approved scheme.
xii	No water bodies including natural drainage system in the area shall be disturbed due to activities associated with the setting up/ operation of the power plant.	Complied No water body including natural drainage system of the area has been disturbed.
xiii	Hydro geology of the area shall be reviewed annually through an institute/ organization of repute to assess impact of surface water and ground water (especially around ash dyke). In case, any deterioration is observed specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months.	Complied Baseline Hydro-geological study was carried out through National Institute of Hydrology (NIH), Roorkee. Annual review of hydro geology to assess impact of surface water and ground water (especially around ash dyke) has been also carried out through NIH, Roorkee. Please refer **Annexure-2** for copy of hydrogeology review study report for 2022. Reports of surface and ground water quality are regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer **Annexure-1** for Surface & Ground water quality reports.
xiv	Wastewater generated from the plant shall be treated before discharge to comply with the standards prescribed by the SPCB/CPCB.	Complied Effluent Management Scheme has been designed and implemented with the objective to treat the entire wastewater as per the prescribed statutory standards of MPPCB/CPCB. It is to be submitted that during normal course of operations, zero liquid discharge being adopted based on maximum recycle/reuse of wastewater for various plant usage.
xv	Additional soil for leveling of the proposed site, if require shall be taken from within the sites (to the extent possible) so that natural drainage system of the area is protected.	Complied For leveling of site all additional soil being taken from within the sites only (to the extent possible) with all necessary precautions to protect natural drainage system of the area.
xvi	Fly ash shall be collected in dry from and storage facility (silos) shall be provided. Un-utilized fly ash shall be disposed-off in the ash pond in the form of slurry. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) will be monitored in the effluents emanating from the ash pond and in the bottom ash also. No ash shall be disposed-off in low-lying area.	Complied An ash management & disposal scheme is implemented consisting of dry ash extraction system (DAES) for dry collection of fly ash with adequate storage facility (silos) to supply ash to entrepreneurs for utilization. Un-utilized ash is being safely disposed in the ash pond in the form of slurry. Two different systems are being provided for ash disposal: Conventional wet slurry disposal system with ash water re-circulation for bottom ash and

		High Concentration Slurry Disposal (HCSD) system for fly ash disposal. Mercury & other heavy metals (As, Hg, Cr, Pb etc.) are regularly monitored in the ash water emanating from ash pond and in the bottom ash. No ash is being disposed-off in low-lying area at present. Prior permission shall be obtained for ash disposal in low-lying area. Please refer **Annexure-1** for Mercury & Heavy metals in ash water & bottom ash
xvii	Fugitive emission of fly ash (dry or wet) shall be controlled such that no agricultural or non-agricultural land is affected. Damage to any land shall be mitigated and suitable compensation shall be provided in consultation with the local Panchayat.	Complied Dust suppression system comprising of water spray nozzles are provided all around the ash ponds for effective control of fugitive emission of fly ash. Further, closed trucks/ bulkers/covered vehicle are being used for transportation of fly ash to avoid fugitive dust emission.
xviii	Ash pond shall be line with HDPE/LDPE lining or any other suitable impermeable media so that no leaching takes place at any point of time. Adequate safety measures shall also be implemented to protect the ash dyke from getting breached.	Complied To avoid any leaching and ground water contamination from ash slurry, adequate lining or other suitable impermeable media provided. Bottom ash lagoons are lined with impervious media i.e., bentonite blended clay in order to achieve the required permeability. In HSCD lagoon the disposed layers of ash are solidified and there is very less free water. Overflow lagoon of ash dyke is also designed with and lined with impervious thick liner of 300 mm at bottom. The structure of ash dykes has been designed, constructed, and being operated as per state-of-the-art engineering practices for the design and construction of earth dams with adequate factor of safety. Ash dyke being constructed considering the seismic parameters in its design. Further, Regular monitoring and inspection of ash dykes and an emergency response system will ensure that there are no risks of failure as apprehended.
xix	A long-term study of radioactivity and heavy metals contents of coal to be used shall be carried out through a reputed institute and results shall be analyzed every two years and shall be reported to the Ministry along with the monitoring reports. Thereafter, mechanism for * *in-built continuous monitoring* for	Complied Regular periodical monitoring of Radioactivity content of coal has been carried out through reputed institute 'Board of Radiation & Isotope Technology '(BRIT) under Bhabha Atomic Research Centre, Navi Mumbai. Please refer **Annexure-3** for

	radioactivity and heavy metals in coal and fly ash (including bottom ash) shall be put in place. *As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as *"regular periodical monitoring"* in place of in-built continuous monitoring.	Radioactivity content report in coal & ash samples Further, Regular periodical monitoring of Heavy metals content of coal has been also carried out through MOEF&CC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional office of MOEF&CC along with half-yearly compliance reports. Please refer **Annexure-1** for Heavy metals content report.
xx	Green Belt of least 50m width consisting of three tiers of plantations of native species around the plant shall be raised. Wherever 50m width is not feasible, an adequate justification shall be submitted to the Ministry and appropriate width not less than 20m shall be planted. Tree density shall not be less than 2500 per ha with survival rate not less than 80%.	Compliance assured Green belt development/tree plantation is being carried out at all available spaces inside and outside the plant and township premises. Further tree plantation being taken up at external forest land and Govt land to enhance the green cover. Avenue plantation along the approach roads and ash dyke also being taken up. About 3.85 lakhs tree have been planted till date at inside and outside the NTPC-Khargone premises through Madhya Pradesh Rajya Van Vikas Nigam Ltd. under Govt. of M.P.
xxi	Green belt shall also be developed around the ash pond over and above the Green Belt around the plant boundary.	Compliance assured Tree plantation at the vicinity of ash pond sites and along peripheral roads is being planted.
xxii	CSR schemes identified based on need-based assessment shall be implemented in consultation with the village Panchayat and the District Administration starting from the development of project itself. As part of CSR, prior identification of local employable youth the eventual employment in the project after imparting relevant training shall be also undertaken. Company shall provide separate budget for community development activities and income generation programs.	Compliance assured NTPC Khargone is presently executing development schemes under its Community Development program as it has not entered CSR Phase yet. The said Community Development activities are carried out as envisaged in the approved R&R Plan for NTPC Khargone project. Under its Community Development activities in the FY 2022-23, an amount of Rs. 9.50 Cr has been utilized in the project affected and vicinity villages in both civil and non-civil work. Please refer **Annexure-4** for the Community Development activities undertaken during the report period in the FY 2022-23.
xxiii	For periodic monitoring of CSR activities, a CSR Committee or a Social Audit committee or a suitable credible external	Compliance assured

	agency shall be appointed. CSR activities shall also be evaluated by an independent external agency. This evaluation shall be both concurrent (every six months) and final.	NTPC Khargone is presently executing development schemes under its Community Development program as it has not entered CSR Phase yet. The said Community Development activities are carried out as envisaged in the approved R&R Plan for NTPC Khargone project. Presently, the final report of Social Impact Evaluation Study is under finalization. Need Assessment survey (NAS) has been kick-started for Khargone.
xxiv	An Environmental Cell comprising of at least one expert in environmental science/ engineering, ecology, occupational health, and social science shall be created preferably at the project site itself and shall be headed by an officer of appropriated seniority and qualification. It shall be ensured that the Head of the cell shall directly report to the Head of the Plant who would be accountable for implementation of environmental regulations and social impact improvement/ mitigation measures.	Complied An Environment Management Group (EMG) with qualified team, headed by AGM (Ash & Envt. Mgmt.) is already functional at the Khargone project site. EMG is responsible for implementation and compliance of environmental stipulations and ensure mitigation measures.
B	**General Conditions:**	
i	Space for FGD shall be provided for future installation, if required.	Complied Space for FGD was already provided. Further, erection of FGD plant completed for both Units. Commissioning of FGD for both Units in under progress.
ii	The treated effluents conforming to the prescribed standards under Environment (Protection) Act 1986 only shall be re-circulated and reused within the plant. Arrangements shall be made that effluents and storm water do not get mixed.	Complied Effluent treatment system comprising of effluent treatment plant, neutralization pit, oil & grease separator, settling ponds and cooling towers etc. provided to treat effluents conforming the prescribed standards. An integrated scheme for treatment, recycle and reuse of effluents is implemented. Cooling water blow down reused in CHP, AHP and firefighting. Ash water effluent recirculation also being provided for reuse in ash handling purpose. Provision also made for treatment, recirculation & reuse of effluents from coal handling plant. Further, Zero Liquid Discharge (ZLD) scheme is implemented for recycle & reuse of wastewater generated, thereby

		reducing, and optimizing the quantities of water requirement. Independent plant effluent drainage system provided to ensure that plant effluents do not mix with storm water drainage.
iii	A sewage treatment plant shall be provided (as applicable) and the treated sewage shall be used for raising greenbelt/plantation.	Complied Sewage treatment plant (STP) provided to treat sewage effluents emanating from plant and township. The STP treated water, conforming to prescribed standards utilized for plantation & raising greenbelt to the extent possible.
iv	Adequate safety measures shall be provided in the plant area to check/ minimize spontaneous fires in coal yard, especially during summer season. Copy of these measures with full details along with location, plant layout etc. as and when finalized, shall be submitted to the ministry as well as to the regional office of the Ministry.	Complied Adequate no. of Fire Spray & Hydrant system covering the entire power station including all the auxiliaries and buildings in the plant area is provided as per fire safety requirements. The system is adequately equipped with piping, hydrants, valves, instrumentation, hoses, nozzles, hose boxes/stations etc. Copy of safety measures details already submitted along with Half-yearly compliance dated 22.04.2019.
v	Separate storage facilities for auxiliary liquid fuel such as LDO/HFO/LSHS shall be made in the plant area in consultation with Department of Explosives, Nagpur. Sulphur content in the liquid fuel will not exceed 0.5%. Provisions of the Manufacture, Storage and Import of Hazardous Chemical Rules and the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996 shall be applicable as per the quantity stored. Disaster Management System shall be established as per the Disaster Management Plan to meet any eventuality in case of an accident taking place due to storage of oil.	Complied Storage facility designed and provided for LDO as auxiliary liquid fuel, inside plant area conforming to the adequate safety standard and where risk is minimal. Necessary license has been obtained from Department of Explosives. Sulphur content in LDO being ensured within limits. A detailed Disaster Management Plan & Risk assessment including fire and explosion issues is prepared and finalized in consultation with Department of Explosives. Regular mock drills being conducted as per plan in order to address any eventuality in case of an accident.
vi	First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase.	Complied Adequate arrangements for first aid, health & safety, and sanitation for workers have been provided and compliance ensured.
vii	Noise levels from turbines in work zone shall be limited to 85 dB (A) from source. For people working in the high noise area, requisite personal protective equipment like earplugs/earmuffs etc. shall be	Complied Design specification for the equipments has been made to comply with the stipulations. Noise levels from turbines in work zone being

	provided. Workers engaged in noisy areas such as turbine area, air compressors etc. shall be periodically examined to maintain audiometric record and for treatment for any hearing loss including shifting to non-noisy/less noisy areas.	maintained within prescribed limits of 85 dB (A) from source. Personal Protective Equipment (PPE's) are also being provided to personnel working in high noise areas. Workers of turbine generator area, compressor area and other high noise area being provided with appropriate ear protection devices. Periodic health examination of workers also being done as stipulated.
viii	Regular monitoring of ambient air ground level concentration of SO_2, $N0_x$, $PM_{2.5}$ & PM_{10} and Hg shall be carried out in the impact zone of the project and record shall be maintained. In case these levels exceed the prescribed limits, necessary control measures shall be taken immediately. The location of the monitoring stations and frequency of monitoring shall be decided in consultation with SPCB. Monitoring reports shall be submitted to the Regional Office of this Ministry every six months. The data shall also be uploaded on the website of the company.	Complied Three nos. of CAAQMS stations have been installed at main-plant and township locations in consultation with MPPCB for regular monitoring of ambient air quality and record is maintained. Adequate control measures have also been ensured to control the exceedance if any. Additionally, one CAAQMS station is also installed at Khargone city as per directions from MPPCB. Regular monitoring of ambient air quality also carried out periodically through MOEF&CC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional Office of MOEF&CC. Please refer **Annexure-1** for ambient air quality reports**.** Online ambient air monitoring data also being uploaded on Intranet webpage.
ix	Fly Ash generated shall be utilized 100% from the 4th year of operation of the power plant. Status of fly ash utilization shall be reported each year to the Regional Office of the Ministry.	Complied Ash utilization plan has been prepared and all efforts are being made to achieve the targets in compliance to MOEF&CC, Fly ash Gazette Notification dated 03.11.2009 and its amendments thereafter. Annual status of fly ash utilization being submitted regularly to the Regional office of MOEF&CC. Copy of Annual compliance report (ACR) of Ash Utilization for the FY 2022-23 is submitted herewith. Please refer **Annexure-5** for ACR.
x	Provision shall be made for the housing of construction labor (as applicable) within the site with all necessary infrastructures and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, crèche etc. The housing may be in the form of temporary structure to be removed after the completion of the project.	Compliance assured Labor colony with necessary infrastructure facilities has been provided for construction labor. The same has been kept under the scope of EPC contractor. However, NTPC ensures effective compliance of the said stipulations.

xi	The project proponent shall advertise in at least two local newspapers widely circulated in the region around the project, one of which shall be in the vernacular language of the locality concerned within seven days from the date of receipt of this clearance letter, informing that the project has been accorded environmental clearance and copies of clearance letter are available with the State Pollution Control Board/Committee and may also be see at Website of the Ministry of Environment and Forests at http://envfor.nic.in.	Complied The information of Environmental Clearance was published in two newspapers widely circulated in the region are- 1. Hindustan Times (English) on dated 04.04.2015. and 2. Nai-Dunia (Hindi) on dated 04.04.2015.
xii	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parisad/ Municipal Corporation, urban local body and the Local NGO, if any, from whom suggestions/representations, if any, received while processing the proposal. The clearance letter shall also be put on the website of the Company by the proponent.	Complied Copy of clearance letter were sent vide our letter dated 06.04.2015 to Sarpanch of village Panchayat of Selda & Dalchi village, CEO of Khargone Distt & CEO of Khargone Municipal Corporation. The Environmental Clearance is uploaded on the NTPC Ltd. website.
xiii	The proponent shall upload the status of compliance of the stipulated environmental clearance conditions, including results of monitored data on their website and shall update the same every six months. It shall simultaneously be sent to the Regional Office of MOEF, the respective Zonal Office of CPCB and the SPCB.	Complied The latest status report of Compliance to the stipulated Environmental Clearance (EC) conditions is regularly uploaded on NTPC website. Compliance status report also submitted to the Regional Office of the MOEF&CC and offices of CPCB & MPPCB regularly at every six months.
v	The criteria pollutant levels namely; SPM, RSPM ($PM_{2.5}$ & PM_{10}), SO_2, NO_x (ambient levels as well as stack emissions) shall be displayed at a convenient location near the main gate of the company in the public domain.	Complied The criteria pollutant levels as prescribed, for ambient air as well as stack emissions are displayed at a convenient location near the main gate of the company in the public domain.
xv	The environment statement for each financial year ending 31st March in Form-V as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall be submitted by the project proponent to the concerned State Pollution Control Board. The same shall also be uploaded on the website of the company along with the status of compliance of environmental clearance	Complied Environment Statement for each financial year ending 31st March in Form-V has been regularly submitted to the M.P. Pollution Control Board & Regional Office of the MOEF&CC. Annual environment statement for the FY 2021-22 was submitted along with half-yearly compliance status of EC conditions on 26.05.2022. Form-V for FY: 2022-23 shall also be submitted within prescribed time.

	conditions and shall also be sent to the respective Regional Offices of the Ministry by e-mail.	
xvi	The project proponent shall submit six monthly reports on the status of the implementations of the stipulated environmental safeguards to the Ministry of Environment and Forests, its Regional Office, Central Pollution Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environment of the environmental clearance conditions on their website and update the same every six months and simultaneously send the same by email to the Regional office, Ministry of Environment and Forests.	Complied Six monthly compliance status report of EC conditions regularly submitted to the Regional Office of MOEF&CC, CPCB & MPPCB. Reports are also uploaded on the NTPC website and periodically being replaced with the updated report.
xvii	Regional office of the Ministry of Environment & Forests will monitor the implementation of the stipulated conditions. A complete set of documents including Environmental Impact Assessment Report and Environment Management plan along with the additional information submitted from time to time shall be forwarded to the Regional Office for their use during monitoring.	Complied A complete set of documents including Environmental Impact Assessment (EIA) Report and Environment Management Plan (EMP) along with the additional information/clarifications was already submitted to Regional Office (Western Zone) of the MOEF&CC at Bhopal on 05.10.2015
xviii	The details of the funds along with item-wise break-up of Rs.1421.2 crores allocated for implementation of environmental protection measures shall be submitted to the Ministry. This cost shall be included as part of the project cost. The funds earmarked for the environment protection measures shall not be diverted for other purposes and year-wise expenditure shall be reported to the Ministry.	Compliance assured The requisite funds for environmental mitigation measures have been included in the project cost. Financial provision stipulated towards environmental mitigate measures shall not be diverted for other purposes.
xix	The project authorities shall inform the Regional Office as well as the Ministry regarding the date of financial closure and final approval of the project by the concerned authorities and the dates of start of land development work and commissioning of plant.	Complied Site leveling/ Land development work started on July 17th, 2015. Trial operation commissioning of Unit#1 (660 MW) achieved on 29/09/2019 and Commercial Date of Operation (COD) declared from 01/02/2020. Trial operation commissioning of Unit#2 (660 MW) achieved on 24/03/2020 and Commercial Date of Operation (COD) declared from 04/04/2020.

xx	Full cooperation shall be extended to the Scientists/officers from the Ministry / Regional Office of the Ministry/ CPCB /SPCB who would be monitoring the compliance of environmental status.	Noted
5	The Ministry reserves the right to revoke the clearance if conditions stipulated are not implemented to the satisfaction. The Ministry may also impose additional environmental conditions or modify the existing ones, if necessary.	Noted
6	The environmental clearance accorded shall be valid for a period of 5 years from the date of issue of this letter to start operation of the power plant.	Noted
7	Concealing factual data or submission of false/fabricated data and failure to comply with any of the conditions mentioned above may result in withdrawal of this clearance and attract action under the provisions of Environment (Protection) Act, 1986.	Noted
8	In case of any deviation or alteration in the project proposed including coal transportation system from those submitted to this Ministry for clearance, a fresh reference should be made to the Ministry to assess the adequacy of the condition(s) imposed and to add additional environmental protection measures required, if any.	Noted
9	The above stipulations would be enforced among others under the water (prevention and Control of pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act,1981, the Environment (Protection) Act,1986 and rules there under, Hazardous Wastes (Management, Handling & Trans-boundary Movement) Rules, 2008 and its amendments, the public Liability Insurance Act, 1991 and its amendments.	Noted
10	Any appeal against this Environmental Clearance shall lie with the National Green Tribunal, if preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.	Noted

COMPLIANCE REPORT OF ADDITIONAL CONDITIONS *(EC Amendment Vide Letter Dated 22nd August 2019)*		
	MOEF & CC Stipulations	**NTPC Response**
A	**Specific Conditions:**	**Status as on 31.03.2023**
1	While commissioning the proposed project, the compliance of revised emission norms vide Notification dated 07.12.2015 for the parameters PM: 30 mg/Nm3; S02: 100 mg/Nm3; NOx: 100 mg/Nm3 and Hg: 0.03 mg/Nm3 shall be achieved along with specific water consumption as per the notification vide dated 28.06.2018. The FGD System, NOx control measures such as SCR/ SCNR/ DeNOx burners shall be installed to achieve the revised emission norms.	Compliance assured NTPC-Khargone ensures compliance to all standards as stipulated in the revised emission norms vide referred MOEF&CC Notification and its amendments thereafter. Particulate Matter (PM) emissions from boiler stacks being controlled within prescribed new emission norms (30 mg/Nm3) under referred notification dated 07.12.2015. FGD installation & commissioning for both units is in progress, for SO2 emission control. Further, Over Fire Air (OFA) combustion system also provided for NOx emission control. Specific water consumption being maintained within prescribed norms as per the referred MOEF&CC notification dated 28.06.2018 Whereas CPCB-Task Force vide his letter dtd. 13.12.2021, for the categorization of TPPs in line with MOEF&CC Notification dated 31/03/2021, has classified both units of NTPC-Khargone under Category-C. Accordingly, as per referred notification above revised emission norms compliance shall be ensured by Dec'2024 for Category-C power plants including NTPC-Khargone. Whereas, as per MOEF&CC Notification dtd.05.09.2022, SO2 emissions timeline for compliance (Non-retiring units) is extended up to Dec'2026 for Category-C TPPs includes both units for NTPC-Khargone.
2	The status of installation of FGD and De-NOx/SCR/SNCR control systems to comply with new emission norms for both units shall be submitted.	Complied assured For SO2 emission control, installation of FGD plant package already awarded to M/s L&T for both units. Erection, Commissioning works & trial are in progress. Status of installation of FGD control system is regularly submitted to the

		Regional Office of the MOEF&CC at every six months. For NOx emission control, Over Fire Air (OFA) combustion control system (air/fuel ratio optimization around the burner) is provided in both units. However, the matter for NOx emission compliance by TPPs commissioned after 2017 is under subjudice at Hon'ble Supreme Court. Please refer **Annexure-6** for FGD installation status report.
3	The detailed progress report of construction of proposed project shall be submitted to the Ministry and its Regional Office along with six monthly compliance report till both units are commissioned.	Complied Both unit#1 and unit#2 were commissioned and under commercial operation from 01/02/2020 & 04/04/2020 respectively.
4	As per the Revised Tariff Policy notified of Ministry of Power issued vide dated 28.01.2016, project proponent shall explore the use of treated sewage water from the Sewage Treatment Plant of Municipality/ local bodies/ similar organization located within 50 km radius of the proposed power project to minimize the water drawl from surface water bodies. The details of Sewage Treatment Plants located within 50 km radius along with the capacities shall be submitted.	Noted & Compliance assured
5	Daily quantity of (Average, minimum and maximum) fresh water withdrawn from Narmada River at Omkareshwar Dam for the plant purpose shall be submitted along with six monthly compliance report.	Noted & Compliance assured Please refer **Annexure-7** for Fresh water withdrawn data for the reporting period.
COMPLIANCE REPORT OF ADDITIONAL CONDITIONS *(EC Amendment Vide Letter Dated 22nd January 2022)*		
	MOEF & CC Stipulations	**NTPC Response**
A	**Specific Conditions:**	**Status as on 30.03.2023**
i	24x7 online Continuous monitoring system for ambient air quality parameters SOx, NOx and PM shall be established with connected server to CPCB and SPCB.	Complied Realtime Continuous Ambient Air Quality Monitoring Stations (CAAQMS) have been installed. Further, 24x7 online connectivity of the same also provided up to the MPPCB and CPCB.

ANNEXURE-1

Environment Monitoring Report

Industry: **NTPC Ltd. Khargone Super Thermal Power Project**
Period: **October'2022 to March'2023**
Laboratory **M/s Hubert Enviro Care Systems Pvt. Ltd**
(MOEF&CC Accredited and NABL Lab)

Stack Emission Monitoring Report

For the period of Oct'22-Mar'23

Stack attached to	Parameter	PM	SO2	NOx	Hg
	Unit	mg/Nm3	mg/Nm3	mg/Nm3	mg/Nm3
Unit-1	**Avg**	**21**	**1298**	**323**	**<0.01**
	Min	19	1286	287	<0.01
	Max	26	1423	397	<0.01
Unit-2	**Avg**	**21**	**1289**	**311**	**<0.01**
	Min	21	1206	301	<0.01
	Max	24	1394	375	<0.01

Ambient Air Monitoring Report

For the period of Oct'22-Mar'23

Location	Nr. Main Gate/Service Building				
Parameter	**S0x**	**NOx**	**PM10**	**PM2.5**	**CO**
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	**11.4**	**23.5**	**76.0**	**42.1**	**0.5**
Min	9.6	21.6	53.2	22.6	0.1
Max	12.5	24.6	87.4	50.3	0.9
Location	**Nr. DM Plant**				
Parameter	**S0x**	**NOx**	**PM10**	**PM2.5**	**CO**
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	**11.0**	**23.3**	**74.6**	**41.5**	**0.5**
Min	9.6	21.6	50.6	20.5	0.1
Max	13.8	26.1	89.1	51.3	0.9
Location	**At Township**				
Parameter	**S0x**	**NOx**	**PM10**	**PM2.5**	**CO**
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	**12.9**	**22.7**	**76.6**	**42.6**	**0.4**
Min	11.6	21.4	50.3	24.4	0.1
Max	14.6	25.4	83.4	48.5	0.8
Location	**At Selda Village**				
Parameter	**S0x**	**NOx**	**PM10**	**PM2.5**	**CO**
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	**12.5**	**23.0**	**75.5**	**37.6**	**0.4**
Min	10.6	20.5	51.2	18.5	0.1
Max	15.8	26.4	85.7	46.4	0.7

Surface Water Analysis Report

For the period of Oct'22-Mar'23

Parameter	Location	Vill.-Selda	Vill.-Dalchi	Vill.-Katora	Vill.-Jirbhar

PH	_	7.5	7.3	8.1	7.7
TDS	mg/L	439	794	165	363
TSS	mg/L	41.0	2	32	7
BOD	mg/L	2.0	3	<1	<1
COD	mg/L	16.0	24	8	12
O&G	mg/L	<4	<4	<4	<4
Chlorides	mg/L	54.4	99.0	27.4	49.5
Sulphates	mg/L	16.9	49.5	12.4	16.7
Ca	mg/L	68.1	152.3	32.1	52.1
Mg	mg/L	22.4	18.1	12.3	13.3
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ground Water Analysis Report					
For the period of Oct'22-Mar'23					
Parameter	**Location**	**Vill.-Dalchi (Nr. Ash Dyke)**	**Vill.-Selda**	**Vill.-Khedi**	**Vill.-Aarsi**
PH	_	7.7	7.8	7.4	7.5
TDS	mg/L	306	512	712	348
COD	mg/L	<4	<4	<4	<4
Chlorides	mg/L	27.2	59.4	143.5	49.5
Sulphates	mg/L	100.2	160.0	111.2	34.7
Ca	mg/L	34.1	96.2	140.3	52.1
Mg	mg/L	20.7	21.9	55.9	10.9
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ash Efflunet Water Analysis Report					
For the period of Oct'22-Mar'23					
Parameter	**Unit**	**Avg**	**Min**	**Max**	
PH		6.8	6.6	6.9	
TDS	mg/L	637	497	856	
TSS	mg/L	21.7	16.0	26.0	
As	mg/L	<0.005	<0.005	<0.005	
Hg	mg/L	<0.001	<0.001	<0.001	
Cr	mg/L	<0.01	<0.01	<0.01	
Pb	mg/L	<0.005	<0.005	<0.005	
Cd	mg/L	<0.01	<0.01	<0.01	

Bottom Ash Analysis Report-Heavy Metals		
For the period of Oct'22-Mar'23		
Parameter	**Unit**	**Result**
Pb	mg/L	<0.1
Cr-T	mg/L	0.017
Cu	mg/L	<0.1
Zn	mg/L	<0.1
Ni	mg/L	<0.1

As	mg/L	<0.005
Hg	mg/L	<0.1
Cd	mg/L	<0.01
Mg	mg/L	<0.1
Co	mg/L	<0.1

Coal Analysis Report-Heavy Metals		
For the period of Oct'22-Mar'23		
Parameter	**Unit**	**Result**
Cr-T	mg/kg	20.4
Cu	mg/kg	12.9
Zn	mg/kg	16.4
Ni	mg/kg	10.2
As	mg/kg	1.02
Hg	mg/kg	0.09
Co	mg/kg	0.54

ANNEXURE-2

Final Report

REVIEW OF HYDROGEOLOGY TO ASSESS IMPACT ON SURFACE WATER AND GROUND REGIME (ESPECIALLY AROUND ASH DYKE) AND PROPOSE SPECIFIC MITIGATION MEASURES FOR NTPC KHARGONE

Submitted to

NATIONAL THERMAL POWER CORPORATION LTD.
KHARGONE

by

NATIONAL INSTITUTE OF HYDROLOGY
(An ISO 9001:2015 Institute under DoWR, RD and GR, Ministry of Jal Shakti, Govt. of India)
ROORKEE – 247667 (UTTARAKHAND)

APRIL, 2023

REVIEW OF HYDROGEOLOGY TO ASSESS IMPACT ON SURFACE WATER AND GROUND REGIME (ESPECIALLY AROUND ASH DYKE) AND PROPOSE SPECIFIC MITIGATION MEASURES FOR NTPC KHARGONE

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The water level data, hydrogeological data and other data from CGWB and other agencies is also gratefully acknowledged.

The Principal Investigator is thankful to all the scientists and staff of NIH, who have directly or indirectly helped in completing the study.

(Suhas D. Khobragade)
Scientist G and Project Investigator

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

To undertake review of hydrogeology to assess the impact of operation of NTPC Khargone super thermal power plant, located near village Selda and Dalchi in Khargone district of Madhya Pradesh, on the surface water and ground regime, a study was awarded to the National Institute of Hydrology, Roorkee vide Purchase Order No. 4000268090-037-1019 dated 30.11.2021, with the objectives: (i) to assess and review the impact of Khargone STPS (2x660 MW) on soil, surface water and ground water regime (especially around ash dyke) and (ii) to suggest mitigation measures for remediation of surface water and ground water regime, if any. A detailed literature review has been carried out and presented. Reconnaissance survey of the study area was done during March, 2022 and field investigations were carried out during May 2022 for pre-monsoon and November, 2022 for post monsoon season. The field investigation included surface and ground water quality sampling, ground water levels monitoring, collection of soil samples, in-situ determination of latitude & longitudes for the various monitoring locations, construction of piezometers, and DGPS survey for determination of latitude, longitudes and elevations for the various drilled piezometer locations. Detailed analysis of the collected data has been carried out and discussed.

A significant variation in ground water levels at different stations has been observed in the present study due to variable recharge at these stations due to monsoon rainfall as well as due to variation in withdrawl of water at these stations. During the pre-monsoon season, the depth of water below the ground surface varied from 2.75 m to 43.10 m bgl. During the post monsoon season, the depth varied from 1.80 m to 26.44 m bgl. Further, it has been observed that while ground water is very close to ground surface in some areas it is very deep in some areas. Generally, areas which are located near to canals are seen to have shallow water tables while those away from any recharge structures are having deep water levels. The recharge from canal also acts as additional factor influencing the ground water levels. Analysis of ground water level variation carried out under the present study indicates that there is increase in groundwater level in post monsoon over the pre-monsoon for 13 out of 15 ground water level monitoring stations, for which the data of both the stations are available. For the remaining two stations there is a decline in water level. The average rise in water level per station is 4.83 m. The average ground water level during the pre-monsoon season, was 25.93 m during May 2016. During May 2022 the average pre-monsoon water level was observed to be 11.92 m. A comparison of the ground water flow direction during the pre-monsoon and post–monsoon indicates no variation in the flow direction during the two seasons. Ground water is observed to flow from Dabhad region to all the surrounding directions. Similar ground water flow direction for the study area was recorded by NIH during the hydro-geological study carried out earlier during 2015-16.

The various parameters of water quality including physical parameters, major ions and heavy metals have been determined for both the pre-monsoon and post monsoon seasons for surface and ground water. $Ca^{2+,}$ $Mg^{2+,}$ Na^{+}, K^{+}, and NH^{4+} are the major cations while F^{-}, Cl^{-}, HCO^{3-}, SO_4^{2-} NO_2^{-} NO_3^{-} and PO_4^{3-} are the dominant anions in the surface and ground water of the study area. Analysis brings out that during the pre-monsoon season water in most part

of the study area was moderately acidic. During the post-monsoon season it was found to be alkaline. Water quality parameters are generally found to be within the BIS permissible limits, and in many cases even within the acceptable limits of BIS, for most of the parameters and at most of the locations during both the pre and post monsoon season. At some locations however, some of the parameters are found to exceed the limits. The comparison of pre-monsoon and post monsoon data indicates a general improvement in many of the the water quality parameters for most of the locations in the study area indicating a dilution effect of monsoon rainfall recharge. However, an increase in concentration of some parameters at some locations is also observed. As far as the newly constructed piezometers around the ash dyke are concerned, while none of the piezometers exceeded the BIS permissible limits for calcium and magnesium, all the piezometers exceeded the acceptable BIS limit for calcium and one piezometer exceeded the limit for magnesium. Ammonium was not detected in 5 out of 6 piezometers. While none of the piezometers exceeded the acceptable limit for fluoride and chloride, two piezometers exceeded the acceptable BIS limit for sulphate, although it was within the permissible limit. Only one piezometer location was found to exceed the BIS acceptable limit for nitrate. Nitrite was not detected in five out of the six piezometers. Iron was found to exceed the limit in 4 out of 6 piezometers, copper in one piezometer and lead in 4 out of the 6 monitored piezometers. None of the other heavy metal was observed to exceed the BIS limit.

Comparison of the pre-monsoon data of 2016 and 2022 brings out that while some of the parameters show an increase, others vary in similar range while decline is observed in some parameters. Heavy metals in ground water in general indicate lower values in pre-monsoon of 2022 compared to pre-monsoon of 2016. As far as post monsoon data are concerned physical parameters and ions of surface waters are higher in 2022 compared to 2015. As far as water quality of ground waters during post monsoon is concerned, most physical parameters and ions show higher values during post monsoon of 2022 compared to post monsoon of 2015. But heavy metals in general show lower values in post monsoon of 2022 compared to post monsoon of 2015. This could be due to significant variation in rainfall during June to November during 2022 (2073 mm) than in 2015 912 mm), as such a high magnitude of rainfall can cause significant recharge and runoff consequently causing significant leaching to groundwater or runoff to surface water bodies. The various analysis carried out in the study brings out that there is no specific increasing trend in the water quality parameters of either the surface water or ground waters of the study area from 2015-16 to 2022. There are variations which could be due to various reasons such variable recharge during different years on account of variation in rainfall, variation in recharge at different locations within the same year, variation in amount of polluted substances reaching the surface and ground water bodies locally etc.

The study recommends that regular monitoring of the surface and ground water (particularly the newly constructed piezometers) for atleast about a decade or so, should be carried out so that changes in hydro-geology can be detected.

1.0 INTRODUCTION

Power development is one of the key infrastructural elements for the economic growth of the country. The National Electricity Policy has set up the goal of adding new generation capacity to not only eliminate energy and peaking shortages but also to have a spinning reserve of 5% in the system. NTPC plays a significant role in fulfilling the objectives of National Electrical Policy. NTPC is committed to generating power responsibly and sustainably. Besides fossil fuels, the company has diversified into producing energy through cleaner and greener sources such as hydro and solar energy.

The National Electricity Policy has set up the goal of adding new generation capacity not only to eliminate energy and peaking shortages but also to have a spinning reserve of 5% in the system. NTPC plays a significant role in fulfilling the objectives of National Electrical Policy. NTPC is committed to generating power responsibly and sustainably. NTPC is India's largest energy conglomerate. NTPC Limited, a Central public sector undertaking under the Ministry of Power, GOI, was set up in November 1975 with the objective of planning, promoting and organizing integrated development of thermal power in India.Since then, it has established itself as the dominant power major with presence in the entire value chain of the power generation business. From fossil fuels it has forayed into generating electricity via hydro, nuclear and renewable energy sources. This foray will play a major role in lowering its carbon footprint by reducing greenhouse gas emissions.

NTPC occupies premier position in the Indian energy sector in terms of size and efficiency. The total installed capacity of the company is 71,594 MW (including JVs). Its own stations include 33 coal based, 11 gas based, 1 Hydro, 1 Wind, 29 Solar and 1 Small hydro plant. Under JV, NTPC has 9 coal based, 4 gas based, 8 hydro based and 5 renewable energy projects. The capacity will have a diversified fuel mix and by 2032, non-fossil fuel-based generation capacity is expected to make up nearly 30% of NTPC's portfolio. NTPC has been operating its plants at high efficiency levels. As on 31.03.2020 the company had 16.78% of the total national capacity and, it contributes 20.96% of total power generation due to its focus on high efficiency. It aims to be the world's largest and best power major. NTPC became a Maharatna company in May 2010. As of January 2020, there are 10 Maharatna CPSEs in India. NTPC is ranked No. 2 Independent Power Producer (IPP) in Platts Top 250 Global Energy Company rankings. In 2019, NTPC was recognized as "Laureate" for consistently ranking among "Top 50 Best Companies to Work for in India" for last 11 years in the Great Place to Work and Economic Times survey. Besides, NTPC was also recognized as the best among PSUs and in Manufacturing.

To meet the power demand of States and UT of Western Region, NTPC has set up 1320 MW (2X660 MW) coal fired thermal power project based on super critical, once through boiler parameters, at village Selda in Khargone district, MP. The Environmental Clearance (EC) for the Khargone STTP was accorded by the Ministry of Environment, Forest and Climate Change (MoEF&CC) vide letter Ref. No. J-13012/54/2010-IA. II(T), dated 31/03/2015. Unit 1 (660 MW) was commissioned in September 2019 while Unit 2 (660 MW) began commercial operation in April 2020.

Thermal power projects consume large quantities of water for their operation, which is obtained from the surface water sources, which may affect the surface water hydrology

of the area. In addition, there are certain structures and activities which may affect the ground water hydrology also such as – dewatering during construction of the project, construction of water impoundment structure on streams to draw water, construction of raw water reservoir inside main plant area, construction and operation of ash dyke area etc. Therefore, assessment of the impact of construction and operation of the thermal power plants on the hydrogeology of the area and subsequently its regular review is very important.

As per specific, condition of the Environmental Clearance letter "*Hydrogeology of the area shall be reviewed annually from an institute/organization of repute to assess impact of surface water and ground regime (especially around ash dyke). In case and deterioration is observed specific mitigation measures shall be undertaken and reports/ data of water quality monitored regularly and maintained shall be submitted to the Regional Office of the Ministry".* Furthermore, monitoring of surface water quality shall be conducted regularly. Monitoring points shall be located between the plant and drainage in the direction of flow of ground water. Also, monitoring for heavy metals in ground water in the vicinity of plant shall also be undertaken and monitoring report shall be submitted to the ministry every six months.

In order to fulfil the requirements of MOEF&CC as well as NTPC's concern towards conservation of surface and ground water resources for the benefit of the project as well as general population, a study on hydro-geology of the area was awarded to National Institute of Hydrology (NIH), Roorkee vide LOA dated 29.06.2015. Further, during the operation phase of the project the study is to be reviewed annually from an institute/ organization of repute to assess impact of surface water and ground regime (especially around ash dyke). Accordingly, NTPC invited quotation from the National Institute of Hydrology, Roorkee and subsequently issued a Letter of Intent (LOI) to the National Institute of Hydrology, Roorkee vide Purchase Order No. 4000268090-037-1019 dated 30.11.2021 for a period of one year from for a total order value of INR 1,722,600.00 (Rupee Seventeen Lakh Twenty-Two Thousand Six Hundred Only) to undertake the study "Review of Hydrogeology to assess impact on surface water and ground regime (especially around ash dyke) and propose specific mitigation measures NTPC Khargone" (Annexure-I). The technical terms of reference and the scope of the consultancy are given below.

1.1 Objectives of the Study

The specific condition no. (xiii) under Environmental Clearance (EC) accorded by The Ministry of Environment, Forest and Climate Change (MoEF&CC) vide letter Ref. No. J-13012/54/2010-IA. II(T), dtd. 31/03/2015 stipulates, "Hydro geology of the area shall be reviewed annually through an institute/ organization of repute to assess impact of surface water and ground water (especially around ash dyke). In case, any deterioration is observed specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months."

In view of the above condition and need for assessment and review of Hydrogeology to assess impact of NTPC-Khargone on surface water and ground regime (especially around ash dyke), this study has been assigned with the following objectives:

i) To assess and review the impact of Khargone STPS (2x660 MW) on soil, surface water and ground water regime (especially around ash dyke).
ii) To suggest mitigation measures for remediation of surface water and ground water regime, if any.

1.2 Scope of the Study

To achieve the proposed objectives, following scope of work is included:

A) Literature Review

The consultant has to undertake a detailed literature search for the documents/ reports already available for the study area with various agencies such as Geological Survey of India, State Department of Geology and Mining, Central and State Water Boards, State Water Resources/ Irrigation departments, Central Water Commission, India Meteorological Department etc. Based on the review of the literature available, the consultant shall make a detailed plan for the study covering all the objectives identified above.

B) Field Studies

I. Hydrogeological investigations:

i) Preparation of groundwater flow direction map in Pre-monsoon and Post-monsoon periods.
ii) Analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO3, HCO3, Cl, SO4, NO3, F-, and PO4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) at 10 selected locations at surface, 30 cm and 60 cm depth.

II. Surface water quality monitoring around the Ash-pond:

i) Water quality parameters like pH, EC, DO, BOD, COD, Major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO3, HCO3, Cl, SO4, NO3, F-, and PO4 etc.) and Heavy etals (Cd, Zn, Hg, As, Cr, Pb etc.) during Pre and Post monsoon seasons at 16 locations (including water bodies i.e. streams and ponds especially near ash pond, water bodies within 10 Km, samples from ash ponds and raw water reservoir.

III. Groundwater monitoring network around the Ash-pond: (to check leachability from ash pond):

i) Design of the groundwater level and quality observation network.
ii) Construction of 06 piezometers around the ash pond and project area, particularly in the groundwater flow direction. Regular monitoring of ground water level shall be carried out in network of existing wells and constructed peizometers in the vicinity of ash pond. Water table monitoring and depletion status in and around the project area.
iii) Water quality parameters like, pH, EC, TDS, DO, Major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO3, HCO3, Cl, SO4, NO3, and PO4 etc.), heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) and isotope monitoring during Pre & Post monsoon

seasons at 16 locations (including 6 piezometers and 10 existing hand pumps and/or bore wells).

2.0 DESCRIPTION OF STUDY AREA

2.1 General

The Khargone ultra-supercritical thermal power project is a 1.32GW coal-fired power station constructed in the Khargone district of Madhya Pradesh, on a 526 ha-site near Selda and Dalchi villages. It is the country's first ultra-supercritical coal-fired unit built on engineering, procurement and construction (EPC) basis. The Khargone thermal power plant comprises two 660MW ultra-supercritical coal-fired units. The domestic coal for the plant is sourced from NTPC's captive coal block Pakri Barwadih in Jharkhand. Pakri Barwadih is the first captive coal mine of NTPC that commenced commercial production in April 2019.

Total quantum of land acquired for plant, ash dyke and township is 428.899 Hectares (1059.498 Acres) comprising of 317.19 Hectares (783.7904 Acres) private land and 111.709 Hectares (276.039 Acres) Govt. land and is in NTPC possession. In addition, land of about 115 Hectares (about 284 acres) has been acquired for makeup water pipeline corridor.

For the STPP water is needed for meeting the various requirements. The required water is proposed to be drawn from Omkareshwar dam of NHDC located on river Narmada, at a distance of about 45 Km from proposed site. The plant's water requirement is estimated to be 3,800m^3 an hour. Water is proposed to be drawn from Omkareshwar Dam (North East) constructed on river Narmada. Govt. of Madhya Pradesh vide letter dated 02.02.2010 have accorded commitment for 55 Cusecs of water from Narmada river for the project.

While developing the details of water system for the project utmost care has been taken to minimize water requirement as well as effluent generation. Main features of the water system shall include: (i) Re-circulating type C.W. system with cooling towers / Open System complying with MOEF requirements. (ii) In case of Cooling Towers, utilization of Cooling Tower blow down for Coal dust suppression and extraction system, Service water system, Ash handling and Firefighting. (iii) Recycle and reuse of effluents from coal dust suppression and extraction system and service water system. (iv) Ash water recirculation system, and (v) Recirculation of filter backwash to clarifier inlet. An effluent management scheme, consisting of collection, treatment, recirculation and disposal of effluents has been implemented in order to optimize the makeup water requirement as well as liquid effluent generation.

2.2 Location and Extent

The project site is located near village Selda and Dalchi in Khargone district of Madhya Pradesh. The Khargone district is surrounded by the districts of Dhar, Indore and Dewas in the North, state of Maharashtra in the South, Khandwa, Burhanpur in the East and Barwani in the West. The project site is located at a distance of about 105 Kms from

Indore, about 30 Kms from Sanawad town and 42 km from Barwah. It is at a distance of about 15 kms from Bedia (on Sanawad-Khargone Road). The Khargone city is about 40 kms from the project site. The site is approachable from Sanawad on Indore – Khandwa State Highway through PWD road. The nearest Railway Station is Sanawad on Indore – Khandwa meter gauge section which is about 32 Kms. Khandwa is on the main line of Central Railway on Mumbai-Itarsi section. The nearest airport at Indore is located at about 105 Kms from the site. Narmada River is passing at about 15 Kms (North) from the project site.

The geographical extent of study area consists of an area within 10 km from the periphery of the project components (Main plant, Ash pond area & Township). In addition, the source of water and location of intake point, type of intake structures (barrage, dam, intake well, intake channel etc.) is to be covered for the study, even if located beyond 10 Km and significant for identification of the impact due to NTPC Khargone. Further, any significant surface or ground water body located within 10-15 Km which is likely to influence the project/ get influenced from the project isl also to be covered.

Figure 1 presents the vicinity map of the NTPC Khargone STPP while the location map of the project is presented in ***Figure 2***. ***Figure 3*** presents the lay out map of the NTPC Khargone plant area while ***Figure 4*** presents a view of the NTPC Khargone power plant

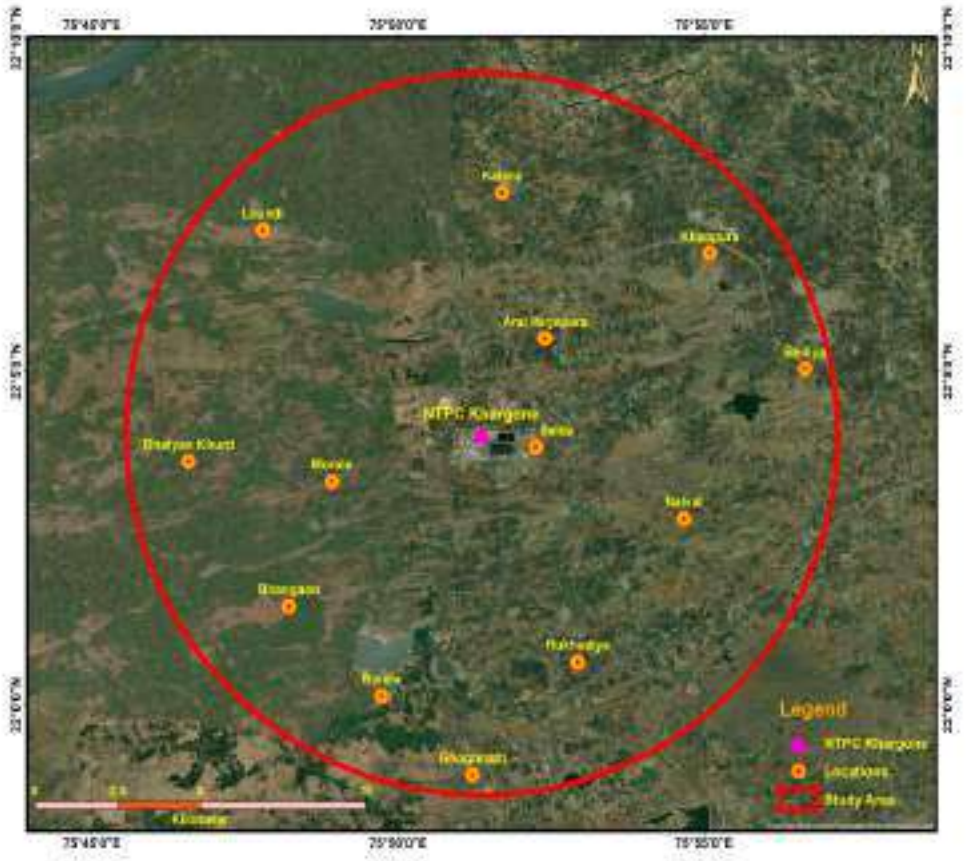


Figure 1: Vicinity map of the NTPC Khargone STPP

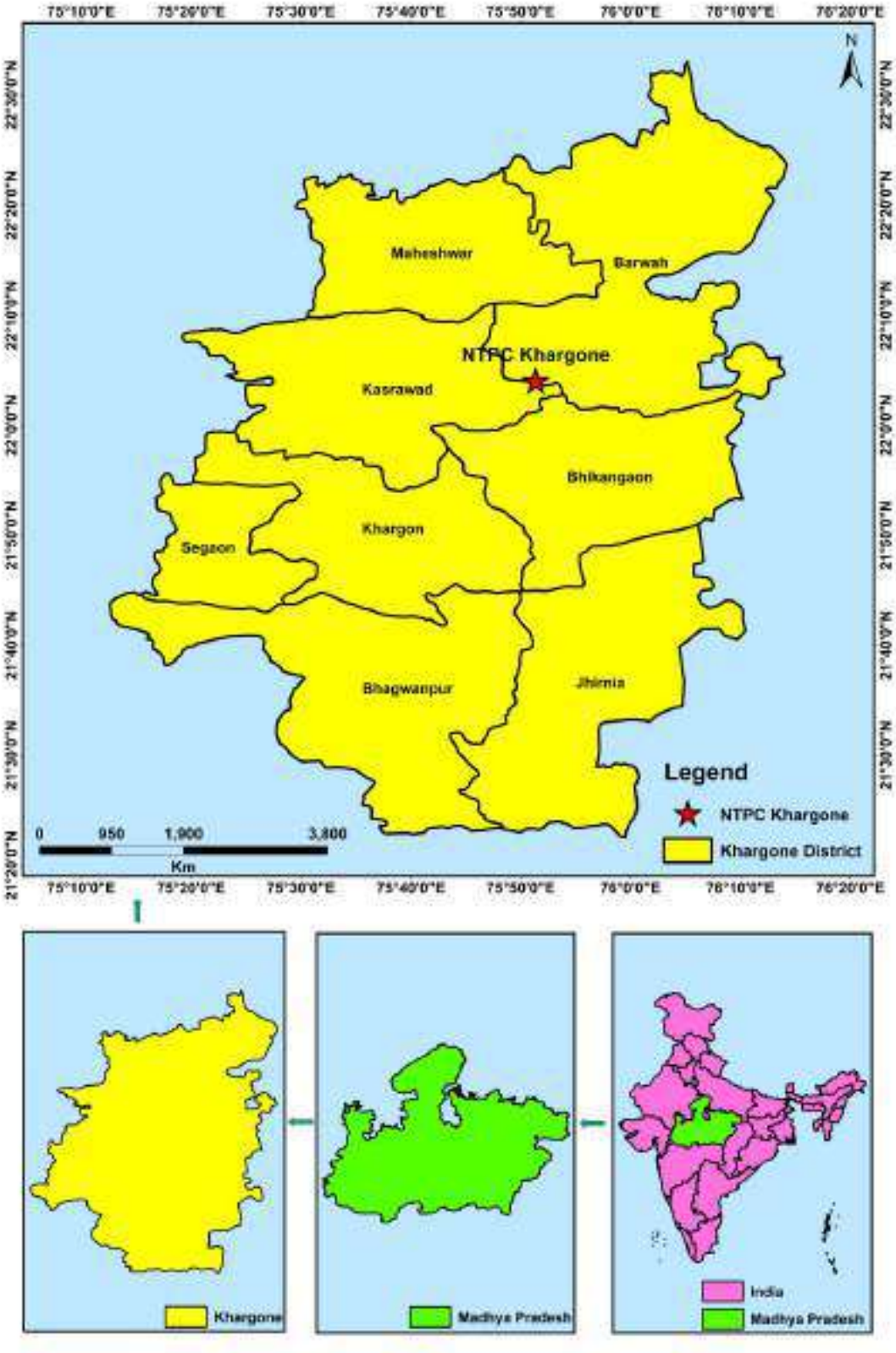


Figure 2: Location Map of NTPC Khargone STPP

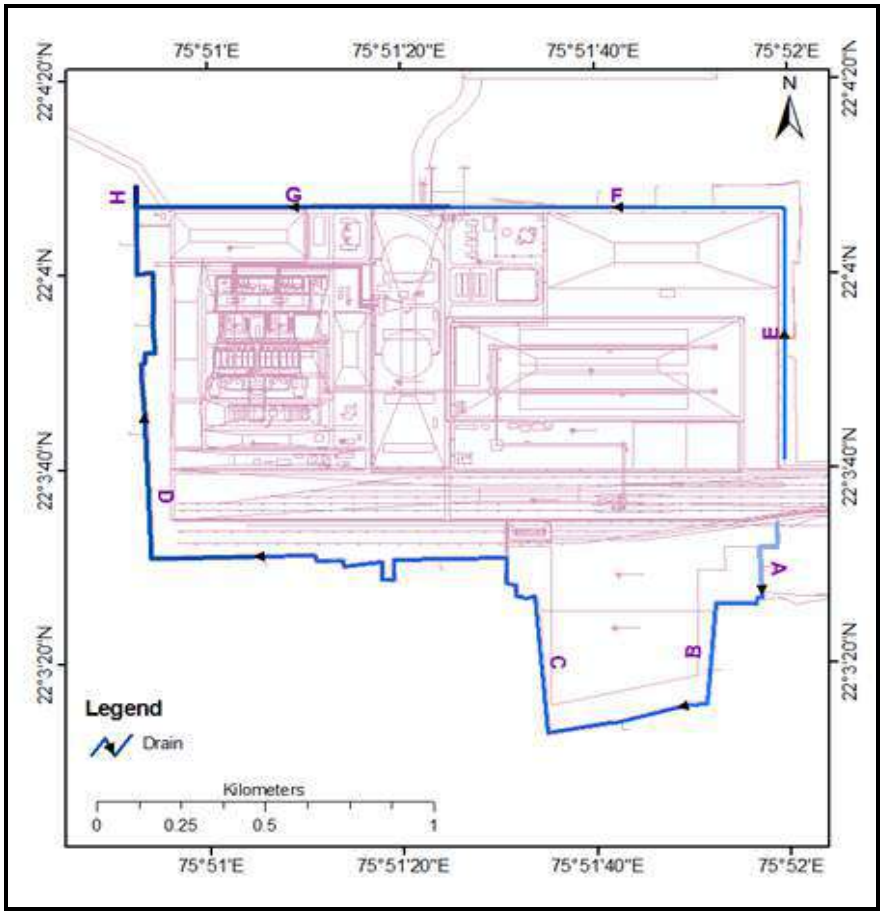


Figure 3: Lay out map of the NTPC Khargone plant area

Figure 4: A view of the NTPC Khargone power plant

2.3 Geomorphology and Physiography

Khargone is in the middle of the Narmada River valley with the Vindhyachal mountain range situated in the north and Satpura in the south. The River Narmada flows along a path of 50 kilometres inside the district. Veda and Kunda are the other two main rivers in the district. According to the CGWB (2013) report "The district exhibits varied geomorphic units, the presence of fluvial units showing the occurrences of alluvium in the flood plains of all major stream and rivers, buried Pedi plains showing denudational hills as seen in the north western parts of the district. Similarly, structural hogbacks and Cuesta belonging to vindhyan meta sedimentary, are restricted to northern boundary of the district. Basaltic uplands form lower belt that extends from west to east in the southern parts of the district. This upland tract also forms major forests in the district." Geomorphologic maps of Khargone district are presented in ***Figure 5 and 6***.

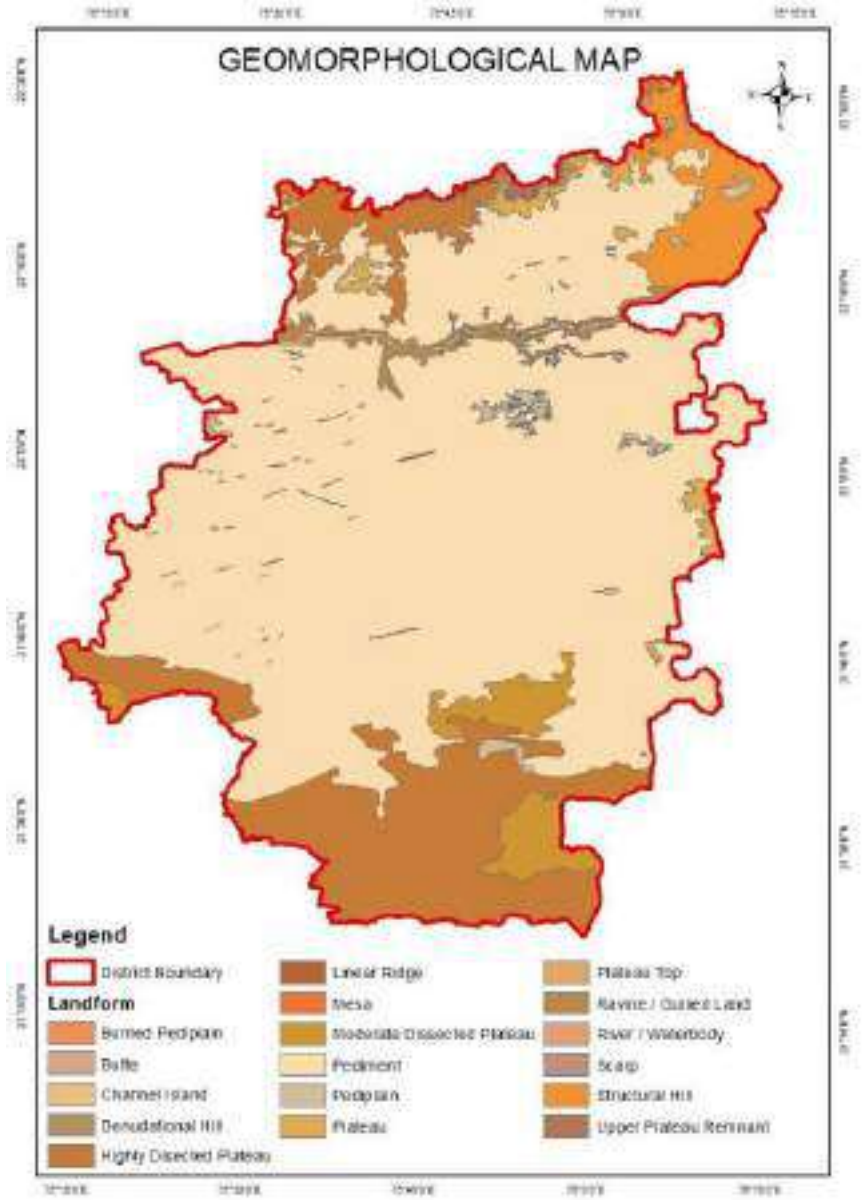


Figure 5: Geomorphologic map of Khargone district (Source: District Survey Report of Mining Department for Khargone district)

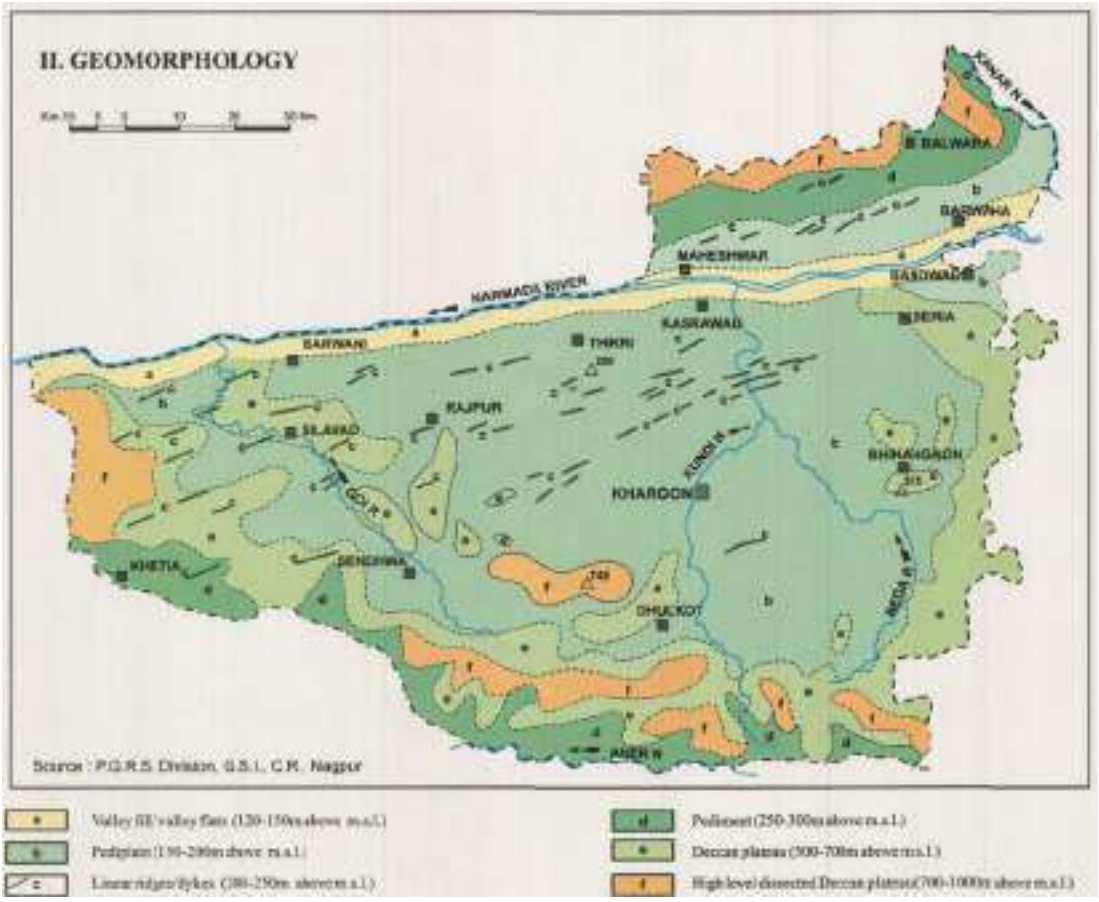


Figure 6: Geomorphologic map of Khargone district and surrounding area (Source: GSI)

As far as the study area is concerned, topography of the area is fairly undulating. Major land forms present in the area are basaltic uplands of Deccan plateau with minor lineaments. Columnar, jointing and compact basalt are present in the area.

Figure 7 presents the Digital Elevation Model (DEM) of the study area (10 km radius buffer zone). The DEM has been prepared with ARC GIS 10.3 software using the satellite data (ASTER DEM 30m). The data have been downloaded from Earth Explorer website. (https://earthexplorer.usgs.gov/). The general slope of the area is towards north-northwest. The general gradient of the plant area is south east to north west direction. The maximum and minimum elevations ranges in between 159 and 312 m amsl. ***Figure 8*** presents the DEM of the project area. The general gradient of the area is towards NNW. The maximum and minimum elevation ranges between 227 and 260 m amsl

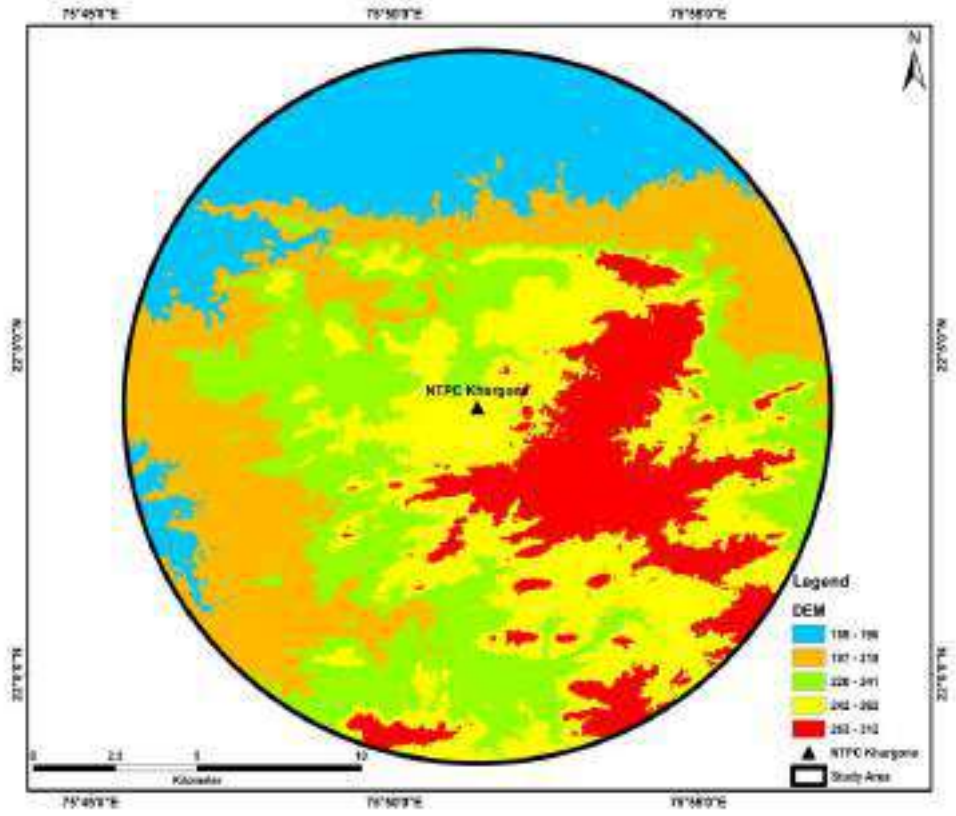


Figure 7: Digital Elevation Model (DEM) of the study area covering 10 km radius from the plant site

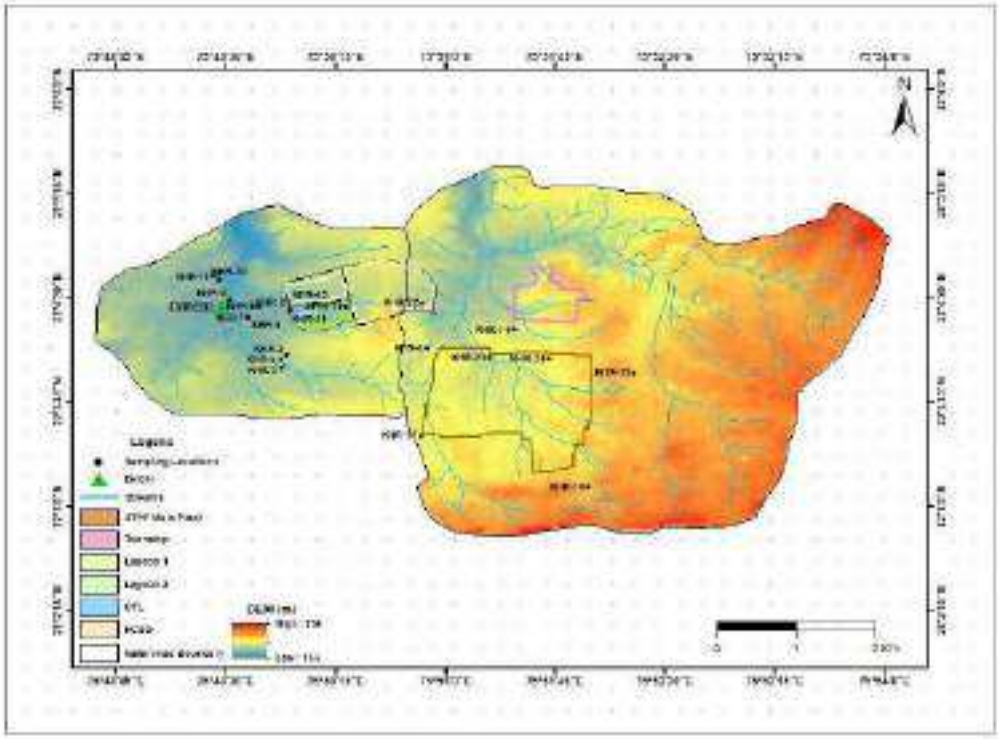


Figure 8: Digital Elevation Model (DEM) of the project area
(Source: NIH Report, 2020)

2.4 Soils and Vegetation

Generally, there are five types of soils namely Kali I, (0-1 mbgl) and Kali II (1-2 mbgl) (2-3 mbgl) Halkikhardri and Bardi in the district. These soils are classified as medium black cotton soils containing 50% silt and clay to gather. Alluvial type of soils is found on both the sides of the river Narmada and in some patches along its tributaries. The project area is covered by black to brown soil having a thickness of about 0.20 to 1.50 metres which is underlain by fractured basalts of rocks belonging to Deccan Traps. Most part of the surrounding area of project is covered by agricultural land, supporting single to multi–crop pattern, and barren land. The study area has sparse vegetation mainly open scrub type. The area near project site is surrounded by various kinds of trees, herbs, shrubs, climbers and grasses.

2.5 Drainage

Drainage map of Khargone district is shown in ***Figure 9.*** The main drainage is formed by Narmada River and various small nalas and rivulets that joins to Narmada. The Tapti drainage system extends in a limited area along the southern boundary of the district. About 88% of the district lies in Narmada Basin and 12% in Tapti Basin. Major tributaries of Narmada namely Deb and Goi flow in the district. All of these tributaries flow from south to north and join Narmada River. Similarly, tributaries like Tori, Churi, Dudhikheda etc. flow from north to south. Major rivers are perennial to semi-perennial in nature. No major tributary of Tapti flows in the district. The surface water availability at 75% dependability for both the Basins is 966.70 MCM of which 921.95 MCM is from Narmada Basin and 44.75 MCM from Tapti Basin.

Drainage map of the study area covering 10 km radius from the plant site has been prepared using Arc GIS 10.0 and is shown in ***Figure 10.*** Drainage pattern of the project area in general is dendritic in nature. Streams up to 5th order are identified in the area. The area is mainly drained by Vamsali and Amba River which is a tributary of Narmada River flowing about 11.50 km in North direction from the project area. There are a few scattered water bodies (lakes and ponds) in the study area, most of which (except probably the Jhirbhar talab) appear to be insignificant from the usage point of view.

The NTPC plant is located towards the eastern side of its watersheds and the ash dyke is located towards the west. The problem of waterlogging has been reported in the western side of the watershed.

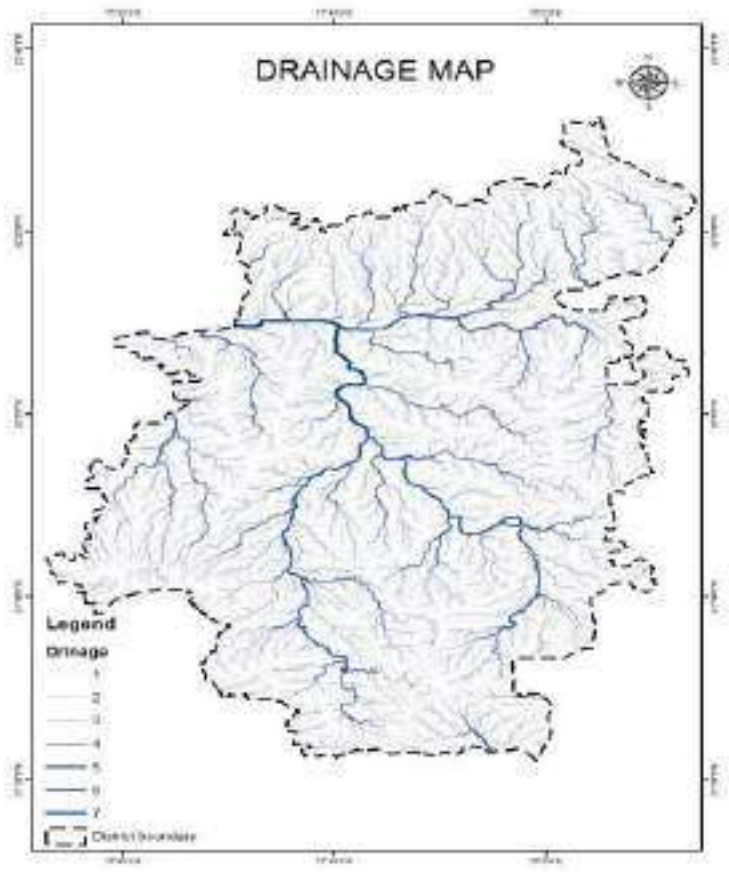


Figure 9: Drainage map of Khargone district

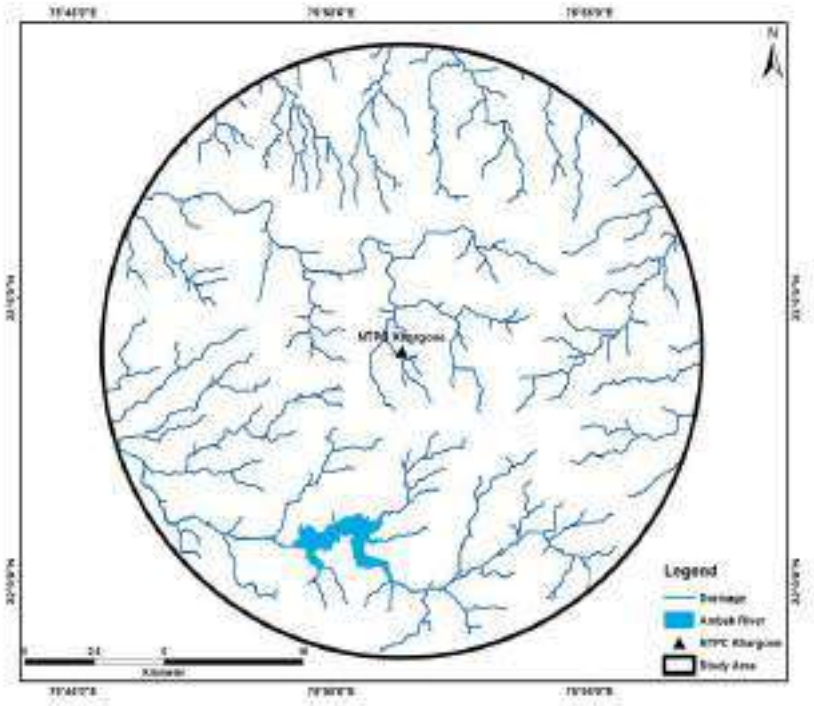


Figure 10: Drainage map of the study area covering 10 km radius form the plant area

2.6 Geology and Hydro-Geology

Figure 11 presents the geological map of Khargone district. ***Table 1*** provides the geological succession of the district.

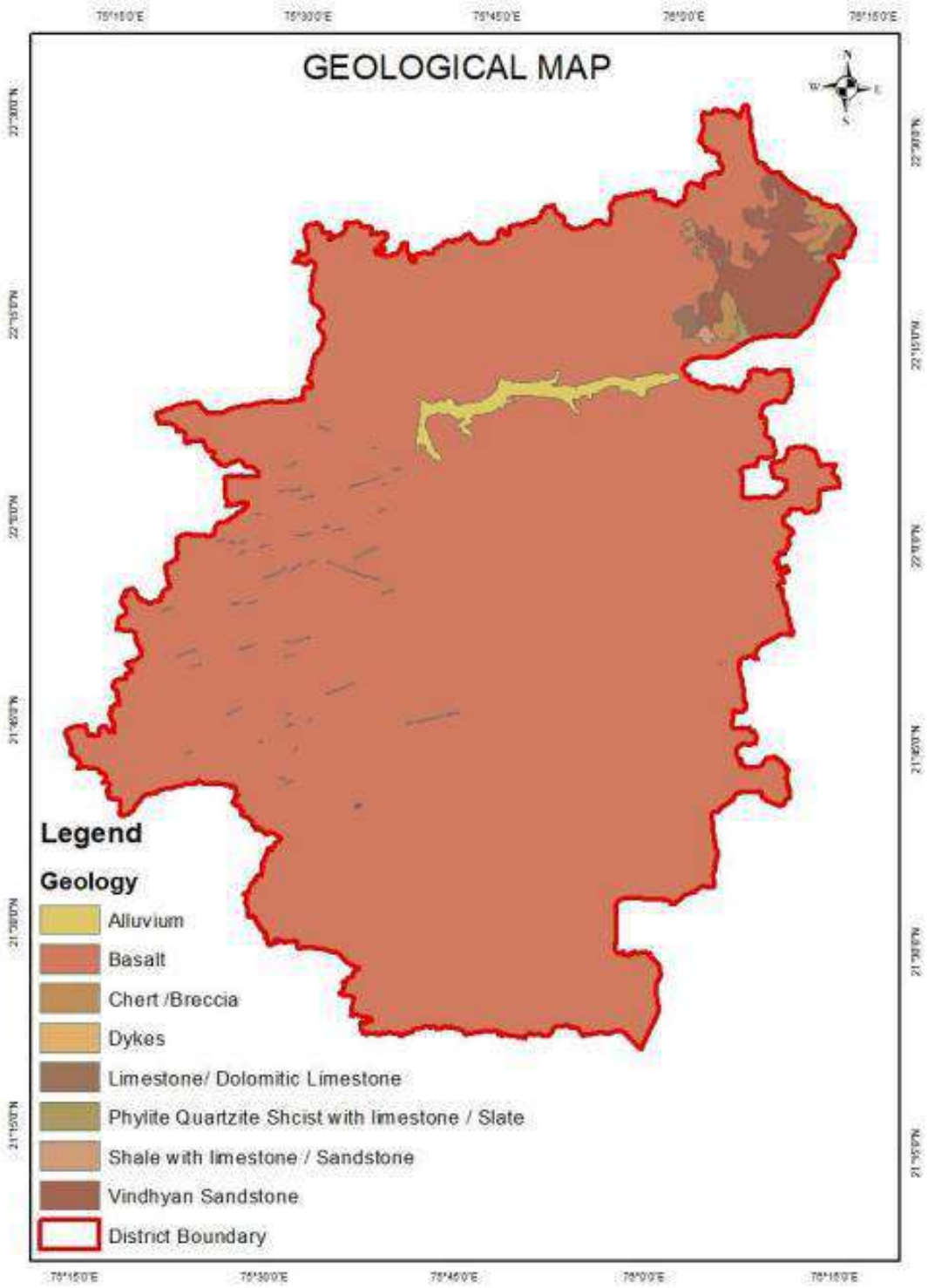


Figure 11: Geological map of Khargone district (Source: District Survey Report of Mining Dept. for Khargone)

Table 1: Geological succession of Khargone district

Age	Geological Formation	Extent (in%)
Recent	Alluvium	10%
Pleistocene to recent	laterite	
Upper cretaceous to Eocene	Deccan traps and inter trappean beds	85%
Upper cretaceous	Lameta and Bagh beds	5%
Late Precambrian to early Paleozoic	Vindhyan Sandstone & Shales	
Archeans	Bijawar Series Granites & Gneisses	

Khargone district is underlain mainly by Basaltic lava flows of Deccan trap. Archaen granite and gneisses form phreatic aquifers wherever jointed or weathered. In general, this aquifer has a poor potential. Bagh beds forms phereatic as well as confined condition at the contact with Deccan trap. They form good potential aquifers system in phreatic as well as in confined condition.

The bore wells drilled by CGWB, reveal that basaltic aquifers have depth range from 20.00 to 160.00 mbgl, and a yield potential of 24 to 70 m3/day. The transmissivity ranges from 15 to 350 m3/day. In Bagh beds, potential zones form at depth 52-54 mbgl & 67-86 mbgl, yield potential is 180-245 lpm, transmissivity is 108 m3/day and storage coefficient is 1.99x10-3. In Deccan trap deeper aquifers potential depends on the intensity of fracture and its areal extent. It ranges from 5 lps to as high as 800 lpm, with the transmissivity characteristics of the confined aquifers ranging from 2 m^2/day to as high as 312 m^2/day (CGWB, 2013).

As far as study area is concerned, basaltic flows of Deccan Trap occupy the entire project area of Dalchi and Selda Village. The basaltic lava flows are of compound pahoehoe type. The thickness of individual units is 12 to 35mts. All the flows are nearly horizontally disposed. The rock is fine to medium grained, aphyric to sparsely /moderately porphyritic and mega porphyritic in nature. The basalts are Black to Grey, Greenish in colour and are medium grained, moderately porphyritic, hard compact rocks, which are mainly used for road construction purposes. The porosity and permeability of these basalts is very low. The northern eastern and north-western part of the watershed is covered by moderately porphyritic basalts, which are not suitable for percolation.

Aquifer characteristics of the aquifer in the study area have been evaluated by NIH during its previous study by carrying out the pump test in the Ash Pond Area of the project site. For conducting the pump teat pumping well was drilled. The discharge from the pump was measured to be 6 m^3/hr. The pumping was conducted for a period of 1 hr. The drawdown and recovery in pumping well was recorded at an interval of 10 sec. The average transmissivity of the aquifer is 6.55 m^2/d and the storage coefficient as 3.61 x 10^{-2}. The pump test data shows that the aquifers in the ash pond area of Khargone STPP are poor aquifers with poor transmissivity and storage coefficient.

Figure 12 presents the hydro-geological map of Khargone district.

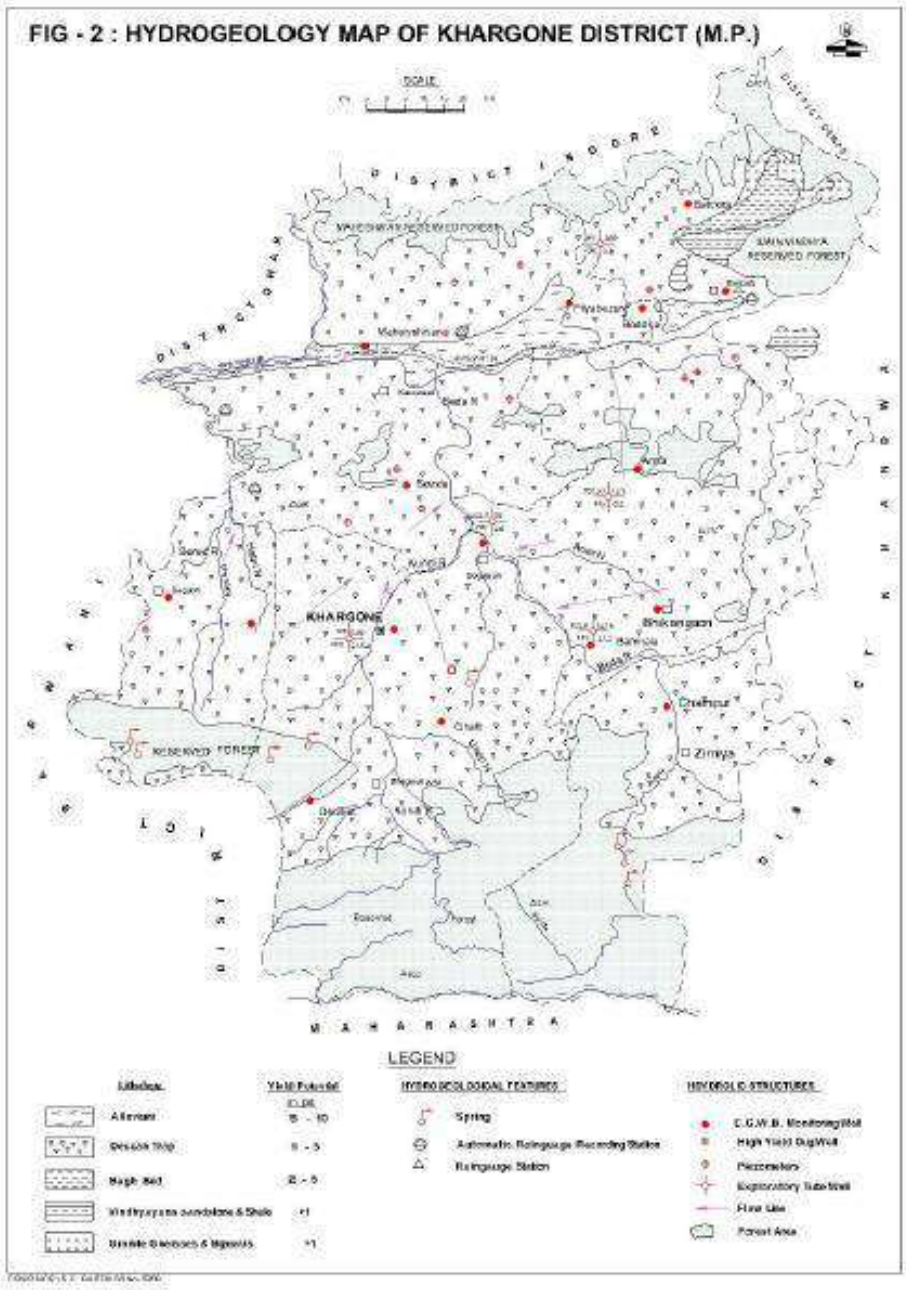


Figure 12: Hydro-geological map of Khargone district

2.7 Climate

Khargone district has a transitional climate between a tropical wet and dry climate and a humid subtropical climate. The climate of the area can be divided into four seasons. The cold season in December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the southwest monsoon season. October and November form the post monsoon or transition period. Summers (mid-March to mid-June) are extremely hot and dry in this region with temperatures usually above 40 °C during April–May. The temperature also remains quite high during the night. The normal maximum temperature received during

the month of May is 41.8^0 C and minimum is 11.1^0 C during the month of December. The normal annual mean maximum and minimum temperature of Khargone district is 34°C and 19.6 °C respectively.

As per IMD, normal annual rainfall of Khargone district is 758.5 mm. The maximum rainfall received during southwest monsoon period i.e. June to September about 92.8% of the annual rainfall received during monsoon season. Only 7.2% of the annual rainfall takes place from October to May period. The rainfall during four monsoon months of June to September has an average value of 134.3 mm, 252.1 mm, 214.7 mm and 150.6 mm respectively. The maximum annual rainfall recorded for Jirbhar is 1734.6 mm in the year 2003-04 with 363 mm occurring in 1 day. During the southwest monsoon season, the relative humidity generally exceeds 85% (August month). Rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less 34%. April is the driest month of the year. The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity of 9.0 km/hr is observed during the month of June and minimum of 2.5 km/hr during the month of December. The average normal wind velocity of Khargone district is 4.9 km./hr.

2.8 Land Use Land Cover

The land use land classification map of the study area prepared (during the previous study) from the satellite data (Landsat) using ARC GIS 10.3 software indicates that agriculture is the predominant land use in the study area. Broadly, the various land uses have been grouped under five categories namely, settlement (2.3%), waterbodies (3.6%), vegetation (27.7%), barren land (4.8%) and agricultural land (51.6%).

3.0 LITERATURE SURVEY

Various reports related to the study area have been collected from the NTPC Khargone and other related agencies, as well as from the internet. These have been reviewed. A brief review of the available literature is presented in this section.

CGWB (2013) has provided aquifer map of the state of Madhya Pradesh. It is shown in ***Figure 13***. From the ***Figure 13*** it is clear that the aquifer system in Khargone district is Basalt.

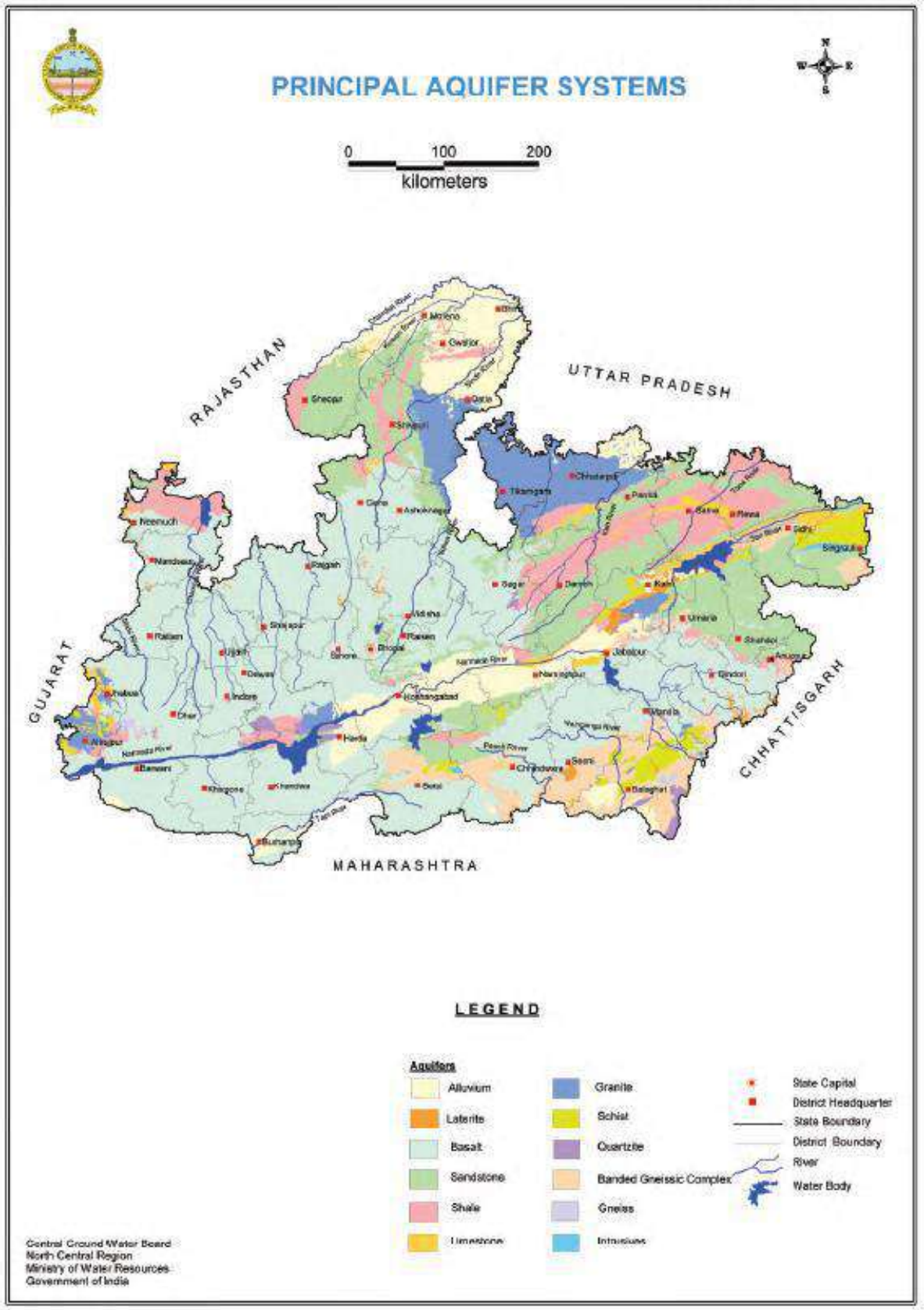


Figure 13: Aquifer map of the state of Madhya Pradesh

Central Pollution Control Board (2011) has reported the water quality of all major rivers of India. and their tributaries including river Narmada. As per the report "the State Pollution Control Boards of Madhya Pradesh and Gujarat are doing the water quality monitoring of the River Narmada at 21 locations and its tributary streams Chota Tawa, Gour, Katni and Kunda at one location each. The water quality of mainstream of Narmada with respect to pH ranges from 7.2- 8.5. The conductivity ranges from 194-727 µmhos/cm. The DO varies from 4.8- 11 mg/l. The BOD ranges from 0.2- 5.4 mg/l and is not meeting the criteria at Hoshangabad U/s (5.4), Hoshangabad D/s (5.2), Sethanighat (4.6), Korighat, Hoshangabad (3.8) and Nemawar (3.7) that indicates about the moderately polluted river. The Total Coliform count in the river ranges from 4-11000 MPN/100ml and is observed highest at Garudeshwar, whereas the Faecal Coliform count varies from Nil-4600 MPN/100ml and is observed highest at Garudeshwar and Panetha. The water quality of River Narmada is broadly meeting the criteria for beneficial uses.

CGWB (2013) has discussed the variation of ground water levels. The variations for the years 2012 are presented in ***Figure 14.*** The water level ranged from 4.20 mbgl to 12.70 mbgl during pre-monsoon (May 2012). In major part of the district depth to water level was in the range of 8 to 12 mbgl during the pre-monsoon season. During post monsoon period (November 2012) water level ranged from 1.90 mbgl to 11.70 mbgl. In major part of the district, water level was between 5 to 10 m during the post monsoon season.

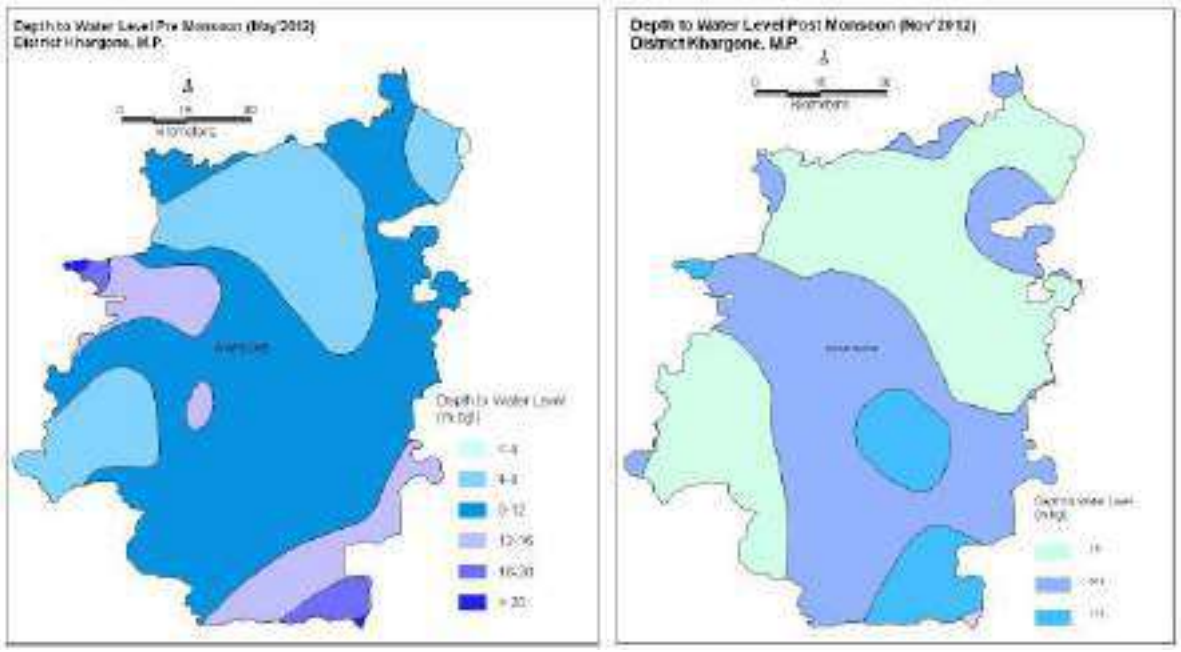


Figure 14: Water level variation in Khargone district during pre and post monsoon of 2012

As per the CGWB (2013) report "analyses of long term groundwater level data of pre-monsoon period by CGWB indicates that there is a rise as well as decline in water level in the district. In general, rise in water level was in the range of 0.01 to 26.02 cm/year whereas decline was in the range of 3.49 to 12.39 cm/yr"

CGWB (2013) has also reported the ground water quality for the Khargone district on the basis of water samples collected from the district. Groundwater in the district was observed to be generally fresh to saline as electric conductivity values varied between 260 to 4150 µs/cm at 25° C. Fluoride in the district ranged from 0.01 to 0.89 mg/l and the nitrate concentration ranged from 1.2 to 620 mg/l.

Detailed geophysical investigations of the project area of NTPC Khargone and the surrounding area were carried out by M/s Rajmi Geoexploration & Eng. Pvt Limited, Indore for NTPC Khargone. Based on field data and well inventoried, depth to water level of pre-monsoon period of the area was found in the range of 8.5 m to 15.0 m. below ground level (mbgl) in the dug wells. The average depth to water level during pre-monsoon period was 9.5 mbgl. In bore wells the depth to water level was found to be in the range of 18 to 42 mbgl. The average depth of depth to water level in bore wells was 36.0 mbgl. Depth to water level of post-monsoon period of the area was found in the range of 1.5 m to 5.8 mbgl. The average depth to water level during post monsoon period was 3.15 mbgl. In the bore wells the depth to water level ranged between 11 to 15 mbgl. The average depth to water level in the bore wells was 12.8 mbgl. The fluctuation in groundwater levels was interpretated to be mainly due to withdrawal, recharge and movement of groundwater. The average seasonal water level fluctuation in the area was 4.50 m and in the bore wells the average fluctuation was 18.00 m.

Geophysical investigations based on vertical electrical soundings were carried out by M/s Rajmi Geoexploration & Eng. Pvt Limited, Indore for NTPC Khargone to know the depth and thickness of water bearing zone at the Township of Khargone Super Thermal Power Project. The expected yield of the tube wells was observed to vary between 3000 to 5000 lph.

Geo-hydrological investigations in and around NTPC project in Selda and Dalchi villages of Khargone district were carried out by M/s Rajmi Geoexploration & Eng. Pvt Limited, Indore for NTPC Khargone during 2014-15. The major findings of the study were:

i) The climate of the area is semi-arid, the minimum and maximum temperature of the area is 9.5^0C and 42.75^0 C respectively. Average annual rainfall of the Khargone rain gauge station is 770.0 mm.

ii) Geologically the area comprises of basalts, black to gray, greenish in color and are medium grained, moderately porphyritic, hard compact rocks which are mainly used for road metal purposes. The porosity and permeability of these basalts is very low. The northern eastern and north western part of the project area is covered by moderately porphyritic basalts, which are not suitable for percolation. Being massive rocks exposed on ground surface runoff in the entire project area will be more.

iii) Recharge through recharge shaft and pond will be effective in the project area as the weathered rocks are exposed on ground surface.

iv) Weathered, fractured and jointed basalts are the main hydrological units of the area. The brownish vesicular basalt with flow contact is more productive than grey basalt.

v) Three potential aquifer are exiting in the study area. First aquifer (6-12 m bgl), second aquifer (30 to 50 m bgl), third aquifer (75-95 m bgl), Fourth aquifer (165 to 180 m bgl) and 210 to 240 m bgl.

Area drainage study of the NTPC Khargone area was carried out by NIH, Roorkee for NTPC Khargone during 2011-12 using data of 4 rainfall stations. The 1-day annual maximum rainfall for various return period were estimated for the four rainfall stations of Kasrawad, Maheshwar, Mortaka and Jhirbhar. It was observed that Jirbhar station is very close to study area and has maximum rainfall value among the four stations. Hence, 1-day annual maximum rainfall at Jirbhar station for various return periods were used for design flood estimation and drain design. The 1-day annual maximum rainfall at Jirbhar for 25, 50 and 100 year return period area 39.17 cm, 46.22 cm and 53.41 cm respectively. The regional rainfall estimated by using rainfall data of four raingauges are 27.42 cm, 31.5 cm and 35.77 cm respectively for 25, 50 and 100 year return period respectively

Geological Society of India (GSI) has provided a Geo-hydrological map of Khargone district and surrounding areas of the district in its district resource map for Khargone district. It is shown in ***Figure 15***. As per the map, the depth of water level around the NTPC Khargone area varies form 3-9 m. The year of data is not mentioned. Nor it is mentioned whether the data is for pre-monsoon or post monsoon.

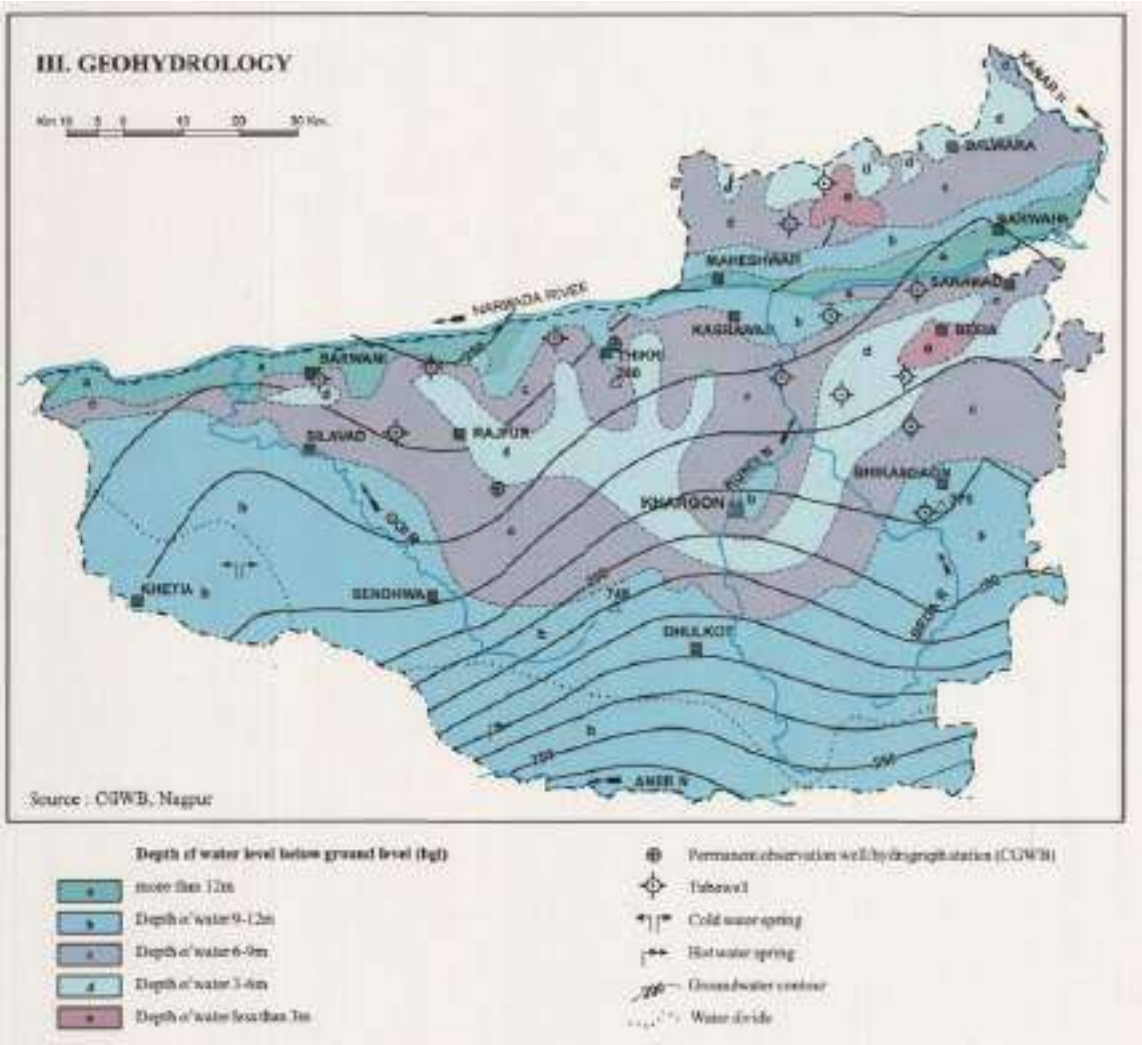


Figure 15: Geo-hydrological map of Khargone district and surrounding areas (Source: GSI)

Mining Department has prepared a District Survey Report which is available online. The report has been prepared in pursuance to the Gazette Notification, Ministry of Environment, Forest and Climate Change (MoEF& CC), Notification No S.O. 141 (E) Appendix– X, Dated 15.01.2016 & S.O. 3611 (E) New Delhi, 25th July 2018 for preparation of District Survey Report of sand mining or river bed mining. The report provides a soil map of the Khargone district which is shown in ***Figure 16.*** Unfortunately, the legend of the map is illegible. The report also discusses the ground water conditions of the district. According to the report "During pre-monsoon period in the water level ranges from 4.20 mbgl to 12.70 mbgl during pre-monsoon. In major part of the district depth to water level is in the range of 8 to 12 mbgl. During the post monsoon period, water level ranges from 1.90 mbgl to 11.70 mbgl.In major part of the district, water level is between 5 to 10m. The long term water level trend (pre monsoon 2003-2012) indicates that there is rise as well as decline in water level in the district. In general, rise in water level is in the range of 0.01 to 26.02 cm/year whereas decline is in the range of 3.49 to 12.39 cm/yr". Although source of data is not quoted in the report, it appears that the data pertain to CGWB.

(Source: NBSS&LUP, Amravati Road, Nagpur)

Figure 16: Soil map of Khargone district

Environmental impact assessment studies have been carried out by NTPC Khargone for its Khargone STTP. Under this study, to assess the water quality of the study area, three surface water locations and three ground water locations were selected and samples were drawn and analyzed on monthly basis during the study period. Analysis of all

ground water samples revealed that the water quality conforms to the IS: 10500. The observed data are shown in ***Table 2.***

Table 2: Reported water quality of surface and ground waters in the study area
(Source: EIA Report, NTPC Khargone)

S.NO	MAIN PARAMETERS	UNITS	IS:10500	MIN-MAX LEVEL OBSERVED DURING THE STUDY PERIOD
	Surface water quality	**IS-2296**		
1	pH		6.5-8.5	7.28-7.52
2.	Total Dissolved solids	mg/l	500	83-309
3.	Total Hardness	mg/l	300	56 -156
4.	B.O.D	mg/l	-	BDL - 5
	Ground water Quality		**IS-10500**	
1	pH		6.5-8.5	6.93-7.65
2.	Total Dissolved solids	mg/l	500	430-602
3.	Total Hardness	mg/l	300	184-364
4.	B.O.D	mg/l	-	2.0-3.2

Under the EIA study, to assess the soil quality, soil samples from ten different locations were collected and analyzed in the laboratory. The soil in the study area was found to be grey and brown in colour with pH varying from 7.37 to 8.12. The EC was observed in the range of 83.8 to 284.39 µs/cm. Nitrogen content and phosphorous content in the soil was found to be in the range of 293.0 to 381.72 kg /ha and 4.12 to 36.1 kg/ha respectively. The impacts of the STTP on soil and water quality was also studied and it was observed that the impact on soil during construction phase shall be mainly due to loss of top soil in the construction areas and contamination of the soil of surrounding area due to construction materials such as cement, sand, oils etc. It was, however, pointed out that such disturbances will remain confined to the area of activity and will be temporary in nature. It was suggested that appropriate soil conservation measures associated with improved construction techniques would minimize such impacts. The impact on the soil during operation of the project could result due to deposition of residual particulate matter and gaseous emissions. The impact on the soil due to operation of the power plant and gaseous emissions would be negligible. However, it was informed that periodic monitoring of soil will be undertaken at the maximum impact zone of the pollutants mentioned above. The impact on water quality during construction phase will be mainly due to run off from the construction area. It was suggested that adequate arrangements for proper drainage and disposal of waste water and routing of the effluents from construction area through sedimentation basins and provision of proper sanitary facilities with treatment will eliminate problems of water pollution during construction phase. The impacts of the project during operation phase could result from discharge of hot cooling water, discharge of main plant effluents and sanitary effluents and discharge of ash pond overflow. These effluents will be treated adequately to conform to the regulatory standards to minimize the impacts.

Hydro-geological study of the study area covering 10 kms radius from the NTPC Khargone plant was conducted by the National Institute of Hydrology, Roorkee during 2015-2017. Various aspects were studied which include analysis of source water

sustainability, hydro-geology of the study area including variation in ground water levels and direction of ground water flow, infiltration characteristics of the study area, pumping test and aquifer parameterization, assessment of ground water resources of the study area, water quality of the surface and ground water in the study area, and rain water harvesting etc.

Detailed analysis was carried out to analyze the surface water availability scenario and its sustainability for the project and its impact on the committed allocations for hydropower generation and other purposes. The analysis of inflows, storages and releases from the ISP, indicated that water availability scenario is favourable and the diversion of 40 MCM of water from Omkareshwar dam is sustainable to meet the water demands of NTPC.

Analysis of variation in ground water levels indicated that the area located near the canals are seen to have shallow water tables while those away from any recharge structures are having deep water levels. Variation in water levels during pre-monsoon (May 2016) and post monsoon (November 2015) clearly indicated that the drop in water levels is significant. It varied from 13.21 to 45 m. However, in most other areas the drop in water level from November, 2015 to May end 2016 was observed to be in the range of about 16-20 m. The general direction of flow of water in the study area was observed to be from Dabhad area, to the surrounding area.

Under the above said hydro-geology study, infiltration tests were conducted at eight different locations in the study area during November, 2015, representing different drainage and soil formations. Final infiltration rates (Hydraulic conductivity) at different sites was observed to vary from 6.15 mm/hr to 22.34 mm/hr in different areas.

Aquifer characteristics were evaluated through the pump test in the ash pond Area of the project site. The average transmissivity of the aquifer was found to be 6.55 m^2/d and the storage coefficient was 3.61×10^{-2}. The pump test data indicated that the aquifers in the ash pond area of Khargone STPP are poor aquifers with poor transmissivity and storage coefficient

As per the hydro-geological study**, t**he dynamic ground water resources for Barwah block in which the NTPC Khargone plant is located, indicated that after making allocation for future domestic and industrial supply upto 2033, balance available ground water for future irrigation would be 2340 ham. Thus, the exploitable groundwater potential due to groundwater recharge is surplus compared to the existing and projected groundwater draft. Further, no groundwater is proposed to be used in the proposed thermal power plant. All the required water for power generation and domestic consumption is to be drawn from Omkareshwar dam. Therefore, no adverse impact of the thermal power plant on groundwater regime was anticipated in the study.

Under the Hydro-geological study carried out by NIH, water quality of surface and ground water was also measured for the pre-monsoon (May 2016) and post-monsoon periods (November 2015) for 28 ground water locations including hand pumps, tube wells and open wells and 5 major surface water sources. The ionic balance for majority of the samples was within 5%. The pH was found to vary between 7.2 to 7.8 during the

post monsoon season and 7.6 to 9.7 during the pre-monsoon for groundwater. For surface waters, it varied from 6.9 to 7.6 during post monsoon and 7.1 to 7.4 during pre-monsoon. EC was found to vary between 486 to 1830 µS/cm in post monsoon and 419 to 1784 µS/cm in pre-monsoon for groundwater. For the surface water, it was 298-602 µS/cm during post monsoon and 320 µS/cm to 642 µS/cm during the pre-monsoon. TDS for ground water varied widely between 279 to 1171 mg/L during post monsoon and 268 to 1119 mg/L during pre-monsoon. For surface water, it was 187-378 mg/L during the post monsoon and 205 mg/L to 411 mg/L during pre-monsoon. Hardness in groundwater during the post monsoon season was found to vary widely between 112 to 549 mg/L. During the pre-monsoon the range was 56 to 411 mg/L. For surface water, during the post monsoon period, it varied within a range of 89-191 mg/L. During the pre-monsoon period, it ranged from 95 mg/L to 211 mg/L. Alkalinity of the groundwater was observed to be between 150 to 418 mg/L during post monsoon and 86 to 526 mg/L during pre-monsoon. For the surface waters, during the post monsoon period, it varied within a range of 87-170 mg/L and during the pre-monsoon period ranged from 102 mg/L to 209 mg/L. The anion chemistry of the analyzed samples shows that HCO_3-, Cl-, SO_4^{2-} and NO_3- are the dominant anions in both surface and groundwater of the study area. The major cations observed in the waters of study area included Ca, Mg, Na and K. Analysis of trace metals did not indicate any trace metal pollution in the waters of the study area either during pre or post monsoon period.

A brief study of rainwater harvesting was also carried out under the hydro-geological study. It was observed that out of the total 1334 acres of total land area of the project site, rainwater harvesting can be implemented only in the Main Plant area, Green Belt and Afforestation area and Township Area. Based on the maximum probable precipitation (PMP) per day for this area (550 mm) as suggested by IMD, water generated from the Main Plant area was estimated to be about 35,835m^3/hr, from green belt and afforestation area about 10,239m^3/hr and from Township area about 9,308m^3/hr. It was suggested that the water collected from the rainwater harvesting may be utilised in the Power Plant and the Township for various purposes, such as, gardening, washing and cooling etc.

NIH, Roorkee also carried out a study for identification of source of seepage in the villages surrounding the ashy dykes of NTPC Khargone plant. Groundwater and surface water samples were collected from different sources such as hand pumps, tube wells, open wells, pond, reservoir and rivers. The water samples were analyzed for stable isotope composition of Hydrogen (δ^2H) and Oxygen ($\delta^{18}O$). The water sampling in September 2020 (Just after monsoon) showed that the isotopic composition of the groundwater in the waterlogging affected area and unaffected area is almost same, and does not match with that of ash dyke water. Based on the geological, geomorphological, isotopic and water quality investigations in the waterlogging affected area, the study concluded that the cause of waterlogging in the area may be due to excessive rainfall and groundwater recharge from the nearby large water bodies and not from the ash dyke of NTPC.

3.0 FIELD INVESTIGATIONS

3.1 Reconnaissance Survey

A field visit of NTPC Khargone was undertaken by the scientist of NIH during March, 2022. Reconnaissance survey of the study area was done. Meeting was also held with official of NTPC Khargone and discussions were held regarding the field work including construction of piezometer and proposed methodology.

Figure 17: Some field photographs of the reconnaissance survey

Figure 17:..... Contd.

3.2 Field investigations during pre-monsoon season

A site visit was undertaken to the study area by the NIH team during 19-22 May, 2022 for various field works related to pre-monsoon season of 2022. Following field works were carried out:

i) Surface water quality sampling from 12 locations of surface water including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes.
ii) Ground water quality sampling from 18 locations including samples from various sources such as hand pumps, tube wells, open wells and seepage nallah.

iii) Ground water levels monitoring at 16 locations including hand pumps, tube wells, and open wells
iv) Collection of soil samples from 11 locations
v) In-situ determination of latitude, longitudes for the various sampling locations.

3.3 Field Investigations During Post Monsoon Season

A site visit was undertaken to the study area by the NIH team during 13-15 November, 2022 for various field works related to post-monsoon season of 2022. Following field works were carried out:

i) Surface water quality sampling from 11 locations of surface water including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes.
ii) Ground water quality sampling from 24 locations including samples from various sources such as hand pumps, tube wells, open wells, Piezometer and seepage nallah.
iii) Ground water levels monitoring at 23 locations including hand pumps, tube wells, Piezometer and open wells
iv) DGPS survey for determination of latitude, longitudes and elevations (altitudes, amsl) for the various drilled piezometer locations.

4.0 CONSTRUCTION OF PIEZOMETERS

As per the scope of the work mentioned in the PO, 06 piezometers around the ash pond and project area, particularly in the groundwater flow direction, were to be constructed. Drilling of piezometers was planned for April 2022 so that water level monitoring can be done during pre-monsoon season of 2022. Accordingly, the process was initiated in February-March, 2022. However, none of the identified firms submitted the quotation, so the process could not be completed during April 2022. The drilling was again planned and undertaken after the monsoon was over, so that water level monitoring could be done in November, 2022, for the post monsoon season.

To install 6 nos. of piezometers along ash dyke, a preliminary field visit was made for site inspection along with NTPC Khargone authorities to mark the exact site locations. As per the work order 6 nos. of Piezometers were drilled in and around the 5 km radius of the NTPC, Khargoan, (M.P.). The depth of each drilling bore wells was decided to be about ~100 ft, but due to encountering of the water table at variable depths, the total drilling depth was also varied in one borewell. The geographical location of each piezometer were finalized in consultation with the NTPC Khargone authorities. ***Table 3*** provides the details of the piezometers. The geographical locations are shown in ***Figure 18.*** Some photographs related to drilling are shown in ***Figure 19*** to ***Figure 22.***

Table 3: Details of installed Piezometers at the NTPC Khargone

S.N.	Location	Code	Latitude	Longitude	Drilled Depth (ft)	Casing depth. (ft)
1	**Around Ash Dyke Area**	PZ-1	22.077927°	75.836639°	100	60
2		PZ-2	22.077177°	75.833321°	100	60
3		PZ-3	22.074801°	75.831882°	100	60
4		PZ-4	22.072510°	75.832445°	90	60
5		PZ-5	22.070598°	75.832912°	100	60
6		PZ-6	22.070664°	75.835730°	110	60

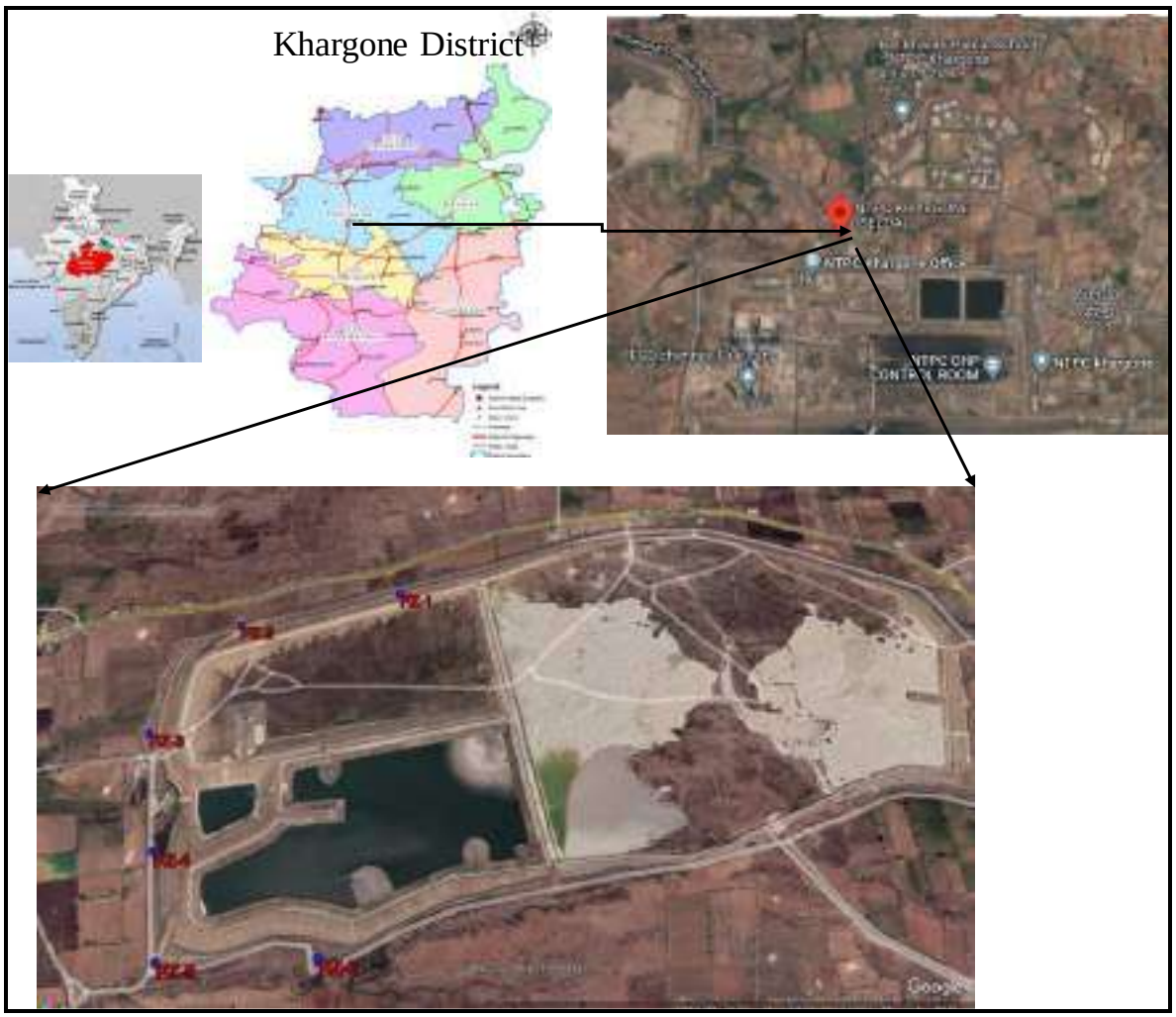


Figure 18: Geographical locations of the installed Piezometers at NTPC, Khargone

Figure 19: Drilling operation in progress for construction of the piezometers around new Ash Dyke, NTPC Khargone

Figure 20: Cleaning of borehole using air compressor, supply and installation of 5-inch casing (PVC) pipe in progress for construction of the piezometers around ash dyke at NTPC Khargone.

Figure 21: Inspection by NTPC Officials during drilling of borehole at location (PZ-6), NTPC Khargone

Figure 22: Preparation of concrete platform and locking arrangement for the piezometers (PZ-1 to PZ-6) installed around the ash dyke of NTPC Khargone

5.0 GROUND WATER LEVEL VARIATION & FLOW DIRECTION

5.1 Ground Water Level Variation

The groundwater level is a key parameter for evaluating spatial and temporal changes in groundwater environments. The groundwater level is governed by various factors. Any phenomenon, which produces pressure change within an aquifer, results into the change of ground water level. These changes in ground water level can be a result of changes in storage, amount of discharge and recharge, variation of stream stages and evaporation. External loads such as tides, trains, atmospheric pressure and earthquake are born in part by the ground water of confined aquifers. Hence they affect peizometric levels. The general consideration is that due to any reason if the aquifer pressure rises above the atmospheric pressure an upleveling in ground water level results and vice-versa.

There are two broad kinds of groundwater level variations:

i) Secular variation: These are variations in ground water level extending over a period of years. Alternating seasons of wet and dry years is which the rainfall in above and below the mean respectively, produce long period fluctuation of level. Recharge is the governing factor, which depends upon the rainfall intensity and distribution and amount of surface run off. In over developed basins where draft exceeds recharge, a down ward trend of ground water level may continue for many years.

ii) Seasonal variation: These variations result from influences such as recharge from rainfall and irrigation and discharge by pumping which follow well defined seasonal cycles.

There are several factors, which change the ground water level. Annual ground water level fluctuation results from seasonal variation of recharge from rainfall. One of the important factors affecting the ground water level is the stream flow. Where a stream channel is in indirect contact with an unconfined aquifer, the stream may recharge the ground water, or receive discharge from the ground water (termed as influent and effluent streams respectively) depending on the relative water levels. During a period of flood, ground water levels are temporarily raised near the channel by the inflow of stream. Another important factor is evapo-transpiration. In areas where the ground water level is very near to the surface, evaporation plays a dominant role in reducing the ground water level. Reduction in ground water level due to transpiration occurs where the root zones of plants are directly in contact with saturated water zone. This also results in reducing the ground water level. But in ploughed areas and areas where no vegetation is there the effect of transpiration in negligible. Hot windy days produce more draw down than cold cloudy day as in the latter case effect of evaporation is negligible. Transpiration discharge does not occur also where the ground water level is below the root zone of plants. Minor fluctuation of water levels is caused by wind blowing over the top of wells. The effect is identical to the action of a vacuum pump. As a gust of wind blows over the top of a casing, the air pressure within the well is suddenly lowered and consequently the water level rises. After the gust parries the air pressure in the well rises and water level falls. External loads may sometimes affect the

ground water levels. The elastic properties of an aquifer (confined) result in changes in hydrostatic pressure when changes in loading occur. One such example is variations exhibited by wells located hear railroads where passing trains produce measurable fluctuation of piezometric surface. Similarly, earthquakes have a variety of effects on ground water.

In the present study ground water level monitoring for the pre-monsoon season of 2022 was carried out during May, 2022 at 16 locations which include 11 hand-pumps, 2 tube-wells and three open wells. Ground water level monitoring for the post-monsoon season of 2022 was carried out during November, 2022 at 23 locations which include 11 hand-pumps, 3 tube-wells, 6 Piezometer and three open wells. Compared to pre-monsoon, there were 7 additional locations which were monitored, 06 of these were the newly constructed piezometers.

Figure 23 provides the location map of the groundwater level monitoring stations. The details of the monitoring stations are provided in ***Table 4.***

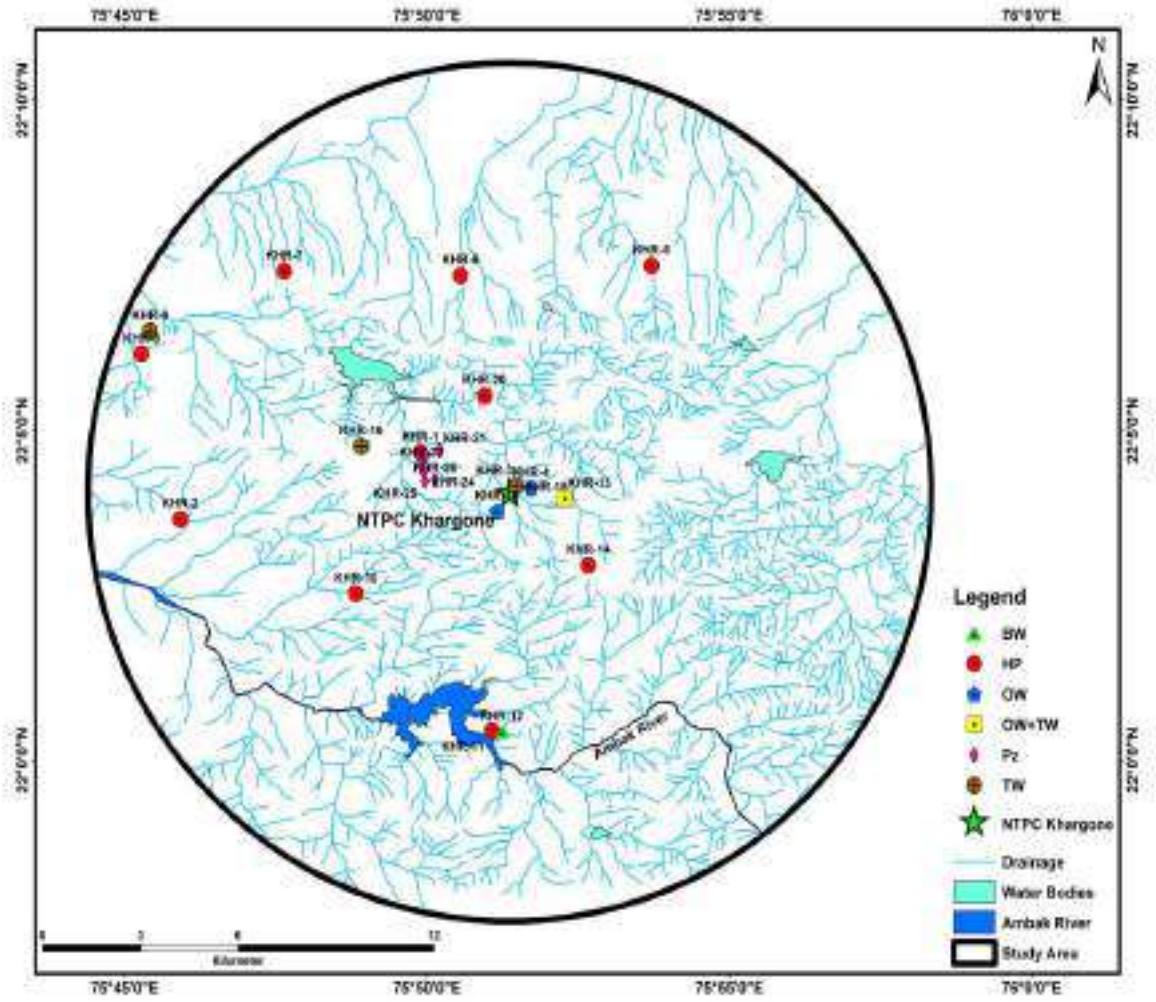


Figure 23: Location map of groundwater level monitoring stations in the study area

Table 4: Details of groundwater level monitoring stations

S. N.	Site Code	Location address	Source	Latitude (°N)	Longitude (°E)	Elevation m, amsl	Pre-monsoon monitoring	Post-monsoon monitoring
1	KHR-1	In House of Sh. Rai Singh S/O Sh. Jai Sing. On Road of Pipalgaon to NTPC Plant ,Near Electric Trangle pole of HT Line, Vill Dalchi	HP	22.077748	75.831549	183.917	√	√
2	KHR-2	Aanganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd	HP	22.060904	75.765297	149.688	√	√
3	KHR-3	Near NTPC opp Bhilal Baba Temple,Gate No. 1,opp Cooling Towers, Below Bargad Tree	HP	22.069258	75.857885	202.55	√	√
4	KHR-4	Between NTPC & Town ship, opp Boundry Piller S.N. 230-240	OW	22.068803	75.862023	216.256	√	√
5	KHR-5	opp Primary School on road. Vill Baddgaon	HP	22.124938	75.895198	139.347	√	√
6	KHR-6	opp Madhya Pradesh Gramin Bank, opp Health Centre. Vill Kanapur	HP	22.122422	75.842507	145.51	√	√
7	KHR-7	In House of sh. Daya Ram, Vill Londhi(Jhirbar)	HP	22.123495	75.794000	143.928	√	√
8	KHR-8	opp Sabir`s House, Sanawat-Kasravad Road,opp Baba Shree Dhaba, Vill Pipalgoan	HP	22.102585	75.754665	139.327	√	√
9	KHR-9	Adjoining of Jai Bajrang Kirana, Neharu Nagar Pipalgoan	TW	22.108389	75.756944		X	√
10	KHR-10	opp Surandra Singh House in Dinesh Nihal House Compound, vill Bhopada	HP	22.042080	75.813743	161.199	√	√
11	KHR-11	opp shivji Panwar House,Vill Padlia Gawli	HP	22.007591	75.851219	175.097	√	√

12	KHR-12	Vill Padalia	BW	22.007275	75.853942		X	√
13	KHR-13	Adjoining of NTPC Community Centre Near New Hanumaan Temple, Village Selda	OW (+TW)	22.066083	75.871388	220.012	√	√
14	KHR-14	Opp Gram Panchayat office. Vill Kheri Bujurg	HP	22.049303	75.877826	223.444	√	√
15	KHR-15	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1	TW	22.069233	75.857978	NA	√	√
16	KHR-16	Sh. Rai Singh field Dalchi Bhatyan road, (B/w Dalchi and Bhatyan)	TW	22.079311	75.815188	NA	√	X
17	KHR-18	Inside of Plant	OW	22.062953	75.852559	NA	√	√
18	KHR-20	opp Sh Mukesh House, Vill Jamnia	HP	22.092052	75.849177	NA	√	√
19	KHR-21	Between ash dyke and road	Pz	22.078296	75.836748	178.304	X	√
20	KHR-22	Just away from road cutof	Pz	22.077181	75.833062	175.182	X	√
21	KHR-23	Before Pump house opp side Near RCC-3 Poles	Pz	22.0747722	75.831750	170.271	X	√
22	KHR-24	Near pump house left side	Pz	22.072914	75.832372	167.585	X	√
23	KHR-25	opp Twin pole no. 8	Pz	22.0705508	75.832784	173.410	X	√
24	KHR-26	Near Trangle pole and Twin pole	Pz	22.0708942	75.835508	174.039	X	√

(HP-Hand pump, OW-Open Well, TB-Tube well, Pz-Piezometer)

Note: At site KHR-13, tube well water is being continuously pumped into the open well.

The water level below the ground surface was measured using automatic water level indicator. DGPS Survey was carried out in the earlier study by NIH at most of these locations. DGPS survey for the new locations such as the piezometers was carried out during the post-monsoon sampling season in November 2022. ***Figure 24*** presents some photographs of the DGPS survey carried out to determine elevations of the ground water level measurement locations. Based on the DGPS data, elevation of the location was determined. The elevation data was used to determine the water level elevation amsl.

Figure 24: Some photographs of the DGPS survey carried out to determine elevations of the ground water level measurement locations

The data of ground water levels (both below the ground level as well as above mean sea level) for the pre-monsoon season (May 2022) is presented in ***Table 5. Table 6*** presents the same data for the post-monsoon season**.** The spatial variation of water depth below ground surface is also shown in ***Figure 25*** and ***Figure 26*** for the pre-monsoon and post monsoon season respectively.

Table 5: Groundwater levels in the study area during pre-monsoon (May, 2022)

S. N.	Location ID	Source	Depth below ground level (m)	Water level elevation amsl (m)
1	KHR-1	HP	26.81	157.11
2	KHR-2	HP	14.42	135.27
3	KHR-3	HP	7.17	195.38
4	KHR-4	OW	6.62	209.64
5	KHR-5	HP	2.75	136.60
6	KHR-6	HP	6.83	138.68
7	KHR-7	HP	6.77	137.16
8	KHR-8	HP	22.97	116.36
9	KHR-10	HP	9.01	152.19
10	KHR-11	HP	6.98	168.12
11	KHR-13	OW	7.37	212.64
12	KHR-14	HP	22.53	200.91
13	KHR-15	TW	15.10	NA
14	KHR-16	TW	43.10	NA
15	KHR-18	OW	4.67	NA
16	KHR-20	HP	18.75	NA

Table 6: Groundwater levels in the study area during post-monsoon (November, 2022)

S. N.	Location ID	Source	Depth below ground level (m)	Water level elevation amsl (m)
1	KHR-1	HP	25.24	158.68
2	KHR-2	HP	6.55	143.14
3	KHR-3	HP	5.83	196.72
4	KHR-4	OW	5.36	210.90
5	KHR-5	HP	3.60	135.75
6	KHR-6	HP	2.55	142.96
7	KHR-7	HP	4.03	139.9
8	KHR-8	HP	5.50	133.83
9	KHR-9	TW	4.90	NA
10	KHR-10	HP	5.79	155.41
11	KHR-11	HP	3.47	171.63
12	KHR-12	TW	16.51	NA
13	KHR-13	OW	4.78	215.23
14	KHR-14	HP	7.86	215.58
15	KHR-15	TW	26.44	NA
16	KHR-18	OW	4.52	NA
17	KHR-20	HP	16.63	NA
18	KHR-21	Pz	11.82	166.48
19	KHR-22	Pz	14.23	160.95
20	KHR-23	Pz	3.98	166.29
21	KHR-24	Pz	1.80	165.79
22	KHR-25	Pz	7.85	165.56
23	KHR-26	Pz	6.04	168.00

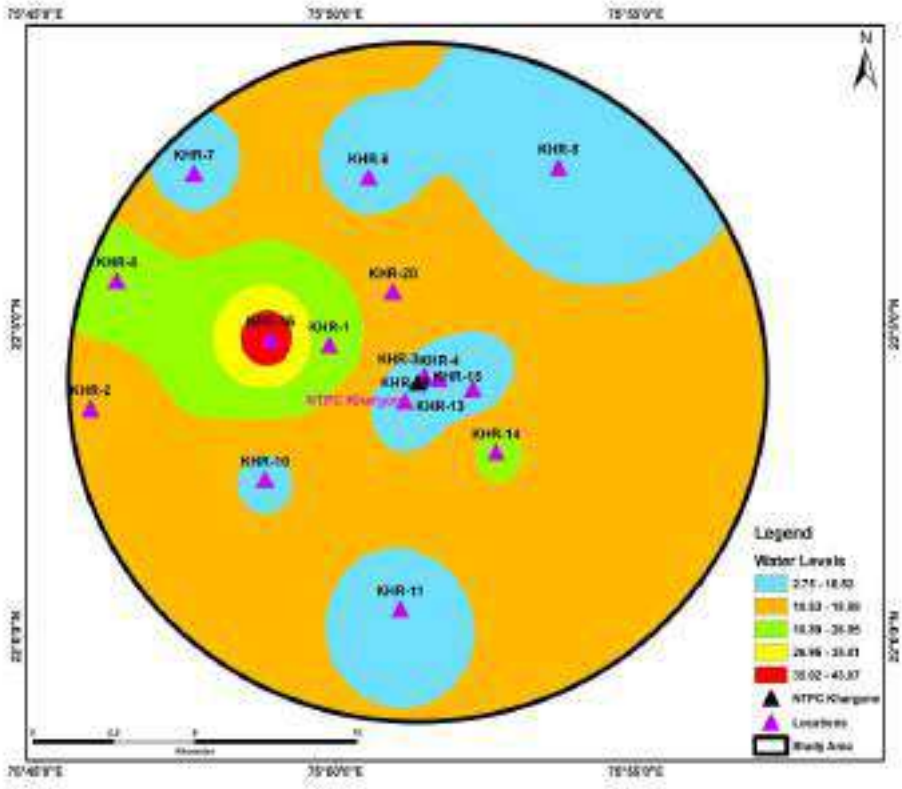


Figure 25: Variation of water depth below ground surface in the study area during pre-monsoon (May, 2022)

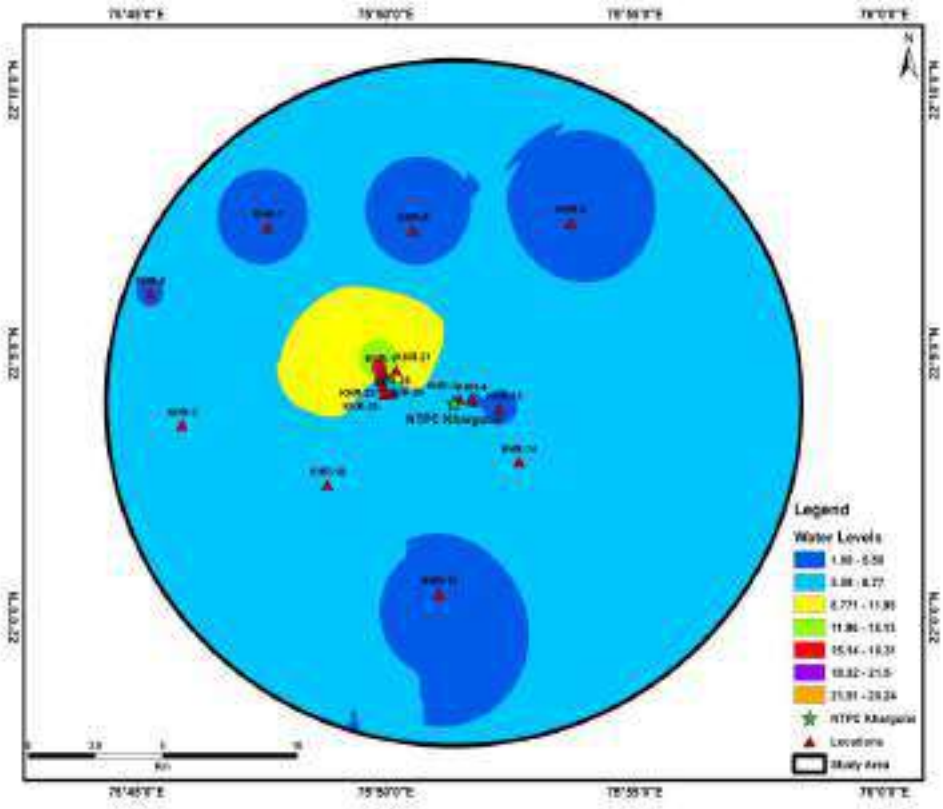


Figure 26: Variation of water depth below ground surface in the study area during post-monsoon (November, 2022)

During the pre-monsoon season (May 2022) the depth of water below the ground surface varied from 2.75 m bgl for the hand pump located opposite Primary School on the road of village Badgaon to 43.10 m for the bore well located in the field of Sh. Rai Singh on the Dalchi Bhatyan road, (located between Dalchi and Bhatyan). As far as water level variation above mean sea level is concerned, the highest water level elevation of 212.64 m amsl was observed at the open well adjoining NTPC Community Centre, Near New Hanumaan Temple, Village Selda. However, it may be noted that this open well is receiving water from tube well, being brought to it through pipe from a far of place. The other highest water level of 200.91 m above mean sea level was observed at the hand pump located opposite Gram Panchayat office at village Kheri Bujurg. The lowest water level of 116.36 m amsl was observed at the hand-pump located opposite Sabir`s House, on Sanawad-Kasravad Road, opposite Baba Shree Dhaba, in village Pipalgaon.

During the post monsoon season (November 2022), the depth of water below the ground surface varied from 1.80 m bgl for the piezometer KHR-24 (near pump house left side) to 26.44 m for the tube well located near Bhilat Baba temple, opposite cooling tower. As far as water level variation above mean sea level is concerned, the highest water level elevation of 215.58 m amsl was observed at the hand pump located opposite Panchayat Bhawan, village Kheri Bujurg. The other highest water level of 215.23 m above mean sea level was observed at the open well adjoining NTPC Community Centre, Near New Hanumaan Temple, village Selda, which as mentioned above, is receiving water from tube well, being brought to it through pipe from a far of place. The lowest water level of 133.83 m amsl was observed at the hand-pump located opposite Sabir`s House, on Sanawad-Kasravad road, opposite Baba Shree Dhaba, in village Pipalgaon.

Figure 27 below presents a comparison of the variation in ground water levels during the pre and post monsoon season.

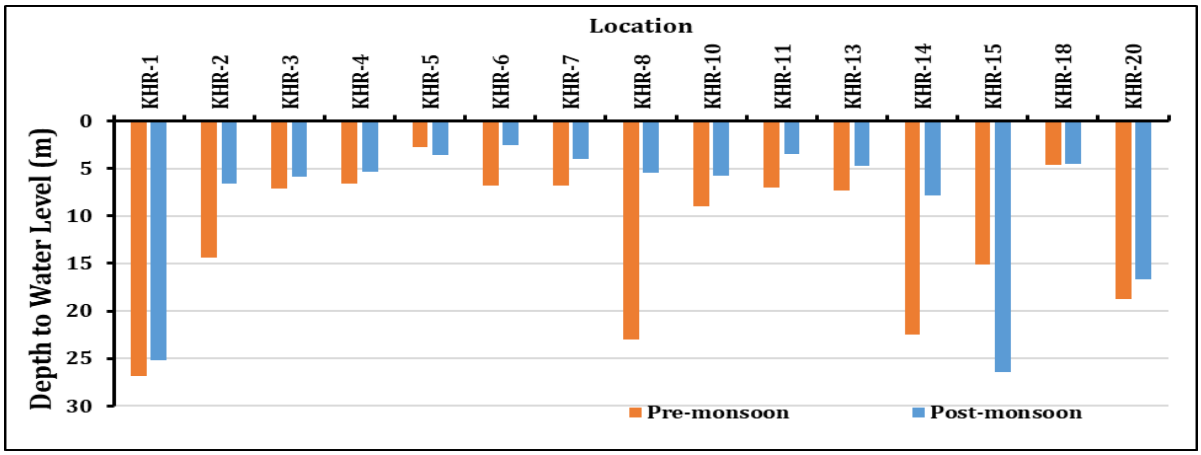


Figure 27: Comparison of depth to water level during pre-monsoon (May, 2022) and post-monsoon (November, 2022)

From ***Figure 27*** it can be seen that there is improvement in water levels at most locations except at KH-5 and KH-15 locations. This general increase in water levels at most locations is obviously because of the recharge of ground water due to monsoon.

Figure 28 presents some photographs of ground water level monitoring carried out for the study area during pre-monsoon season of May 2022 while ***Figure 29*** presents the photographs of the post monsoon season monitoring.

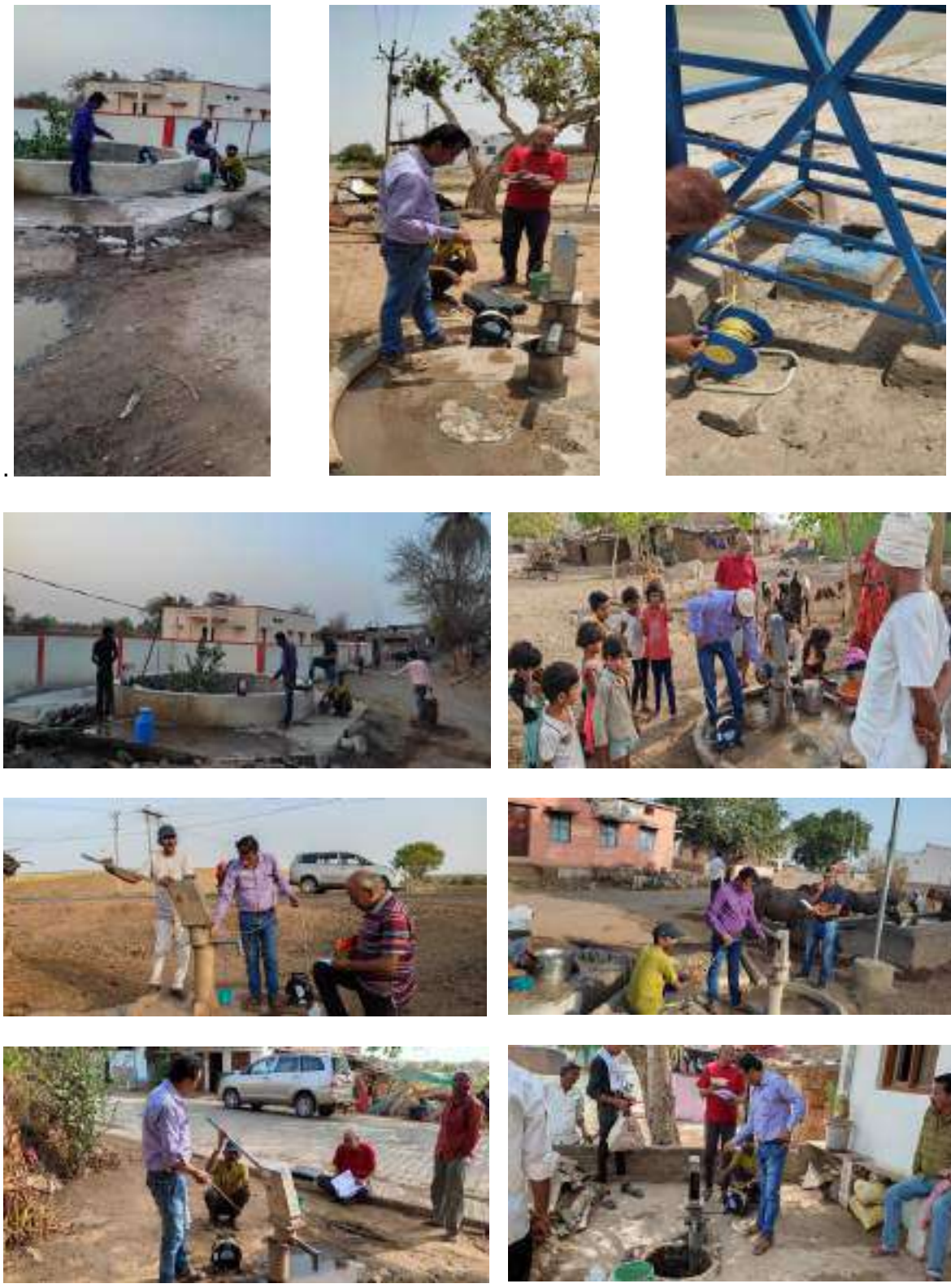


Figure 28: Some photographs of ground water level monitoring in the study area during pre-monsoon season (May 2022)






Figure 28:……. Contd.

Figure 29: Some photographs of ground water level monitoring in the study area during post-monsoon season (November 2022)












Figure 29:....Contd.

5.2 Ground Water Flow Direction

Contour map of the water levels has been prepared using the ground water level elevation data. It is presented in ***Figure 30*** *for the pre-monsoon season of May 2022.* For the post monsoon season of November, 2022, it is presented in ***Figure 31***.

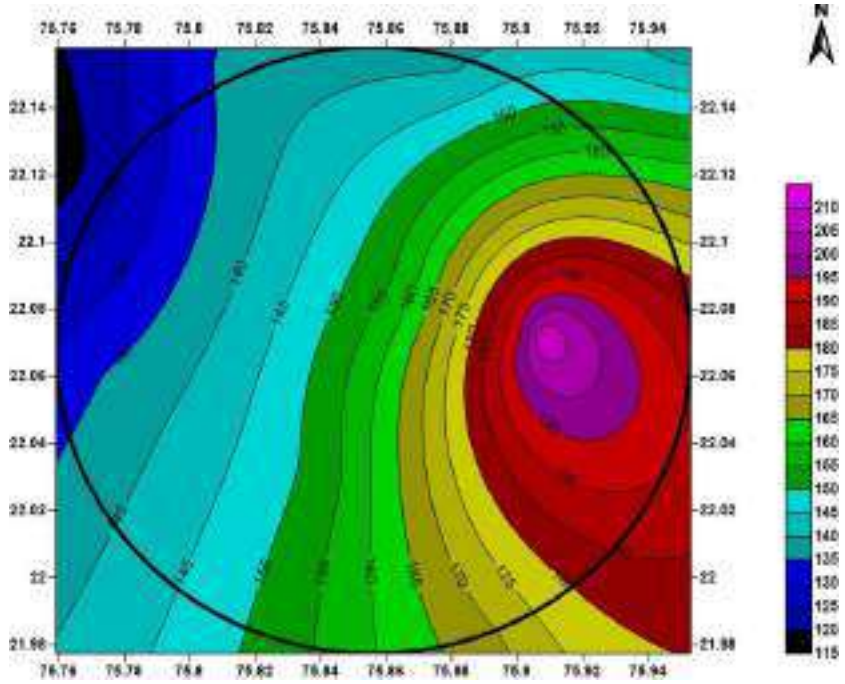


Figure 30: Ground water level contour map indicating groundwater flow direction during pre-monsoon season (May, 2022)

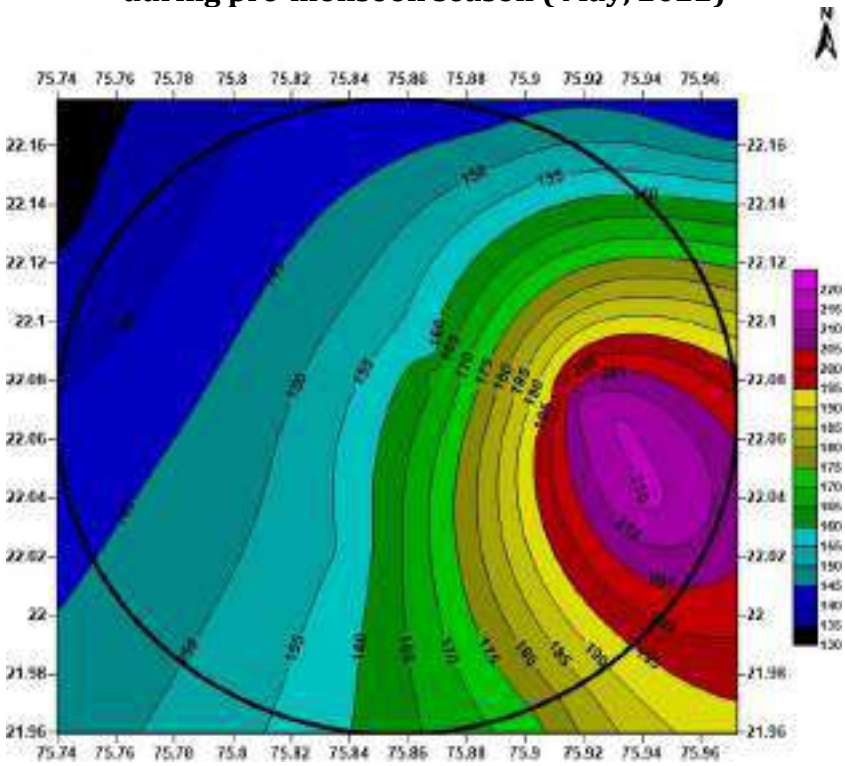


Figure 31: Ground water level contour map indicating groundwater flow direction during post-monsoon season (November, 2022)

A comparison of the ground water flow direction during the Pre-monsoon: (May 2022) and post–monsoon (November 2022) clearly indicates that there is no variation in the flow direction during the two seasons. The highest ground water elevation during both the seasons is observed to be at the immediate west of plant area (in the Dhabhad area). The general groundwater flow direction from this point as evident from the ground water level contour maps (***Figure 30 and Figure 31****)* is from South-East to North-North West direction. There is another pathway wherein water from the immediate west of plant area (Dabhad region) flows in south and south-east direction. In-fact it can be said that water from Dabhad region is flowing along all the surrounding directions. The ground water flow direction is observed to follow the surface water topography in general. Similar ground water flow direction for the study area was recorded by NIH during the hydro-geological study carried out earlier.

6.0 WATER QUALITY

6.1 General

Water quality is commonly assessed through the use of different parameters. The importance of these parameters depends on the use of the water. The term water quality therefore, must be considered relative to the use of water. In other words, the term 'water quality' can be defined as "physical, chemical and biological characteristics of water by which the user evaluates the acceptability of water". Water bodies having high water quality possess properties that make it a high valued resource to society and nature. Declining or low water quality impacts the value – economically, ecologically, and socially, if pollution enters a waterbody.

Water quality parameters can be generally grouped into physical parameters, chemical parameters and biological parameters. In the present study, as per the scope of the study, physical parameters and chemical parameters have been studied. The chemical parameters include ions as well as heavy metals.

Physical parameters are physical aspects of water quality that helps to determine whether water is polluted or not. The various physical parameters include temperature, EC, pH, TDS, alkalinity, Hardness, DO, BOD, COD etc.

The pH (hydrogen ion concentration) of water is a very important measurement concerning water quality. Most of the chemical reactions in aquatic environment are controlled by change in its value. It is a measure of how acidic/basic water is. The range goes from 0 to 14, with 7 being neutral. pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base. EC is the measure of the ability of an aqueous solution to convey an electric current. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. Conductivity is a good and rapid method to measure the total dissolved solids and is directly related to total solids.

Total Dissolved Solid (TDS) in water includes all dissolved material in solution, whether ionized or not. TDS is numerical sum of all mineral constituents dissolved in water and is expressed in mg/l. In natural water, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron and manganese *etc*. The palatability of water with a total

dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid. Measuring alkalinity is important in determining a water sources' ability to neutralize acidic pollution from rainfall or wastewater. There can be long-term changes in the alkalinity of streams and rivers in response to human disturbances. Alkalinity is related to the pH of a solution (its basicity) but measures a different property. Roughly, the pH of a solution is a measure of how "strong" the bases are in a solution, whereas the alkalinity measures the "amount" of chemical bases.

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per litre. The degree of hardness of drinking-water is important for aesthetic acceptability by consumers.

Ions contain positively charged ions (cations) and negatively charged ions (anions) present in water. These ions contribute to the salinity of the water.

Heavy metals are metallic elements that have a relatively high density (generally greater than 5.0 g/cm^3) compared to water, but there are also some other definitions of heavy metals – based on either atomic number or atomic weight, or chemical properties or toxicity. Examples of heavy metals are As, Cd, Co, Cr, Cu, Hg, Mn, Ni, and Pb. Heavy metals like Chromium (Cr), Cadmium (Cd), Mercury (Hg), Lead (Pb), Nickel (Ni), and Thallium (Tl) are potentially hazardous in combined or elemental forms. Heavy metals are highly soluble in the aquatic environments and therefore they can be absorbed easily by living organisms. Heavy metals above allowable limits often lead to disadvantageous effects in humans, other organisms and the environment at large. Heavy metals are quite often synonymously referred to as trace elements, though the former is a broader category. Trace metals are the metals that are present in low concentrations.

The quality of both surface water and groundwater is affected by natural and anthropogenic factors. The natural factors that affect water quality in rural and urban areas are similar. The composition of surface water and groundwater is dependent on e.g. geological, topographical, meteorological, hydrological and biological factors. It varies with seasonal differences in weather conditions, run-off volumes and water levels. Water quality is affected by both point and nonpoint sources of pollution in both the rural and urban areas. Some of these sources include sewage discharge, industrial discharge and agricultural run-off. Water quality is also affected by floods and droughts, as well as lack of awareness among end users. The required water quality varies with the use, and the criteria used to assess water quality also vary. For each parameter of water, the quality is generally reported with reference to a specific standard so as to make the qualitative assessment of the status of the water. The standards are set by governing organizations. In India, the CPCB and BIS have set certain standards for different uses of water (***Table 7*** and ***Table 7***).

Table 7: Water quality standards by CPCB

Designated Best Use	Class	Primary Water Quality Criteria
Drinking water source without conventional treatment but with chlorination	A	Total coliform organisms (MPN/100 ml) shall be 50 or less; pH between 6.5 and 8.5; Dissolved Oxygen 6 mg/l or more, and BOD 2 mg/l or less
Outdoor bathing (organized)	B	Total coliform organisms (MPN/100 ml) shall be 500 or less; pH between 6.5 and 8.5; Dissolved Oxygen 5 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Drinking water source with conventional treatment	C	Total coliform organisms (MPN/100 ml) shall be 5000 or less; pH between 6 and 9; Dissolved Oxygen 4 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Propagation of wildlife and fisheries	D	pH between 6.5 and 8.5; Dissolved Oxygen 4 mg/l or more, and Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling & controlled disposal	E	pH between 6.0 & 8.5; EC less than 2250 µS/cm, SAR less than 26, and Boron less than 2 mg/l

Table 8: Water quality Standards as per BIS

S. N.	Parameter and Unit	A	B	C	D	E
1	Taste	None	-	-	-	-
2	Odour	Un obj.	-	-	-	-
3	Colour (True)(Hazen Unit)	10	300	300	-	-
4	pH (max) (min:6.5)	8.5	8.5	8.5	8.5	8.5
5	Conductivity (25^0C) µS/cm	-	-	-	1000	2250
6	DO (mg/l)(minimum)	6	5	4	4	-
7	BOD (3d, 27^0C) (mg/l)	2	3	3	-	-
8	Total Coliforms (MPN/100 ml)	50	500	5000	-	-
9	TDS (mg/l)	500	-	1500	-	2100
10	Oil and Grease (mg/l)	-	-	0.1	0.1	-
11	Mineral Oil (mg/l)	0.01	-	-	-	-
12	Total Hardness (mg/l as $CaCO_3$)	300	-	-	-	-
13	Chlorides (mg/l as Cl)	250	-	600	-	600
14	Sulphates (mg/l as SO_4)	400	-	400	-	1000
15	Nitrates (mg/l as NO_3)	20	-	50	-	-
16	Free CO_2 (mg/l)	-	-	-	6	-
17	Free NH_3 (mg/l as N)	-	-	-	1.2	-
18	Fluorides (mg/l as F)	1.5	1.5	1.5	-	-
19	Calcium (mg/l)	80.10	-	-	-	-
20	Magnesium (mg/l)	24.28	-	-	-	-
21	Copper (mg/l)	1.5	-	1.5	-	-
22	Iron (mg/l)	0.3	-	50	-	-
23	Manganese (mg/l)	0.5	-	-	-	-

(Class A – Drinking water without conventional treatment but after disinfection. Class B –Water for outdoor bathing. Class C – Drinking water with conventional treatment followed by disinfection. Class D – Water for fish culture and wild life propagation. Class E – Water for irrigation, industrial cooling and controlled waste disposal)

6.2 Water Quality Sampling

During the present study, water quality of surface and ground water was monitored for the pre-monsoon and post monsoon seasons. The sampling for pre-monsoon was carried out during May 2022 and that of post monsoon was carried out during November 2022. While surface samples were collected from ponds, lakes, lagoons, OFL, raw water reservoir, rivers and streams/nallahs, ground water samples were collected from hand pumps, open wells, and tube wells /bore wells. The samples were collected in pre cleaned polypropylene bottles (Tarsons make). The bottles were rinsed and filled with water samples and tightly capped. Preservatives were added as per the requirement of the methodology.

Figure 32 provides the location map of the surface water sampling locations. The details of the sampling locations are provided in ***Table 9. Figure 33*** provides the location map of the ground water sampling locations. The details of the sampling locations are provided in ***Table 10.***

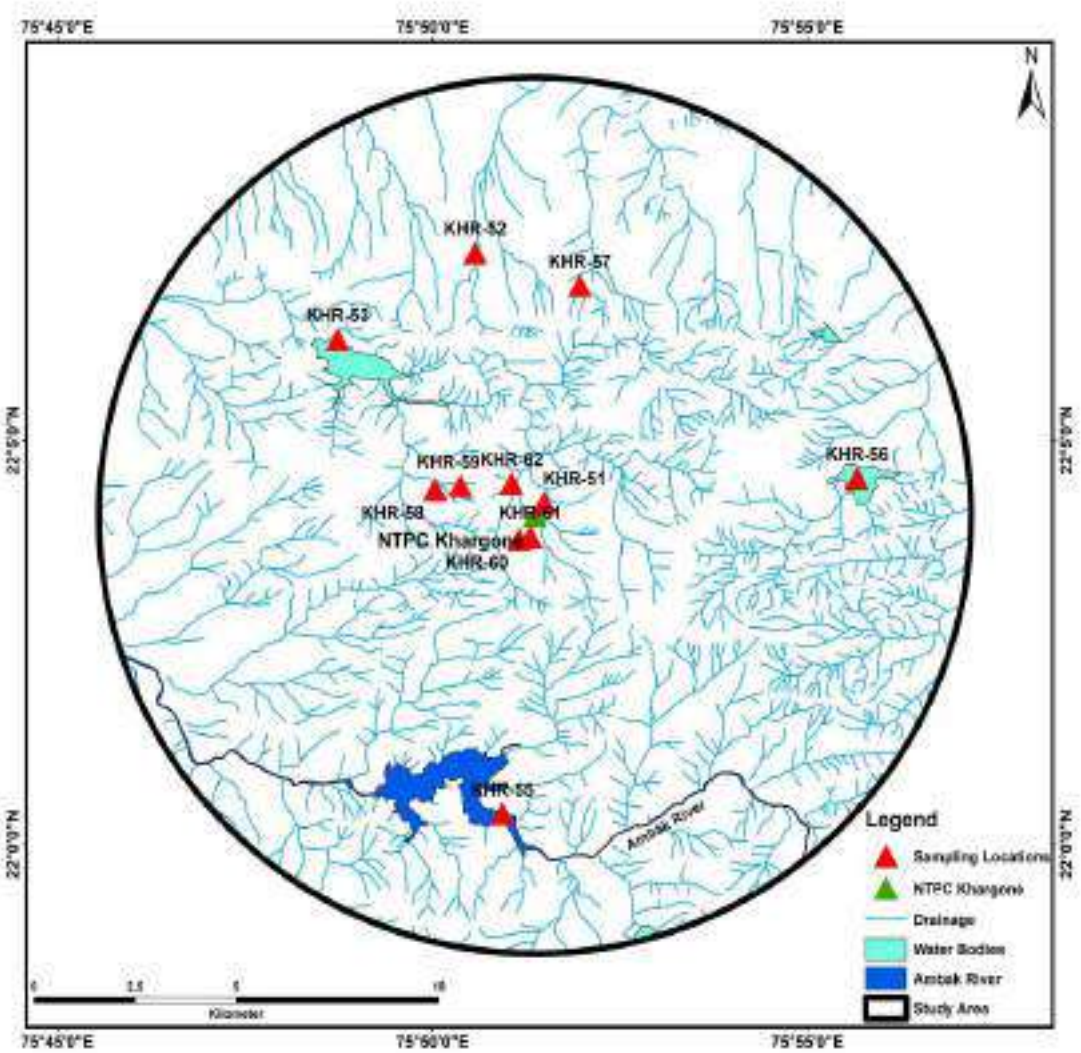


Figure 32: Location map of surface water sampling locations in the study area

Table 9: Details of surface water sampling locations in the study area

S. N.	Site Code	Source	Location	Latitude (°N)	Longitude (°E)	Pre monsoon monitoring	Pre monsoon monitoring
1	KHR-51	Pond	Between NTPC Plant & Town ship,	22.070470	75.858149	√	√
2	KHR-52	Pond	Near Health Centre along Main road, Vill Kanapur	22.122060	75.842803	√	√
3	KHR-53	Lake	Jhirbar Talab	22.104185	75.812277	√	√
4	KHR-54	River	Narmada River, Near Siyaram Baba Ashram	22.158804	75.761670	√	√
5	KHR-55	Lake	Ambak Talab	22.006354	75.848828	√	√
6	KHR-56	Pond	Lachhora Talab	22.075493	75.927687	√	√
7	KHR-57	Pond	Kattora Pond, Shelda Plant-Kattora Road	22.115246	75.866087	√	√
8	KHR-58	OFL	OFL Ash Dyke	22.073230	75.833941	√	√
9	KHR-59	Lagoon-1	Lagoon-1	22.073978	75.839568	√	√
10	KHR-60	Lagoon-2	Lagoon-2	22.062954	75.852575	√	√
11	KHR-61	Reservoir	Raw water reservoir	22.063462	75.855098	√	√
12	KHR-62	Nala	Nala flowing as groundwater drainage below tower line on road crossing near plant	22.074410	75.850902	√	√

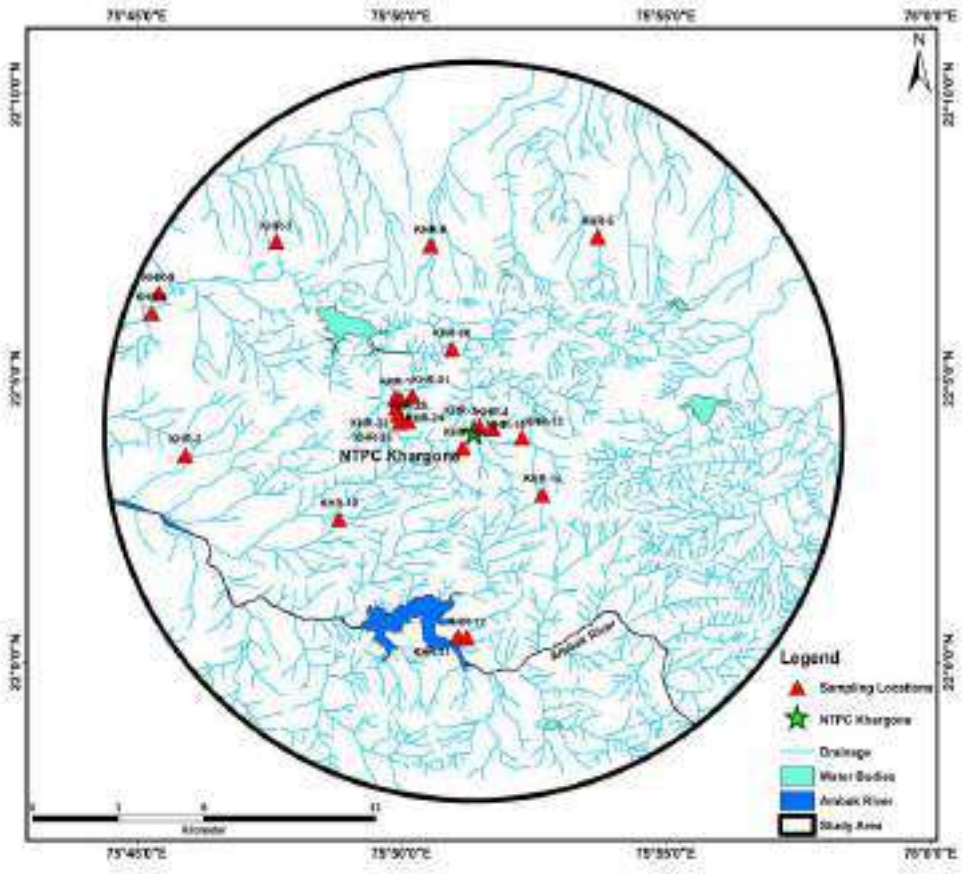


Figure 33: Location map of ground water sampling locations in the study area

Table 10: Details of ground water sampling locations in the study area

S. N.	Site Code	Source	Location	Latitude (deg. N)	Longitude (deg. E)	Pre monsoon monitoring	Post monsoon monitoring
1	KHR-1	HP	In House of Sh. Rai Singh S/O Sh. Jai Sing. On Road of Pipalgaon to NTPC Plant ,Near Electric Triangle pole of HT Line, Vill Dalchi	22.077748	75.831549	√	√
2	KHR-2	HP	Aanganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd	22.060904	75.765297	√	√
3	KHR-3	HP	Near NTPC opp Bhilal Baba Temple,Gate No. 1,opp Cooling Towers, Below Bargad Tree	22.069258	75.857885	√	√
4	KHR-4	OW	Between NTPC & Town ship, opp Boundry Piller S.N. 230-240	22.068803	75.862023	√	√
5	KHR-5	HP	opp Primary School on road. Vill Badgaon	22.124938	75.895198	√	√
6	KHR-6	HP	opp Madhya Pradesh Gramin Bank, opp Health Centre. Vill Kanapur	22.122422	75.842507	√	√
7	KHR-7	HP	In House of sh. Daya Ram, Vill Londhi (Jhirbar)	22.123495	75.794000	√	√
8	KHR-8	HP	opp Sabir`s House, Sanawat-Kasravad Road,opp Baba Shree Dhaba, Vill Pipalgoan	22.102585	75.754665	√	√
9	KHR-9	TW	Adjoining of Jai Bajrang Kirana, Neharu Nagar Pipalgoan	22.108389	75.756944	√	√
10	KHR-10	HP	opp Surandra Singh House in Dinesh Nihal House Compound, vill Bhopada	22.042080	75.813743	√	√
11	KHR-11	HP	opp Shivji Panwar House,Vill Padliya Gawli	22.007591	75.851219	√	√
12	KHR-12	TW	Vill Padalia	22.007275	75.853942	√	√
13	KHR-13	OW	Adjoining of NTPC Community Centre Near New Hanumaan Temple	22.066083	75.871388	√	√
14	KHR-14	HP	Opp Panchayat Bhawan, Vill Kheri Bujurg	22.049303	75.877826	X	√
15	KHR-15	TW	Near Bhilal Baba Temple, opp cooling tower, Near NTPC	22.069233	75.857978	√	√

			Gate no. 1				
16	KHR-18	OW	Inside of Plant	22.062953	75.852559	√	√
17	KHR-19	HP	opp Community Centre Near Primary School, Near Baba Ramdev Mandir, Dalchi	22.075184	75.824819	√	√
18	KHR-20	HP	opp Sh Mukesh House, Vill Jamnia	22.092052	75.849177	√	√
19	KHR-21	Pz	Between ash dyke and road	22.078296	75.836748	X	√
20	KHR-22	Pz	Just away from road cutoff	22.077181	75.833062	X	√
21	KHR-23	Pz	Before Pump house opp. side Near RCC-3 Poles	22.0747722	75.831750	X	√
22	KHR-24	Pz	Near pump house left side	22.072914	75.832372	X	√
23	KHR-25	Pz	Opp. Twin pole no. 8	22.0705508	75.832784	X	√
24	KHR-26	Pz	Near Tringle pole and Twin pole	22.0708942	75.835508	X	√

The samples were brought from the field and were analyzed at the Water Quality Laboratory of the National Institute of Hydrology, Roorkee, which is an NABL accreted laboratory. The surface water samples were analyzed for pH, EC, DO, BOD, COD, major cations (Na, K, Ca, Mg and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F and PO_4) and heavy metals as per IS: 2296. All the parameters were analyzed following Standard Methods for the Examination of Water and Wastewater (APHA, 1995). All anions and cations were analyzed on Metrohm Make Ion Chromatograph (IC) Model 930 (for anions and cations) and Potentiometric Auto Titrator Model 888 system (for bicarbonate). Samples were preserved for heavy metals (Cd, Zn, Hg, As, Cr, Pb etc) using Conc. HNO_3 to reduce their pH<2 and were analyzed using Analysis of heavy metals was carried out using Inductively Coupled Plasma Optical Emission spectrometer (Agilent ICP-OES, VDV 5110). Ground water samples were analyzed for physico-chemical parameters such as pH, EC, temperature, TDS, alaklinity and hardness, major cations (Na, K, Ca, Mg and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F and PO_4) and heavy metals. The ground water quality parameters were monitored as per latest IS: 10500 (BIS, 2012).

For the analysis of heavy metals, the samples were preserved using Conc. HNO_3 to reduce their pH<2. For quality control of analytical results, the samples were run in triplicate and the relative errors were less than ± 6 %. The operational conditions were adjusted in accordance with the manufacturer's guidelines to yield optimal determination. All the laboratory analysis was carried out at the National Institute of Hydrology, Roorkee.

6.3 Water Quality of Surface Waters

The various parameters of the surface samples including physical parameters, major ions and heavy metals have been determined for both the pre-monsoon and post monsoon seasons. The results are discussed in sections ***6.3.1 to 6.3.3.***

6.3.1 Physical parameters

Table 11 presents the physical parameters of the 12 surface water locations monitored for the study area during the pre-monsoon period of May 2022. The physical parameters of the surface water locations monitored for the study area during the post monsoon period of November 2022 are presented in ***Table 12.***

Table 11: Physical parameters of surface waters in the study area during pre-monsoon (May 2022)

S.N.	Site Code	Temp.	pH	EC	TDS	Alkalinity	Hardness	DO	BOD	COD
		°C		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-51	28.2	6.3	1242	795	138	401	3.1	10	41
2	KHR-52	30.9	6.3	945	605	261	210	5.7	17	115
3	KHR-53	28.6	6.3	656	420	77	241	7.2	12	57
4	KHR-54	29.3	6.1	380	243	126	127	6.6	9	41
5	KHR-55	31.4	6.2	383	245	132	132	6.4	8	48
6	KHR-56	23.9	6.7	1484	950	490	555	6.4	12	66
7	KHR-57	26.9	6.5	478	306	163	162	6.3	11	74
8	KHR-58	29.2	6.4	1344	860	82	520	6.9	11	32
9	KHR-59	31.5	6.0	2810	1798	22	985	5.1	9	41
10	KHR-60	30.4	6.0	1050	672	81	415	6.1	11	33
11	KHR-61	28.5	6.4	350	224	122	127	6.4	11	58
12	KHR-62	30.7	6.2	1383	885	155	536	6.5	9	58

Table 12: Physical parameters of surface waters in the study area during post-monsoon (November, 2022)

S.N.	Site Code	Temp.	pH	EC	TDS	Alkalinity	Hardness	DO	BOD	COD
		°C		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-51	26.7	8.2	663	461	159.4	285	6.8	50	61
2	KHR-52	25.9	7.6	609	443	210.4	221	6.8	40	52
3	KHR-53	26.6	7.4	641	458	158.6	284	7.2	5	9
4	KHR-54	26.6	8.3	372	275	143.2	148	6.5	4	9
5	KHR-55	27.8	7.9	424	307	150.4	182	6.2	12	17
6	KHR-56	27.5	7.7	482	454	130.4	208	7.2	6	9
7	KHR-57	24.3	7.5	347	261	141.4	155	6.8	5	9
8	KHR-58	26.7	7.3	740	476	77.0	300	6.7	5	9
9	KHR-59	25.6	6.9	900	605	29.0	318	6.4	12	17
10	KHR-60	26.2	7.9	661	422	76.6	262	6.8	11	17
11	KHR-61	26.2	7.4	281	222	120.8	131	6.8	6	9
12	KHR-62	28.8	8.0	761	524	141.0	318	4.4	14	17

The temperature of the surface waters varied from 23.9^{0}C to 31.5^{0}C during the pre-monsoon season. It varied from 24.3^{0}C to 28.8^{0}C during the post-monsoon season.

During the pre-monsoon season of May 2022, pH ranged from 6.0 to 6.7 in the study area. The average pH of the surface waters of the study area comes out to be 6.3. Thus, water in most part of the study area was moderately acidic. During the post-monsoon season of November 2022, pH ranged from 6.9 to 8.3 in the study area. The average pH of the surface waters of the study area comes out to be 7.7. Thus, water in most part of

the study area was alkaline. The pH was within the acceptable limit at all the locations during the post monsoon. However, it was marginally below the BIS acceptable level of 6.5 for drinking water, at all the locations during pre-monsoon.

As far as EC of surface waters of the study area is concerned, the average value of EC for surface water during the pre-monsoon period (May 2022) was found to be 1042 µS/cm. However, a wide variation was observed at different places with a minimum 350 µS/cm for raw water reservoir in the plant and maximum of 2810 µS/cm for Lagoon-1. The average value of EC for surface water during the post-monsoon period (November 2022) was found to be 573 µS/cm. However, like the pre-monsoon season, a wide variation was observed at different places with a minimum 281 µS/cm for raw water reservoir in the plant and maximum of 900 µS/cm for Lagoon-1.

The variation of TDS for surface waters in the pre monsoon period in the study area was between a lowest value of 224 mg/l for the raw water reservoir to a maximum value of 1798 mg/l for Lagoon-1. The average TDS value for the study for the pre-monsoon season of 2022 was 667 mg/l. The variation of TDS for surface waters in the post monsoon period in the study area was between a lowest value of 222 mg/l for the raw water reservoir to a maximum value of 605 mg/l for Lagoon-1. The average TDS value for the study for the post-monsoon season of November 2022 was 409 mg/l. The TDS was found to be under the BIS acceptable limit of 500 mg/l for drinking water at 10 out of 12 locations (except at KHR-59 and KHR-62) during the pre-monsoon season. During the post-monsoon, however it was found to be under the BIS acceptable limit at five locations with seven locations showing higher concentration than the acceptable limit. It was, however, much below the BIS permissible limit of 2000 mg/l at all the locations during both the pre and post monsoon.

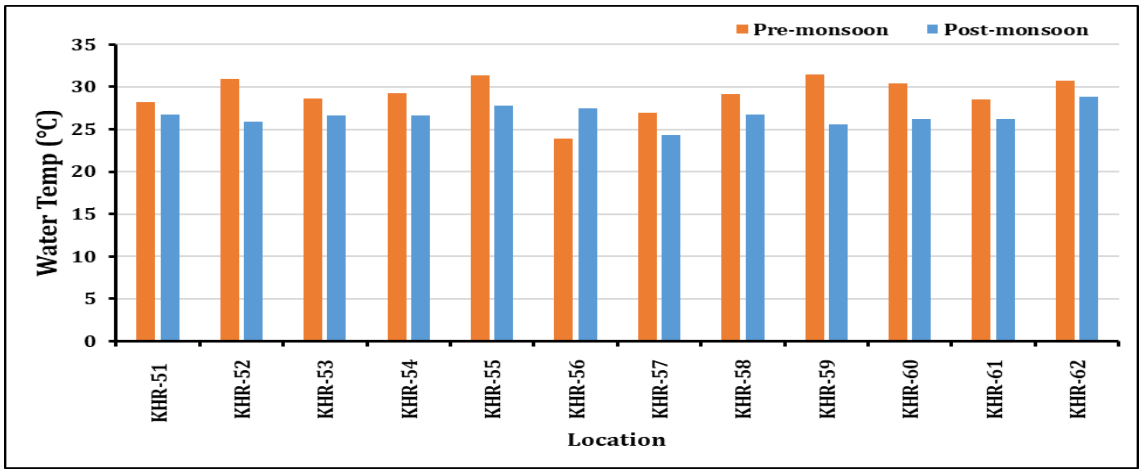
The average value of alkalinity for surface water during the pre-monsoon period (May 2022) was found to be 154 mg/l within a range of minimum 22 mg/l for Lagoon-1 to 490 mg/l for the Lachhora Talab. The average value of alkalinity for surface water during the post-monsoon period (November 2022) was found to be 128 mg/l within a range of minimum 29 mg/l for Lagoon-1 to 210 mg/l for the KHR-52 (near health center along Main road, village Kanapur). The alkalinity values were found to be under the BIS acceptable limit of 200 mg/l for drinking water at all the locations during the post monsoon, except at KHR-52 where it was marginally above at 210.4 mg/l. During pre-monsoon also it was under the acceptable limit at ten out of the twelve locations (except at KHR-52 and KHR-56). However, it was much below the permissible limit of 600 mg/l at all the locations during both the pre and post monsoon.

In the present study, as far as surface waters are concerned, the average value of hardness was 368 mg/l during the pre-monsoon period of May 2022. It varied within a range of 127-985 mg/l. Higher value of 985 mg/l was observed for Lagoon 1 and lower of 127 mg/l was recorded for Narmada River, Near Siyaram Baba Ashram. The average value of hardness was 234 mg/l during the post-monsoon period of November 2022. It varied within a range of 131-318 mg/l. Higher value of 318 mg/l was observed for Lagoon 1 and lower of 131 mg/l was recorded for raw water reservoir in the plant. Although hardness was found to be above the BIS acceptable limit of 200 mg/l at many locations both during the pre-monsoon and post-monsoon, it was observed to be very much within the permissible limit of 600 mg/l at all the locations both during the pre

and post monsoon except at KHR-59 during pre-monsoon when it was higher at 985 mg/l.

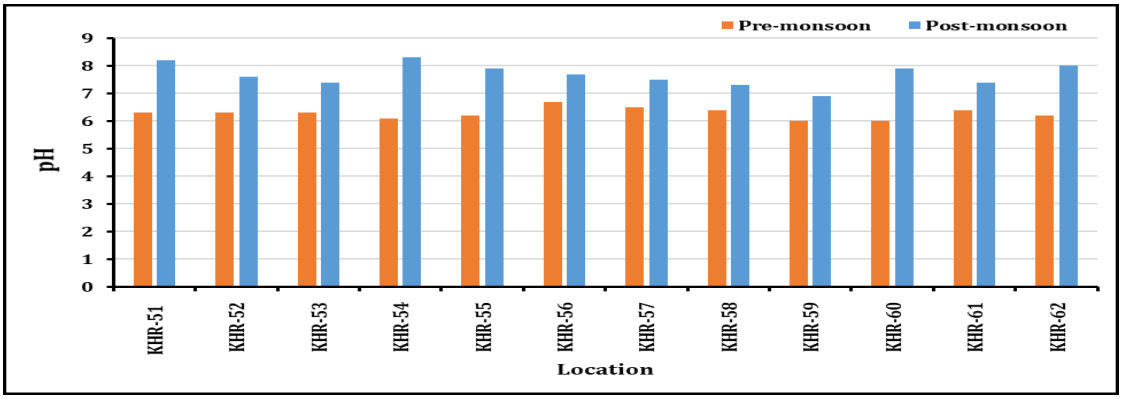
The average values of DO, BOD and COD for the surface waters in the study area during the pre-monsoon season are 6.1, 10.8 mg/l and 55.3 mg/l respectively. DO ranged from 3.1 mg/l to 7.2 mg/l, BOD ranged from 9 mg/l to 17 mg/l, the COD values varied between 32 mg/l to 115 mg/l. The average values of DO, BOD and COD for the post-monsoon period are 6.6 mg/l, 14.2 mg/l and 19.6 mg/l respectively. DO ranged from 4.4 mg/l to 7.2 mg/l, BOD ranged from 4.0 mg/l to 50.0 mg/l, the COD values varied between 8.7 mg/l to 61.0 mg/l.

Comparison of physical parameters of surface waters of the study area during pre and post monsoon periods is shown in ***Figure 34***. Surface water temperature was found to be higher during the pre-monsoon compared to the post monsoon. The variation is obviously due to the variation of corresponding air temperature during the two seasons. Comparison of pH clearly shows a shift in the pH of surface water from moderately acidic to alkaline. This shift from moderately acidic to alkaline is due to the addition of rain water during the monsoon season. EC of surface waters during post monsoon periods indicates reduction in the EC of surface waters due to the dilution effect of monsoon rainfall at almost all the locations, except for a very small rise at KHR-55. A reduction in the TDS of surface waters is observed during post monsoon period due to the dilution effect of monsoon rainfall at most locations, except for a very small rise at KHR-54 and KHR-55. Alkalinity shows marginal rise at KHR-51, KHR-53, KHR-54, KHR-55 and KHR-59. At the remaining locations a reduction was observed. While hardness was lowered in most locations, it marginally increased at a few locations. Comparison of DO, BOD and COD during pre and post monsoon periods indicates that while COD significantly reduced almost at all locations except at KHR-51, DO and BOD decreased at few locations and increased at the other locations.

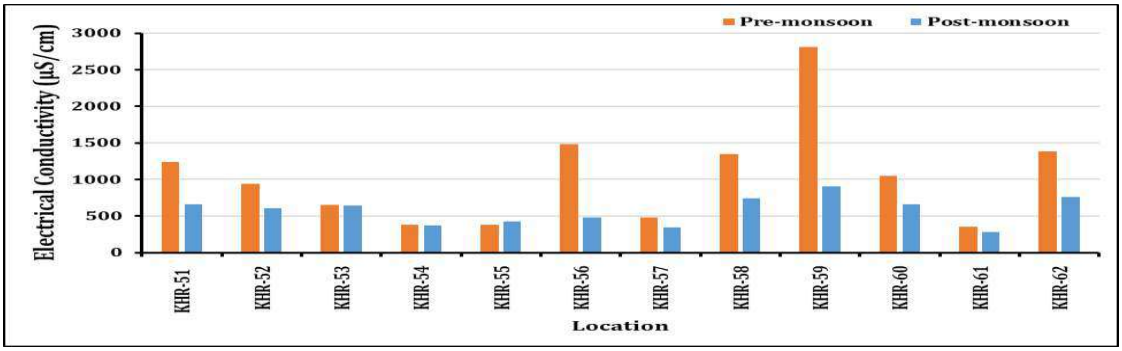


(a) Temperature

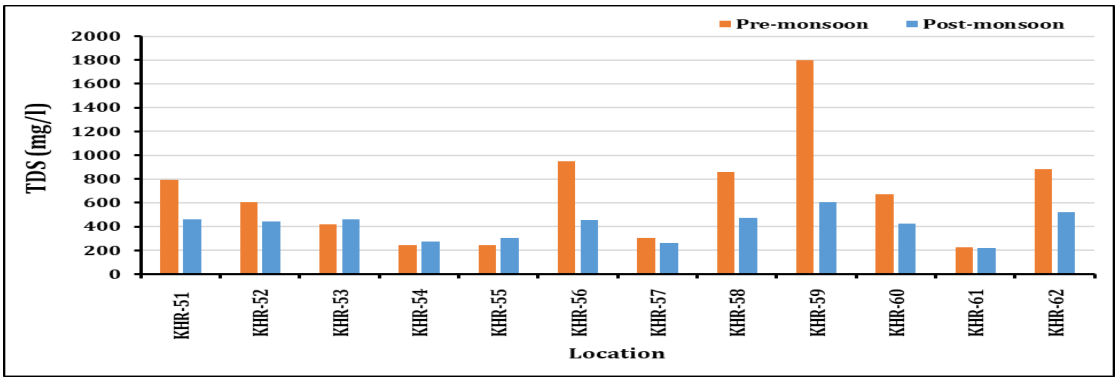
Figure 34: Comparison of physical parameters of surface waters of the study area during pre and post monsoon periods



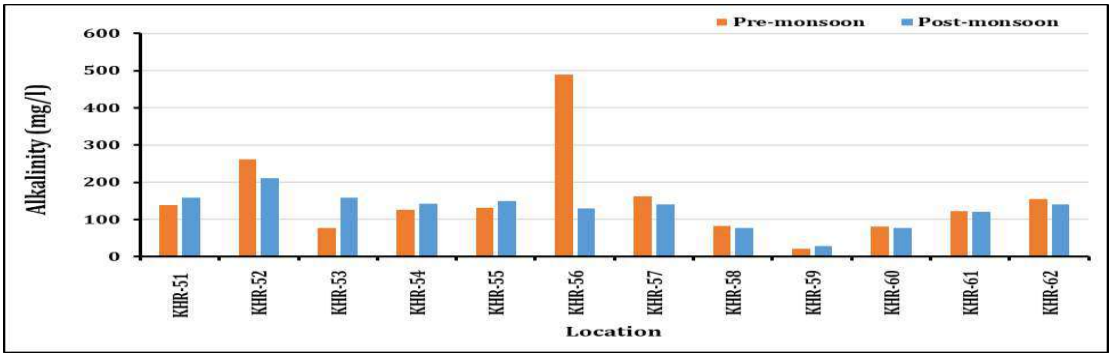
(b) pH



(c) EC

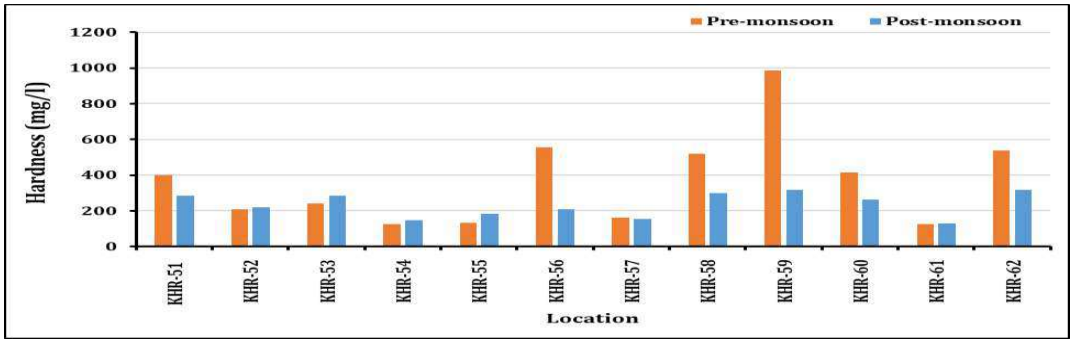


(d) TDS

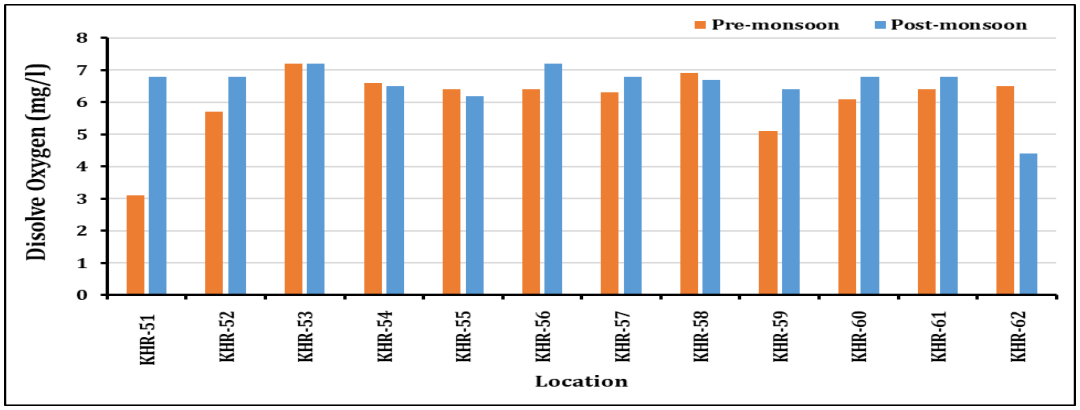


(e) Alkalinity

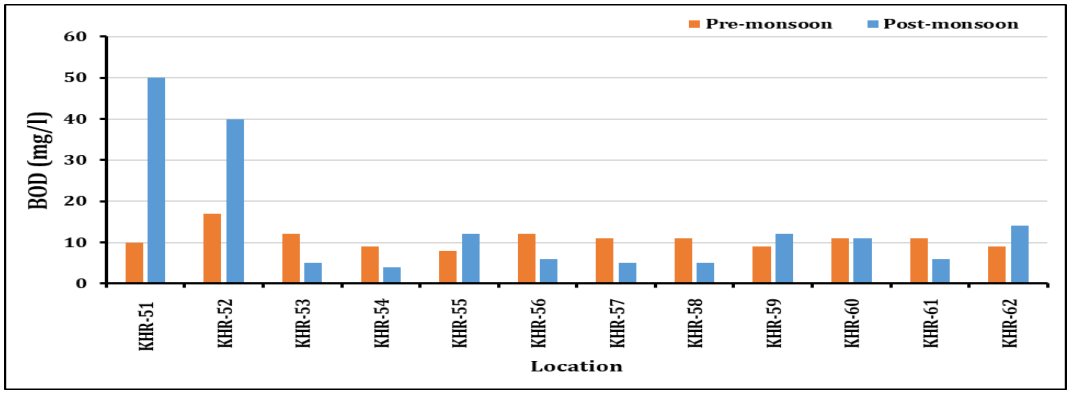
Figure 34:....Contd.



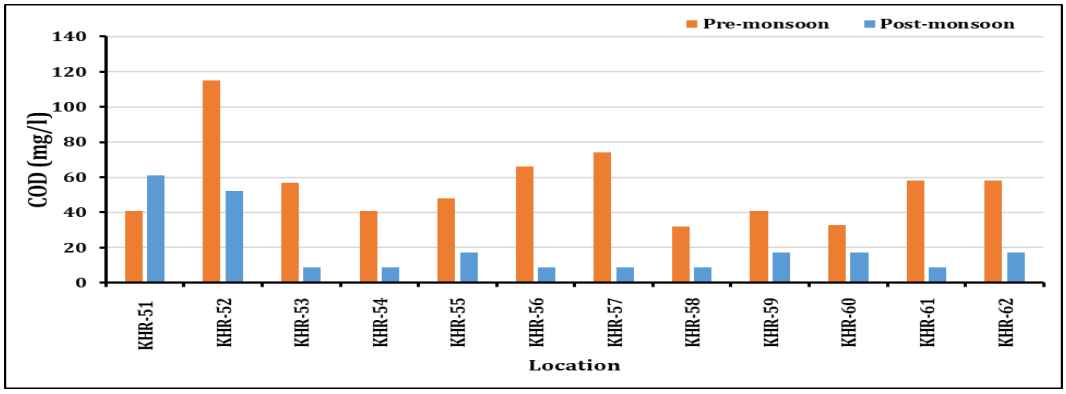
(f) Hardness



(g) DO



(h)BOD



(i) COD

Figure 34:....Contd.

6.3.2 Major ions

Table 13 presents the major ions as observed in the surface water samples of the study area for the pre-monsoon period of May 2022 while ***Table 14*** presents the results for the post monsoon period of November, 2022.

Table 13: Major ions in surface waters of study area during pre-monsoon

S.N.	Site Code	Na	K	Ca	Mg	NH_4	F	Cl	HCO_3	SO_4	NO_2	NO_3	PO_4
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-51	78	4.92	65	58	0.28	0.38	125	168	287	ND	5.63	ND
2	KHR-52	70	45	33	31	0.49	0.48	98	318	6.8	8.7	0.25	ND
3	KHR-53	41	3.34	42	33	0.83	0.47	66	94	135	ND	2.14	ND
4	KHR-54	15	2.44	31	12.12	0.51	0.22	7.39	154	17	ND	0.61	ND
5	KHR-55	16	2.5	33	12	0.66	0.22	9.4	161	7.5	0.21	1.67	ND
6	KHR-56	74	7.6	59	99	2.94	0.22	56	598	45	ND	7.7	ND
7	KHR-57	21	2.1	37	17	0.87	0.39	11	199	13	ND	2.39	ND
8	KHR-58	64	9.3	131	47	3.89	2.9	80	100	425	ND	0.44	ND
9	KHR-59	86	42	301	57	5.9	14	88	27	1192	ND	1.89	ND
10	KHR-60	53	8	107	36	4.4	2.39	64	99	330	ND	1.45	ND
11	KHR-61	14	2.1	31	12	0.35	0.19	6.6	149	6.8	0.01	0.05	ND
12	KHR-62	74	2.8	144	43	4.15	0.61	158	189	262	0.11	8.7	ND

Table 14: Major ions in surface waters of study area during post-monsoon

S.N.	Site Code	Na	K	Ca	Mg	NH_4	F	Cl	HCO_3	SO_4	NO_2	NO_3	PO_4
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-51	26.80	2.53	62.42	31.54	ND	0.30	51.80	194.47	86.82	ND	4.21	ND
2	KHR-52	32.02	24.68	43.24	27.66	ND	0.25	39.34	256.69	14.15	ND	5.06	ND
3	KHR-53	28.45	2.85	63.97	30.26	0.22	0.35	38.66	193.49	91.33	ND	8.77	ND
4	KHR-54	18.68	4.36	38.21	12.82	ND	0.22	9.09	174.70	9.35	ND	7.13	ND
5	KHR-55	18.70	2.25	38.64	20.84	ND	0.20	15.52	183.49	16.94	ND	10.52	ND
6	KHR-56	22.88	1.52	42.86	24.51	0.28	0.24	15.29	159.09	28.29	ND	5.60	153.58
7	KHR-57	14.48	0.68	38.06	14.62	ND	0.29	6.55	172.51	10.65	ND	2.90	ND
8	KHR-58	30.73	2.84	81.58	23.35	ND	1.46	50.77	93.94	189.05	ND	2.09	ND
9	KHR-59	38.12	17.18	91.86	21.48	0.26	8.62	51.63	35.38	337.90	ND	2.11	ND
10	KHR-60	29.21	3.50	75.00	18.09	ND	1.71	44.96	93.45	149.95	ND	6.12	ND
11	KHR-61	10.83	1.40	35.60	10.24	ND	0.12	5.751	147.38	8.63	0.20	1.99	ND
12	KHR-62	35.40	1.07	85.22	25.51	ND	0.44	63.87	172.02	129.93	ND	10.28	ND

Cations

The major cations observed in the surface waters of the study area during the pre-and post-monsoon seasons of 2022 include Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and NH^{4+}.

The concentration of sodium ions (Na^{+}) in the pre-monsoon period of May 2022 in the study area varied between the lowest value of 14 mg/l for the raw water reservoir to a highest value of 86 mg/l for the Lagoon 1. The concentration of sodium ions (Na^{+}) in the post-monsoon period of November 2022 varied between the lowest of 10.83 mg/l for the raw water reservoir to a highest of 38.12 mg/l for the Lagoon 1. Similarly, the concentration of potassium ions (K^{+}) varied between the lowest of 2.1 mg/l for the raw water reservoir to a highest of 45 mg/l for the pond located near Health Centre along Main road in village Kanapur, during pre-monsoon. During post-monsoon, the concentration of potassium ions (K^{+}) varied between the lowest of 0.68 mg/l for the

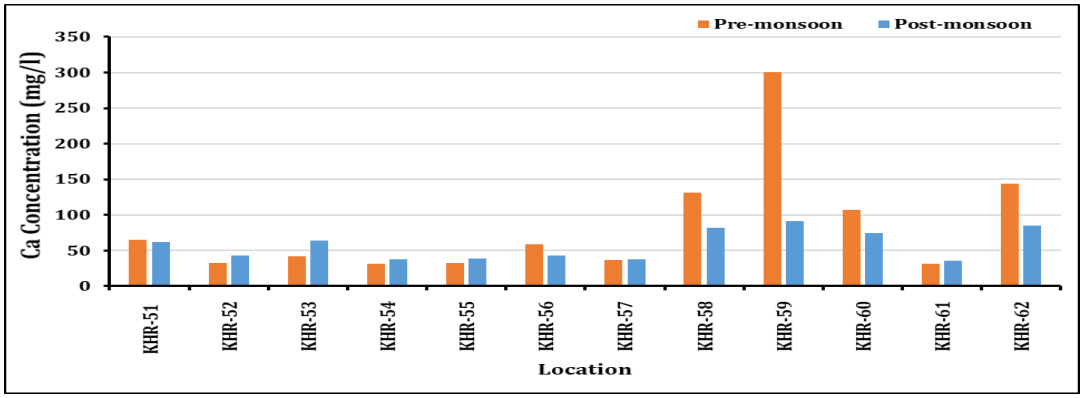
KHR-57 (Kattora Pond, Shelda Plant-Kattora Road) to a highest of 24.68 mg/l for the KHR-52 (pond located near Health Centre along Main road in village Kanapur).

Ca^{2+} in the surface waters of the study area during the pre-monsoon season (May 2022) was found to vary widely between 31 mg/l to 301 mg/l with an average value of 84.5 mg/l for the whole study area. The highest value of 301 mg/l was observed for the Lagoon 1. The lowest value of 31 mg/l was observed for the Narmada River, Near Siyaram Baba Ashram and raw water reservoir. Ca^{2+} in the surface waters of the study area during the post-monsoon season (November 2022) was found to vary between 35.60 mg/l to 91.86 mg/l with an average value of 58.06 mg/l for the whole study area. The highest value of 91.86 mg/l was observed for the Lagoon 1. The lowest value of 35.60 mg/l was observed for the KHR-61 (raw water reservoir). Calcium was found to be under the BIS acceptable limit of 75 mg/l for drinking water at most of the locations during both the pre and post monsoon. It was within the BIS permissible limit of 200 mg/l at all the locations during both the seasons except a KHR-59 during the pre-monsoon with a value of 301 mg/l.

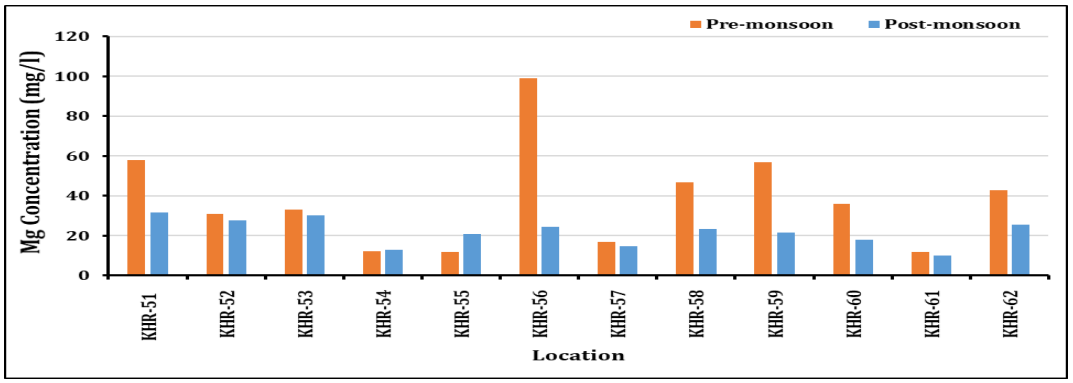
The variation of magnesium (Mg^{2+}) in the surface waters of the study area during the pre-monsoon period of May 2022 ranged between the lowest of 12 mg/l for the Ambak talab to the highest of 99 mg/l for the Lachhora Talab. The variation of magnesium (Mg^{2+}) in the surface waters of the study area during the post-monsoon period of November 2022 ranged between the lowest of 10.24 mg/l for the KHR-61 (raw water reservoir) to the highest of 31.54 mg/l for the KHR-51 (between NTPC Plant and town ship). Magnesium was found to be within the BIS permissible limit of 100 mg/l for drinking water at all the stations during both the seasons. However, it was observed to be slightly above the BIS acceptable limit of 30 mg/l at a few locations during both the seasons, in particular during the pre-monsoon season.

As far as the concentration of ammonium ions (NH^{4+}) in the surface waters is concerned, it ranged between 0.28 mg/l to 5.9 mg/l with an average value of 2.1 mg/l for the whole study area during the pre-monsoon period of May 2022. The highest concentration of 5.9 mg/l was recorded for the Lagoon-1 while the lowest concentration of 0.28 mg/l was observed for the pond between NTPC Plant and Town ship. During the post monsoon period of November 2022, the concentration of ammonium ions (NH^{4+}) in the surface waters is negligible except at three location KHR-53 (Jhirbar Talab), KHR-56 (Lachhora Talab) and KHR-59 (Lagoon-1) where it was 0.22 mg/l, 0.28 mg/l and 0.26 mg/l respectively.

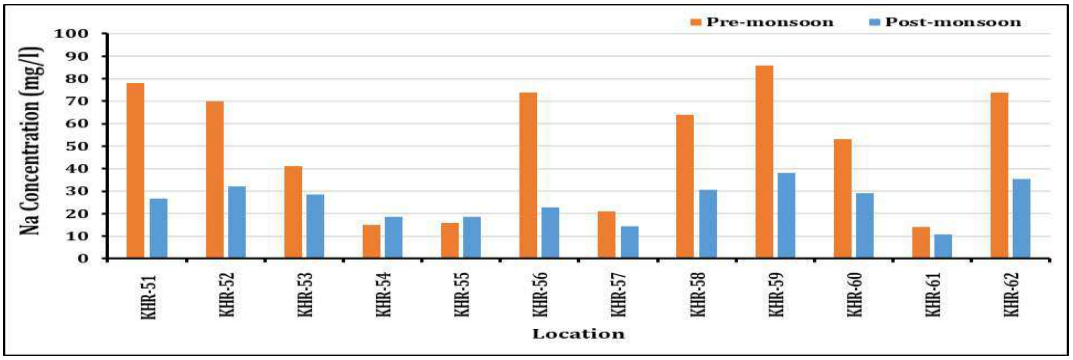
Comparison of the pre-monsoon and post-monsoon data of cations in the surface waters of the study area is shown in ***Figure 35***. It can be observed from ***Figure 35*** that both calcium and magnesium decreased at many locations due to the dilution effect of monsoon rainfall. However, marginal increase was observed at some locations, particularly in the calcium ion concentration. As far as sodium and potassium ion concentration are concerned, comparison of the data indicates that both sodium and potassium decreased at most locations due to the dilution effect of monsoon rainfall. However, marginal increase in potassium at KHR-54 and in sodium at KHR-54 and 55 was observed. Ammonium ion concentration indicates a significant dilution effect.



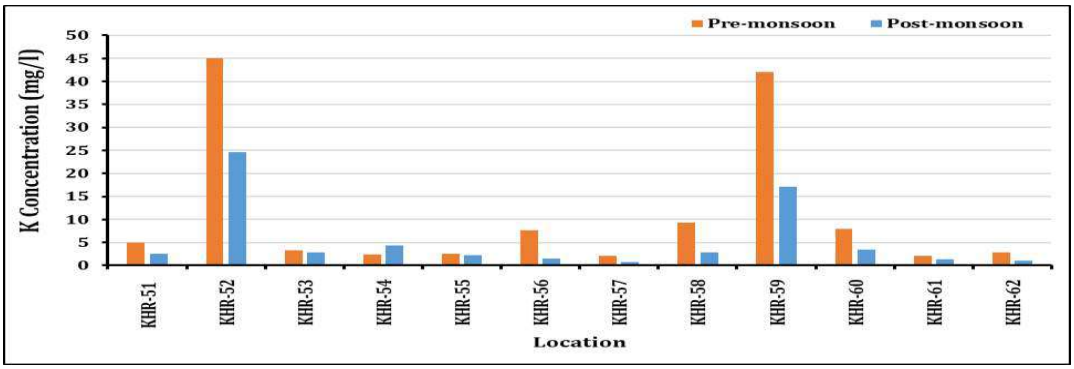
(a) Calcium



(b) Magnesium

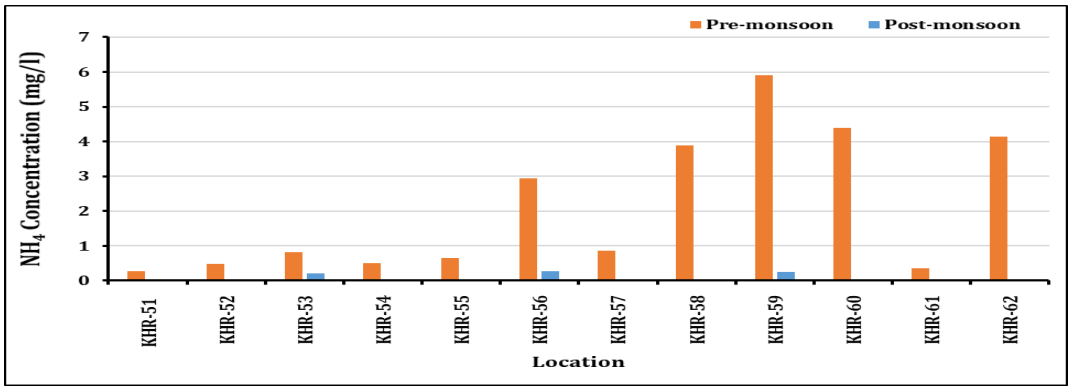


(c) Sodium



(d) Potassium

Figure 35: Comparison of cations of surface waters of the study area during pre-monsoon and post-monsoon



(e) Ammonium

Figure 35:...Contd.

Anions

The anion chemistry of the analyzed samples of the study area shows that F^-, Cl^-, HCO^{3-}, SO_4^{2-} NO_2^- NO_3^- and PO_4^{3-} are the dominant anions in the surface waters of the study area. (***Table 8***).

F^-- in the surface water during the pre-monsoon season (May 2022) was found to vary widely between 0.19 to 14 mg/l with an average value of 1.9 mg/l for the study area. The highest value of 14 mg/l was observed for the Lagoon 1. Lowest value of 0.19 mg/l was observed for the raw water reservoir. F^-- in the surface water during the post-monsoon season (November 2022) was found to vary between 0.13 to 8.62 mg/l with an average value of 1.19 mg/l for the study area. The highest value of 8.62 mg/l was observed for the KHR-59 (Lagoon 1). Lowest value of 0.13 mg/l was observed for the KHR-61 (raw water reservoir). Fluoride was found to be within the BIS acceptable limit of 1 mg/l at nine out of the 12 locations monitored, both during the pre and post monsoon season. At the remaining three locations it was found to be higher than even the permissible limit of 1.5 mg/l, with significantly higher values at KHR-59.

Like fluoride, Chloride (Cl^-) in the surface water was found to vary widely between 6.6 to 158 mg/l with an average value of 64.1 mg/l for the study area during the pre-monsoon. The highest value of 158 mg/l was observed for the Nala flowing as groundwater drainage below tower line on road crossing while the lowest value of 6.6 mg/l was observed for the raw water reservoir. Chloride (Cl^-) in the surface water was found to vary widely between 5.75 to 63.87 mg/l with an average value of 32.77 mg/l for the study area. The highest value of 63.87 mg/l was observed for the KHR-17 (Below Tower Line, North side of Plant, side of NTPC road) while the lowest value of 5.75 mg/l was observed for the KHR-61 (raw water reservoir). Chloride was very much within the BIS permissible limit of 1000 mg/l. Infact it was found to be very much within the BIS acceptable limit of 200 mg/l at all the stations during both the seasons.

HCO_3^- in the surface waters, during the pre-monsoon season (May 2022) was found to vary widely between 27 mg/l to 598 mg/l with an average value of 188 mg/l for the study area. The highest value of 598 mg/l was observed at Lachhora Talab. Lowest value of 27 mg/l was observed Lagoon-1. HCO_3^- during the post-monsoon season

(November 2022) was also found to vary widely between 35.38 mg/l to 256.69 mg/l with an average value of 156.38 mg/l for the study area. The highest value of 256.69 mg/l was observed at KHR-52 (near Health Centre along main road, village Kanapur). Lowest value of 35.38 mg/l was observed KHR-59 (Lagoon-1).

Sulfate (SO_4^{2-}) in the surface waters of the study area was found to vary very widely between 6.8 mg/l to 1192 mg/l during the pre-monsoon season of May 2022. The highest value of 1192 mg/l was observed for the Lagoon 1 while the lowest value of 6.8 mg/l was observed for the pond located near Health Centre along Main road in village Kanapur as well as raw water reservoir. During post-monsoon, the sulfate ion concentration varied between 8.63 mg/l to 337.90 mg/l. The highest value of 337.90 mg/l was observed for the KHR-59 (Lagoon 1) while the lowest value of 8.63 mg/l was observed for the pond located (near Health Centre along main road, village Kanapur). Concentration of sulphate ions was found to be within the BIS acceptable limit of 200 mg/l for 11 out of 12 stations during the post-monsoon. During the pre-monsoon, it was within the acceptable limit at 7 out of 12 monitoring stations. It was within the permissible limit of 400 mg/l at all the stations during post monsoon and at 10 out 12 stations during pre-monsoon.

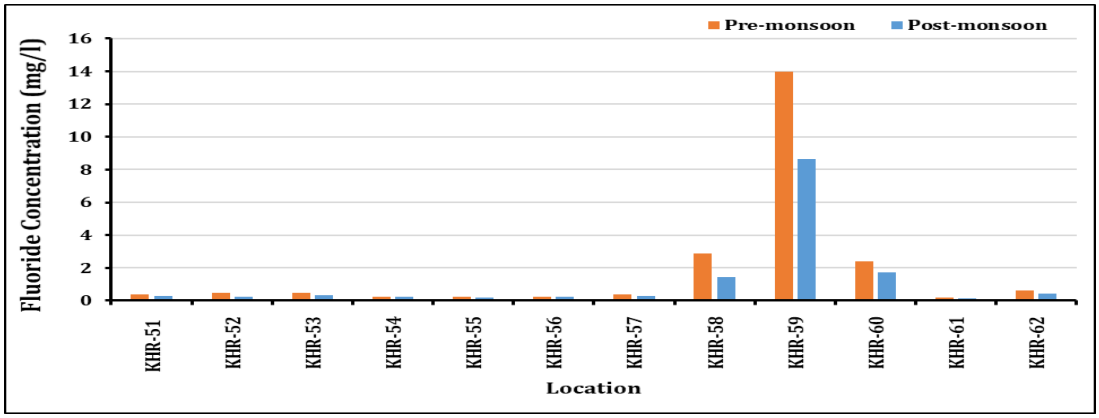
Nitrite (NO_2^-) was not detected in 8 out of the 12 surface water sampling locations in the study area monitored during the pre-monsoon period of May 2022. At the four locations where it was detected, it was observed to be highest at 8.7 mg/l for the pond located near Health Centre along Main road in village Kanapur and lowest at 0.01mg/l for the Nala flowing as groundwater drainage below tower line on road crossing near plant as well as for raw water reservoir. Nitrite (NO_2^-) was not detected in 11 out of the 12 surface water sampling locations in the study area monitored during the post-monsoon period of November 2022. At the one locations where it was detected, it was 0.20 mg/l for the KHR-61 (raw water reservoir).

The concentration of nitrate (NO_3^-) varied between the lowest of 0.05 mg/l for the raw water reservoir to the highest of 8.7 mg/l for the Nala flowing as groundwater seepage below tower line on road crossing near plant, during the pre-monsoon. During post-monsoon the concentration of nitrate (NO_3^-) varied between the lowest of 1.99 mg/l for the KHR-61 (raw water reservoir) to the highest of 10.52 mg/l for the KHR-55 (Ambak talab). Nitrate was found to be very much below the BIS acceptable limit of 45 mg/l at all the stations during both the seasons.

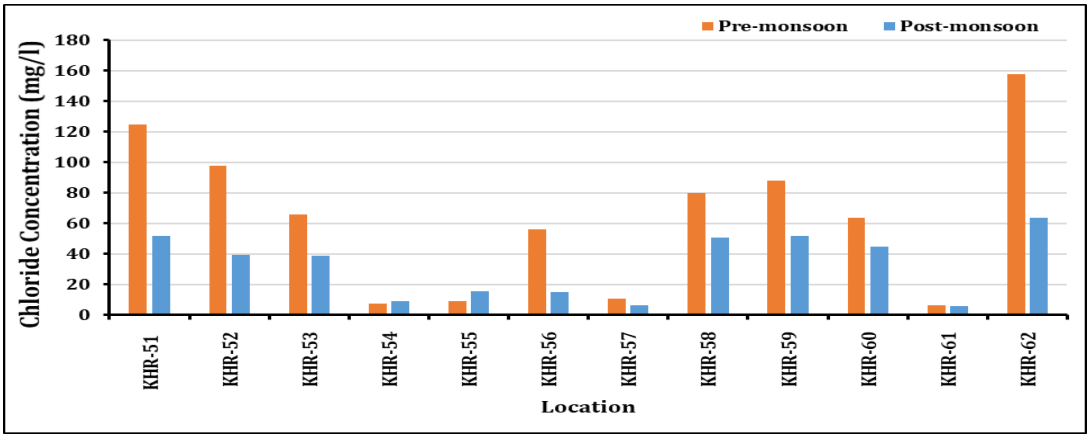
Phosphate was not detected in any of the surface water samples of the study area for the pre-monsoon period of May 2022. During the post-monsoon period of November 2022, it was detected in only one location KHR-56 (Lachhora Talab) where its concentration was observed to be very high (153.58 mg/l).

The comparison of the concentration of anions in the surface waters of the study area during pre and post monsoon is presented in ***Figure 36***. The comparison of fluoride ions indicates a significant dilution effect during the post monsoon period. Similarly, the comparison of the pre-monsoon and post-monsoon data of chloride ions also indicates a significant dilution effect at most of the locations. Bicarbonate ion concentration *indicates* a rise at few places and decrease at other places during the post monsoon season while sulphate indicates a significant reduction in the concentration at

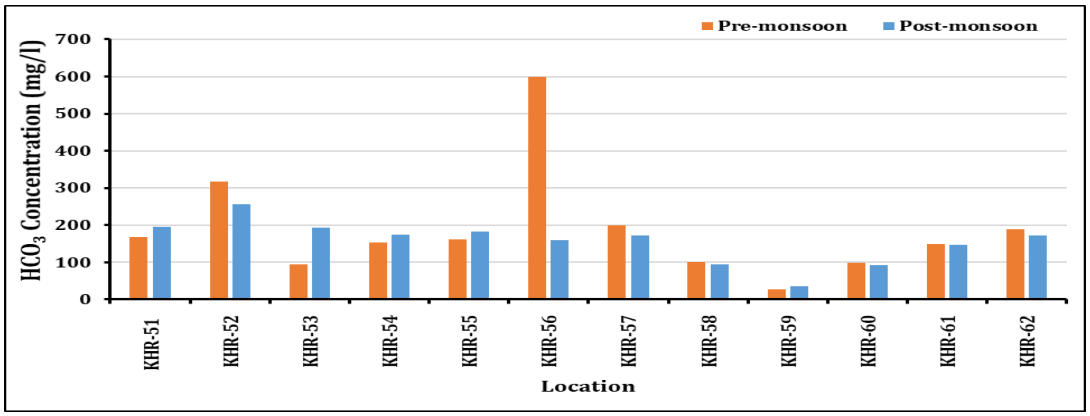
all the location during the post monsoon over pre-monsoon. As far as nitrate ions concentration is concerned, the comparison indicates a significant rise during the post-monsoon at a number of surface water locations in the study area where as decline is observed at a few places.



(a) Fluoride

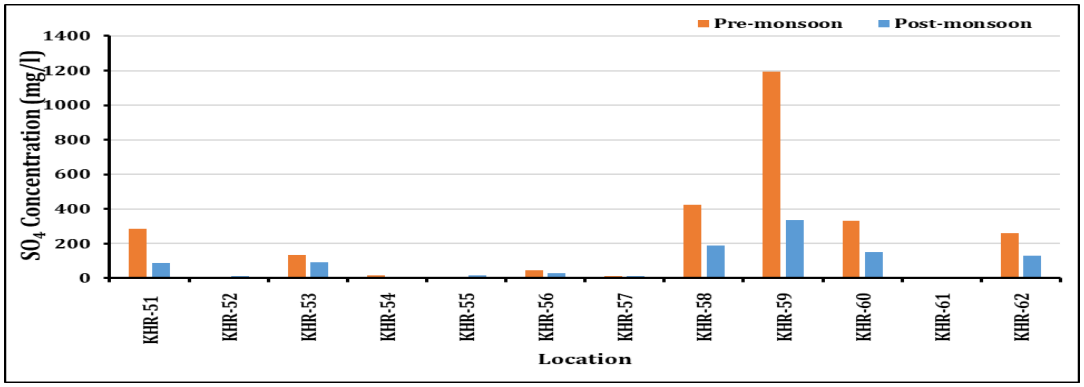


(b) Chloride

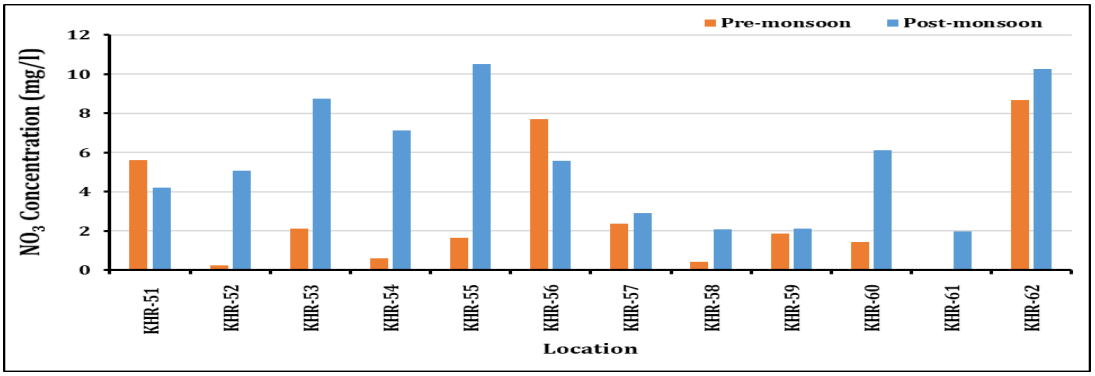


(c) Bicarbonate

Figure 36: Comparison of the concentration of anions in the surface waters of the study area during pre and post monsoon



(d) Sulphate



(e) Nitrate

Figure 36:...Contd.

6.3.3 Heavy Metals

Heavy metal concentrations in surface waters of the study area during the pre-monsoon period of May 2022 is presented in ***Table 15*** while the data for post monsoon is presented in ***Table 16.***

Table 15: Heavy metal concentrations in surface waters of the study area during the pre-monsoon period of May 2022

S.N.	Site Code	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1	**KHR-51**	2.2	336	1136	1.18	4.1	6.9	10	0.72	0.02	0.36	0.5
2	**KHR-52**	3.1	224	1193	1.35	3.9	7.9	115	2.57	0.01	0.31	1.7
3	**KHR-53**	2.5	276	749	0.77	1.9	2.4	96	0.81	ND	0.29	0.2
4	**KHR-54**	2.4	36	235	0.23	1.5	1.5	107	0.75	0.01	0.32	0.6
5	**KHR-55**	2.8	81	928	0.84	2.9	5.0	172	0.78	0.02	0.42	1.0
6	**KHR-56**	2.2	20	172	0.64	3.4	12	61	1.12	0.02	0.28	0.1
7	**KHR-57**	3.9	292	2732	2.51	3.7	9.0	65	0.74	0.01	0.40	0.6
8	**KHR-58**	2.5	52	244	0.44	5.2	2.1	127	7.19	0.03	0.28	0.6
9	**KHR-59**	15	785	788	26	100	20	203	34	1.47	0.54	2.9
10	**KHR-60**	3.7	51	998	1.32	7.7	4.9	119	6.04	0.07	0.30	3.9
11	**KHR-61**	1.9	14	93	0.10	1.3	2.1	86	0.74	0.02	0.27	1.3
12	**KHR-62**	2.3	10	143	0.19	1.4	2.2	95	0.41	0.00	0.33	0.2

Table 16: Heavy metal concentrations in surface waters of the study area during post monsoon period of November 2022

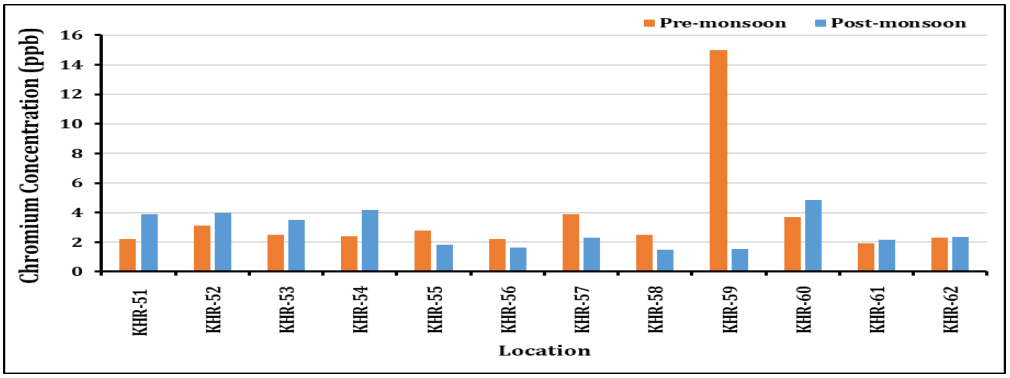
S.N.	Site Code	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1	KHR-51	3.87	349.95	1266.02	1.38	3.47	8.66	30.19	0.77	0.05	0.00	2.28
2	KHR-52	3.97	271.02	678.90	0.98	4.70	5.44	31.21	2.15	0.04	0.00	2.04
3	KHR-53	3.50	121.17	162.55	0.29	1.91	2.29	7.36	0.81	0.02	0.00	0.92
4	KHR-54	4.19	42.31	547.38	0.46	2.47	4.70	18.18	1.20	0.03	0.00	1.33
5	KHR-55	1.82	22.46	232.60	0.24	1.04	2.11	7.91	0.35	0.02	0.25	1.17
6	KHR-56	1.61	21.55	134.61	0.17	0.91	3.03	4.62	0.31	0.02	0.28	1.43
7	KHR-57	2.29	94.95	824.88	0.70	1.48	4.03	6.65	0.31	0.02	0.09	0.94
8	KHR-58	1.50	17.65	210.03	0.23	1.91	2.93	16.33	4.15	0.05	0.06	1.08
9	KHR-59	1.56	489.93	918.74	13.21	47.73	42.67	70.72	7.06	0.84	0.15	2.55
10	KHR-60	4.83	99.98	1543.63	2.93	10.60	17.42	83.92	9.40	0.18	0.07	4.61
11	KHR-61	2.14	16.34	438.93	0.27	1.34	3.37	24.47	0.97	0.02	0.00	1.27
12	KHR-62	2.35	4.38	131.06	0.10	0.76	2.49	19.87	0.27	0.01	0.03	0.79

It can be seen from ***Table 15*** that during the pre-monsoon season, chromium (Cr) ranged from 1.9 ppb to 15ppb. Manganese (Mn) varied in the range of 10 ppb to 785 ppb. The concentration of iron was observed to vary in the range of 93 ppb to 2732 ppb. Cobalt (Co) varied I the range of 0.1 ppb to 26 ppb. The Nickel (Ni) concentration varied in the range of 1.3 ppb to 100. Copper (Cu) varied in the range of 1.5 ppb to 20 ppb. Zinc (Zn) concentration varied from 10 ppb to 203 ppb. Arsenic (As) ranged from 0.41 ppb to 34 ppb. Cadmium (Cd) ranged from 0.0 ppb to 1.47 ppb. Hg varied in the range of 0.27 to 0.54 ppb and Lead (Pb) varied in the range of 0.1 ppb to 3.9 ppb.

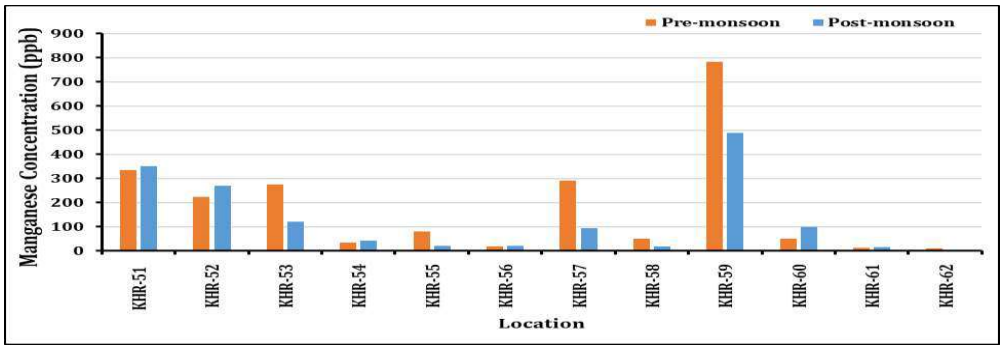
From ***Table 16,*** it can be seen that during the post-monsoon season that chromium (Cr) ranged from 1.50 ppb to 4.83ppb. Manganese (Mn) varied in the range of 4.38 ppb to 489.93 ppb. The concentration of iron was observed to vary in the range of 131.06 ppb to 1543.63 ppb. Cobalt (Co) varied the range of 0.10 ppb to 13.21 ppb. The Nickel (Ni) concentration varied in the range of 0.76 ppb to 47.73 Copper (Cu) varied in the range of 2.11 ppb to 42.67 ppb. Zinc (Zn) concentration varied from 4.62 ppb to 83.92 ppb. Arsenic (As) ranged from 0.27 ppb to 9.40 ppb. Cadmium (Cd) ranged from 0.01 ppb to 0.84 ppb. Hg varied in the range of 0.00 to 0.28 ppb and Lead (Pb) varied in the range of 0.79 ppb to 4.61 ppb.

The concentration of chromium, copper, cadmium, mercury, zinc and lead was found to be very much within the BIS acceptable limits for drinking water at all the stations during both the seasons. Nickel was found to exceed the limit at 1 station each during both the seasons. Similarly, one station was found to exceed the BIS limit for arsenic (0.01 mg/l) during the pre-monsoon season only. Manganese was found to exceed the BIS limit of 0.1 to 0.3 mg/l at two stations each during pre and post monsoon. However, iron was found to exceed the BIS limit of 0.3 mg/l at 7 stations each during both the seasons.

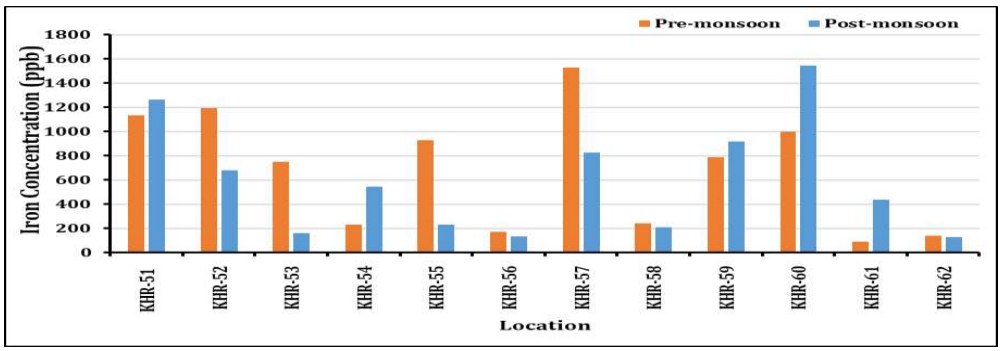
Comparison of pre and post monsoon data of heavy metals in the surface waters of the study area is presented in ***Figure 37.*** The comparison indicates a general reduction in the heavy metal concentration for most of the surface water locations in the study in the post monsoon over the pre monsoon, for all the parameters.



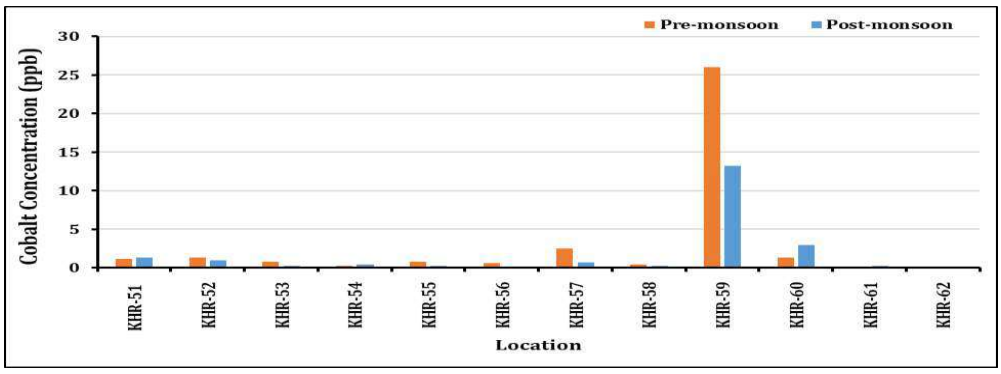
(a) Chromium



(b) Manganese

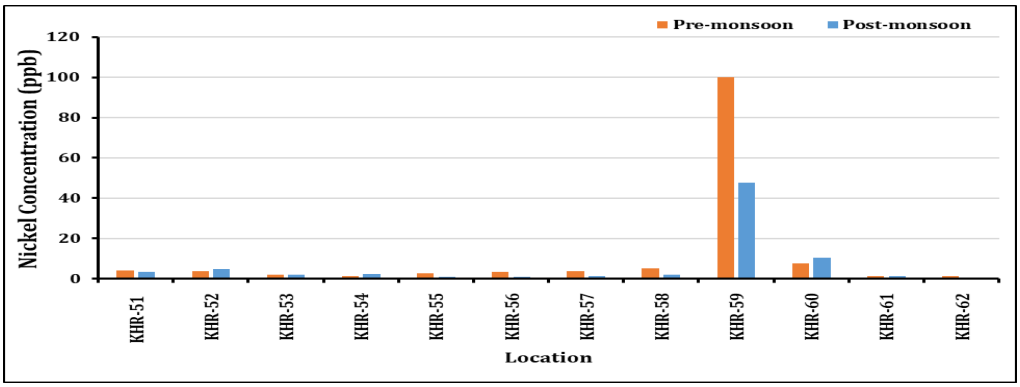


(c) Iron

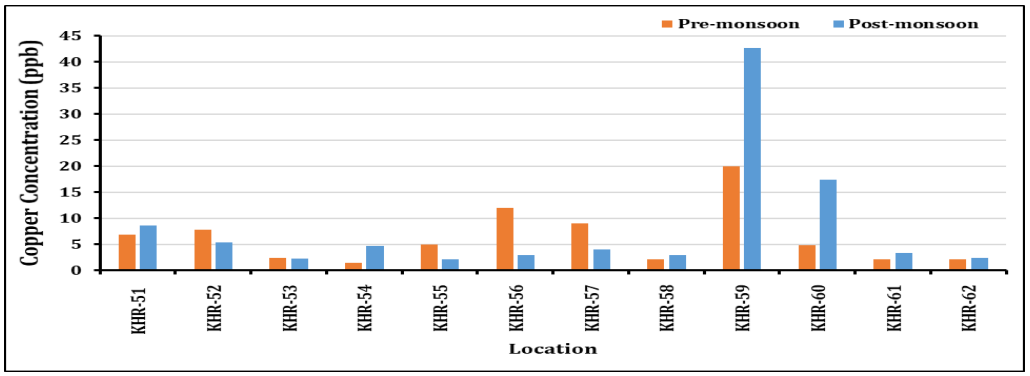


(d) Cobalt

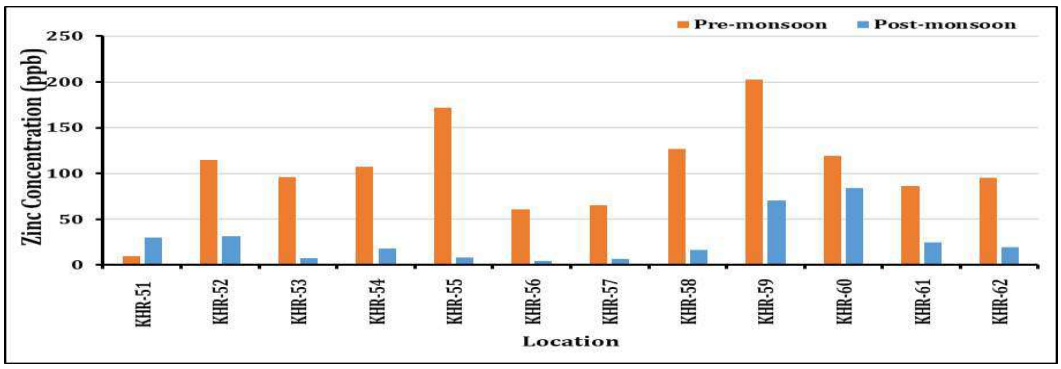
Figure 37: Comparison of pre and post monsoon data of heavy metals in the surface waters of the study area



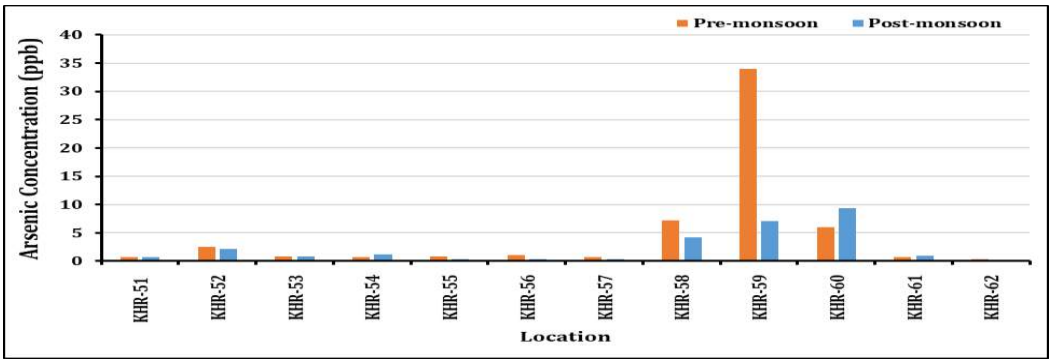
(e) Nickel



(f) Copper

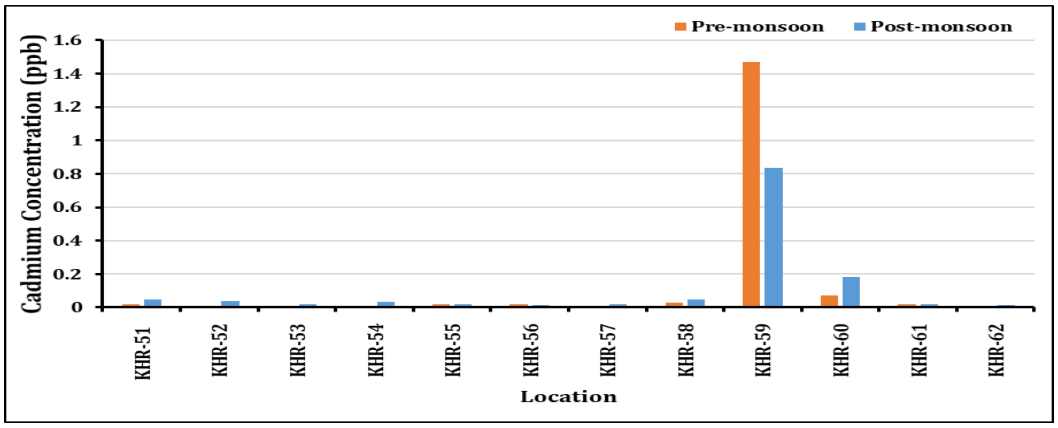


(g) Zinc

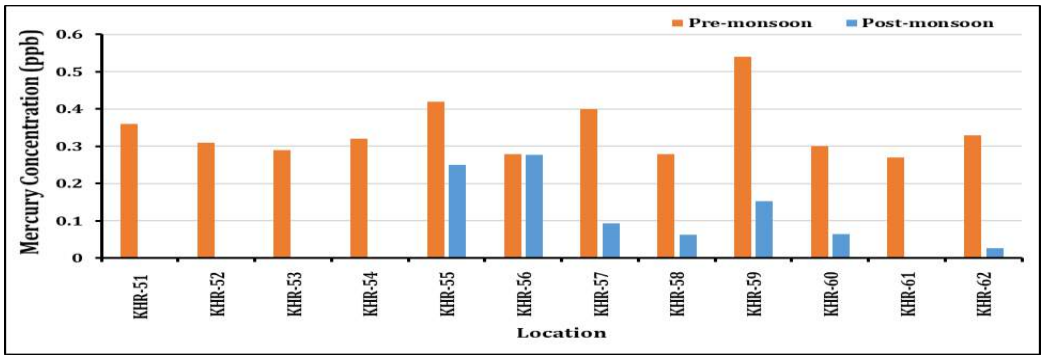


(h) Arsenic

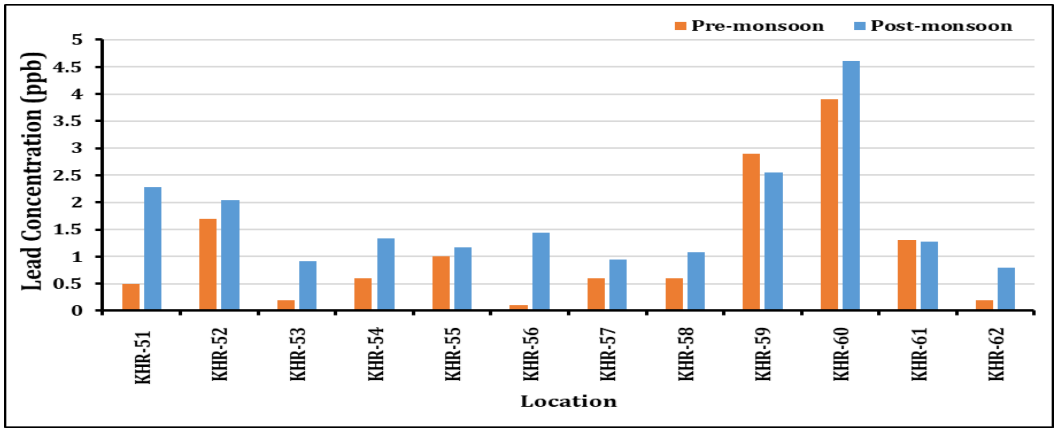
Figure 37:...Contd.



(i) Cadmium



(j) Mercury



(k) Lead

Figure 37:...Contd.

Figure 38 presents some of the photographs of surface water quality monitoring carried out for the study area during pre-monsoon season of May 2022. ***Figure 39*** presents the photographs for the post monsoon monitoring.

Figure 38: Some photographs of surface water quality monitoring in study area during pre-monsoon season of May 2022

Figure 39: Some photographs of surface water quality monitoring in study area during post-monsoon season of November 2022

6.4 Water Quality of Ground Waters

The various parameters of the surface samples including physical parameters, major ions and heavy metals have been determined for both the pre-monsoon and post monsoon seasons. The results are discussed in sections ***6.4.1 to 6.4.3.***

6.4.1 Physical Parameters

Table 17 presents the physical parameters of the groundwater as observed in the study area during the pre-monsoon period of May 2022. The physical parameters of the post-monsoon period of November 2022 are presented in ***Table 18***.

Table 17: Physical parameters of ground waters in the study area during May 2022

S.N.	Sample Code	Temp	pH	EC	TDS	Alkalinity	Hardness
		^{0}C		µS/cm	mg/L	mg/L	mg/L
1	KHR-1	30.6	6.9	952	609	215	400
2	KHR-2	29.9	6.9	1229	787	55.6	305
3	KHR-3	29.7	6.9	1530	979	134	646
4	KHR-4	29.9	6.8	1312	840	159	482
5	KHR-5	29.1	6.9	788	504	235	157
6	KHR-6	27.5	6.9	1359	870	369	492
7	KHR-7	29.3	7.2	884	566	271	362
8	KHR-8	30.6	6.9	1136	727	299	410
9	KHR-9	31.8	7.0	889	569	301	179
10	KHR-10	30.2	6.6	1066	682	225	395
11	KHR-11	28.2	6.6	939	601	276	384
12	KHR-12	32.2	6.9	925	592	287	150
13	KHR-13	31.4	6.7	1264	809	204	375
14	KHR-15	31.9	6.7	1183	757	193	401
15	KHR-17	30.4	6.7	1417	907	199	506
16	KHR-18	29.4	6.6	1536	983	239	673
17	KHR-19	34.1	6.7	1642	1051	260	512
18	KHR-20	30.8	6.7	1198	767	258	544

Table 18: Physical parameters of ground waters in the study area during November 2022

S.N.	Sample Code	Temp	pH	EC	TDS	Alkalinity	Hardness
		^{0}C		µS/cm	mg/L	mg/L	mg/L
1	KHR-1	30.0	6.8	824	594	224.0	388
2	KHR-2	29.8	7.8	1071	749	227.4	253
3	KHR-3	29.7	7.0	843	639	139.2	374
4	KHR-4	26.5	8.2	1436	862	247.8	670
5	KHR-5	28.8	7.2	618	492	239.8	130
6	KHR-6	28.5	7.0	1371	823	380.4	618
7	KHR-7	28.6	7.8	845	642	241.2	408
8	KHR-8	30.5	7.7	590	469	215.4	210
9	KHR-9	29.4	6.9	1652	967	239.0	541
10	KHR-10	29.7	7.3	1361	817	227.4	480
11	KHR-11	28.2	6.8	878	527	318.4	456
12	KHR-12	31.4	7.1	693	526	203.8	152
13	KHR-13	30.2	8.0	946	700	235.0	353
14	KHR-14	29.1	6.7	1131	872	244.8	577
15	KHR-15	31.5	7.2	749	579	224.4	273
16	KHR-18	28.1	7.1	1215	965	245.8	698
17	KHR-19	28.2	6.8	1264	930	177.6	458
18	KHR-20	30.3	6.9	845	783	225.4	524
19	KHR-21	28.6	7.1	663	524	225.4	278
20	KHR-22	30.2	7.1	823	607	209.8	329
21	KHR-23	29.6	7.3	829	628	238.0	260
22	KHR-24	29.1	7.2	1203	919	169.6	631
23	KHR-25	29.8	7.2	948	727	204.8	385
24	KHR-26	29.5	6.8	807	605	188.6	396

During the pre-monsoon season of May 2022, the temperature of the ground waters of the study area ranged from 27.5 to 34.1^{o}C. During the post-monsoon season, the temperature in the ground waters of study area ranged from 24.3 to 31.5 ^{o}C.

pH of the ground waters of the study area ranged from 6.6 to 7.2 during the pre-monsoon season of May 2022. The average pH of the study area comes out to be 6.8. The lowest pH of 6.6 was observed at three places namely open well inside the plant area, villages Bhopada and Padliya Gawli village while the highest pH of 7.2 was recorded for village Londhi. In most parts of the study area pH of the groundwater was very near to neutral or marginally below neutral (i.e. very moderately acidic). During the post-monsoon season of November 2022, pH ranged from 6.7 to 8.2 in the ground waters of the study area. The average pH of the study area comes out to be 7.2. The lowest pH of 6.7 was observed at KHR-14 (Opp. Panchayat Bhawan, village Kheri Bujurg) while the highest pH of 8.2 was recorded for KHR-4 (between NTPC & Town ship, opp. boundary pillar S.N. 230-240). In most parts of the study area pH of the groundwater is very near to neutral or marginally above neutral (i.e. very moderately alakaline). The pH was within the BIS acceptable limit of 6.5-8.5 at all the locations during both the pre and the post monsoon.

The average value of EC for ground water in the study area during the pre- monsoon period (May 2022) was found to be 1181 µS/cm. However, a wide variation was observed at different places with a minimum 788 µS/cm for the hand pump opposite Primary School at village Baddgaon and maximum of 1642 µS/cm for handpump at opposite Community Centre, Near Primary School, village Dalchi. The average value of EC for ground water in the study area during the post-monsoon period (November 2022) was found to be 984 µS/cm. However, like the pre-monsoon season, a wide variation was observed at different places with a minimum 590 µS/cm for the hand pump KHR-8 (opp. Sabir`s House, Sanawat-Kasravad road, opp. Baba Shree Dhaba, village Pipalgoan) and maximum of 1652 µS/cm for handpump at KHR-9 (adjoining of Jai Bajrang Kirana, Neharu Nagar Pipalgoan).

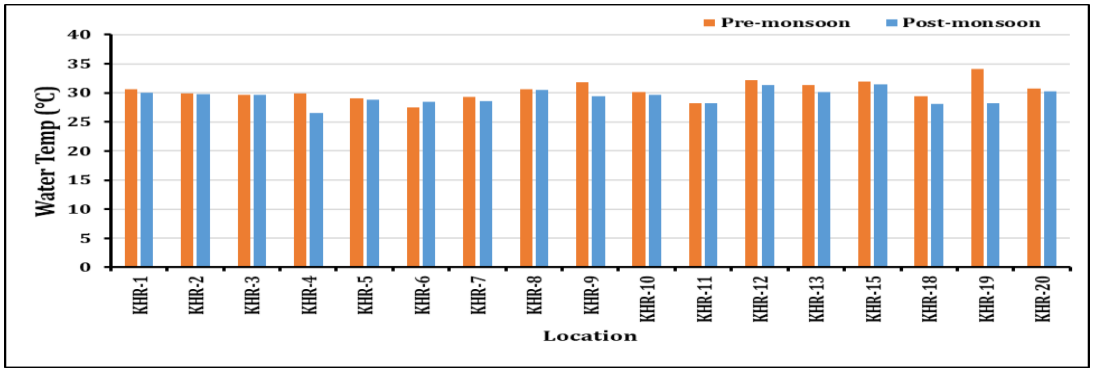
The variation of TDS in the ground waters in the study area during the pre-monsoon period of May 2022 was in the range of lowest value of 504 mg/l for the hand-pump located opposite Primary School in village Baddgaon to a maximum value of 1051 mg/l for handpump located opposite Community Centre, Near Primary School, Near Baba Ramdev Mandir, Dalchi. The average TDS value for the study for the pre-monsoon season of 2022 was 756 mg/l. The variation of TDS in the ground waters in the study area during the post-monsoon period of November 2022 was in the range of lowest value of 469 mg/l for the hand-pump KHR-8 (opp. Sabir`s House, Sanawat-Kasravad road, opp. Baba Shree Dhaba, village Pipalgoan) to a maximum value of 967 mg/l for hand pump located KHR-9 (adjoining of Jai Bajrang Kirana, Neharu Nagar Pipalgoan). The average TDS value for the study for the post- monsoon season of 2022 was 706 mg/l. The TDS was found to exceed the BIS acceptable limit of 500 mg/l for drinking water at most of the locations during both the pre and pre-monsoon season. However, it was found to be well below the BIS permissible limit of 2000 mg/l at all the locations during both the pre and post monsoon.

As far as alkalinity of the ground waters is concerned, the average value of alkalinity of the ground waters during the pre-monsoon period (May, 2022) was found to be 232 mg/l within a range of minimum 56 mg/l for Aanganwadi and School Compound, Near Hanuman Mandir, Village Bhatyaan Khurd to 369 mg/l for the hand pump opposite Madhya Pradesh Gramin Bank, near Health Centre, village Kanapur. As far as alkalinity of the post-monsoon season (November, 2022) is concerned, the average value of alkalinity of the ground waters during the post-monsoon period was found to be 228.9 mg/l within a range of minimum 139.2 mg/l for KHR-3 (near NTPC opp. Bhilal Baba Temple, Gate No. 1, opp. Cooling Towers, below Bargad tree) to 380.4 mg/l for the hand pump KHR-6 (opp Madhya Pradesh Gramin Bank, opp Health Centre, village Kanapur). The alkalinity was found to exceed the BIS acceptable limit of 200 mg/l for drinking water at many locations during both the seasons. However, it was much below the permissible limit of 600 mg/l at all the locations during both the pre and post monsoon

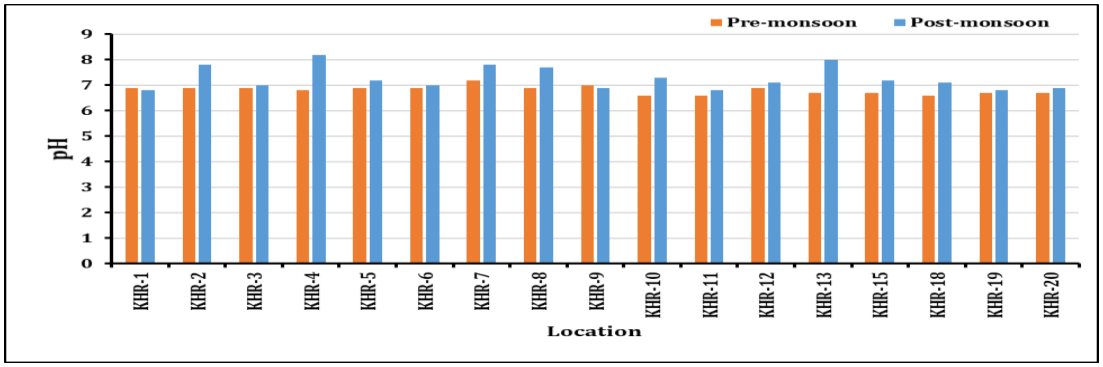
As far as hardness of the ground waters is concerned, the average value of hardness was 410 mg/l during the pre-monsoon period of May 2022. It varied within a range of 150 mg/l to 673 mg/l. Higher value of 673 mg/l was observed for open well inside the plant and lower value of 150 mg/l was recorded for the tube well in village Padalia. As far as hardness of the ground waters is concerned, the average value of hardness was 410 mg/l during the post- monsoon period of November 2022. It varied within a range of 130 mg/l to 698 mg/l. Higher value of 698 mg/l was observed for hand pump KHR-18 (Inside of Plant) and lower value of 130 mg/l was recorded for the hand pump KHR-5 (opp. Primary School on road, village Badgaon). Hardness was found to exceed the BIS acceptable limit of 200 mg/l at most locations during both the pre-monsoon and post-monsoon. It was observed to even exceed the BIS permissible limit of 600 mg/l at two locations during the pre-monsoon and four locations during the post monsoon.

As far as the newly constructed piezometers around the ash dyke are concerned, while none of the piezometers exceeded the acceptable limit for pH, all the piezometers exceeded the acceptable BIS limit for TDS and hardness. While all the piezometer values for TDS were within the permissible limit, one piezometer did exceed the permissible limit for hardness. As far as alkalinity is concerned, while 4 out of 6 piezometers exhibited to exceed the BIS acceptable limit, none of them crossed the permissible limit.

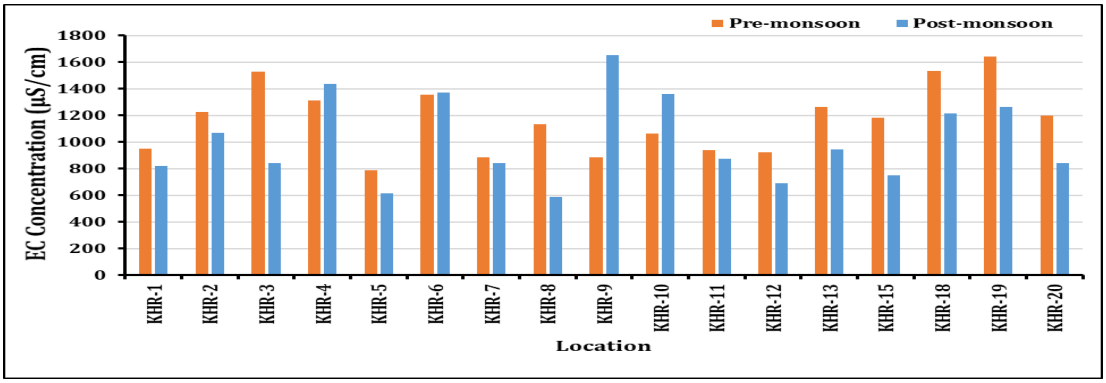
Comparison of physical parameters of the ground waters of the study area during pre and post monsoon periods is shown in ***Figure 40***. Ground water temperature was found to be higher during the pre-monsoon compared to the post monsoon. Comparison of pH clearly shows a shift in the pH of ground water from moderately acidic to alkaline. This shift from moderately acidic to alkaline is due to recharge by the addition of rain water during the monsoon season. EC of ground waters during the post monsoon periods indicates reduction in the EC of surface waters due to the dilution effect of monsoon rainfall at most of the locations, except for an increase at a few places. A reduction in the TDS was also observed during post monsoon period at most of the locations, with an increase witnessed at a few places due to the effect of the monsoon rainfall. Alkalinity showed marginal rise at many places. However, at KHR-, the increase was significant. At the remaining locations a reduction was observed. While hardness was lowered in most locations, it marginally increased at a few locations. Thus, an overall effect of the recharge by ground water on most physical parameters was observed at most of the locations.



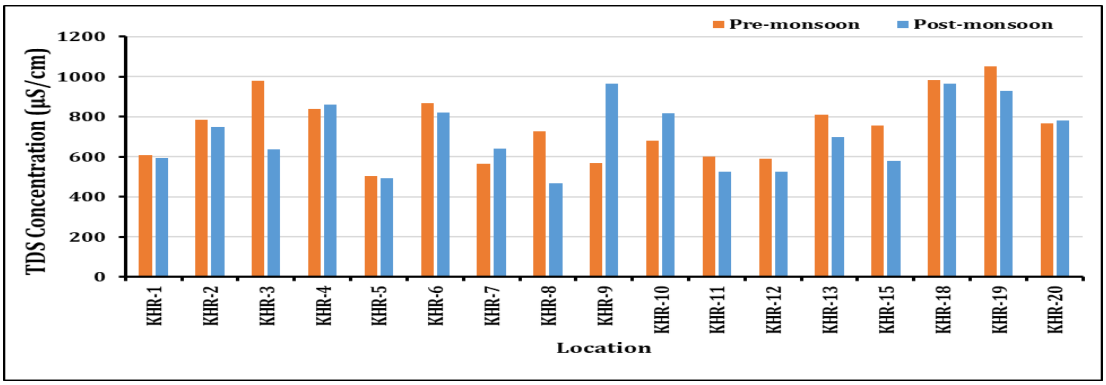
(a) Temperature



(b) pH

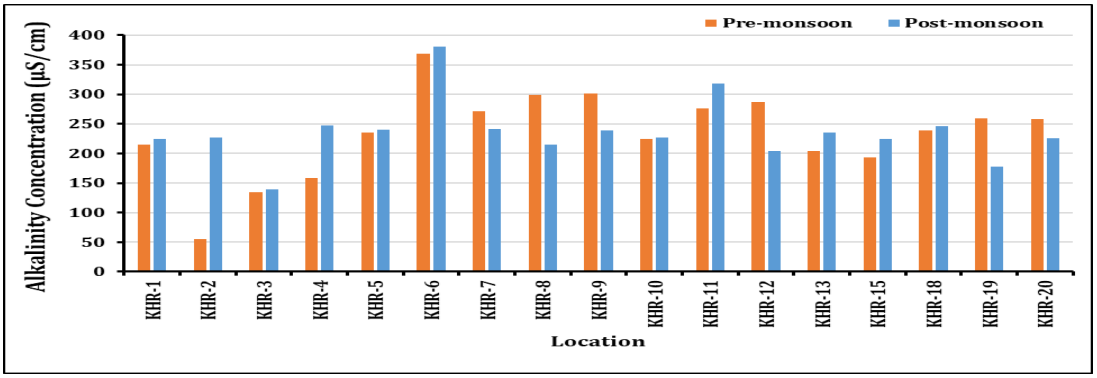


(c) EC

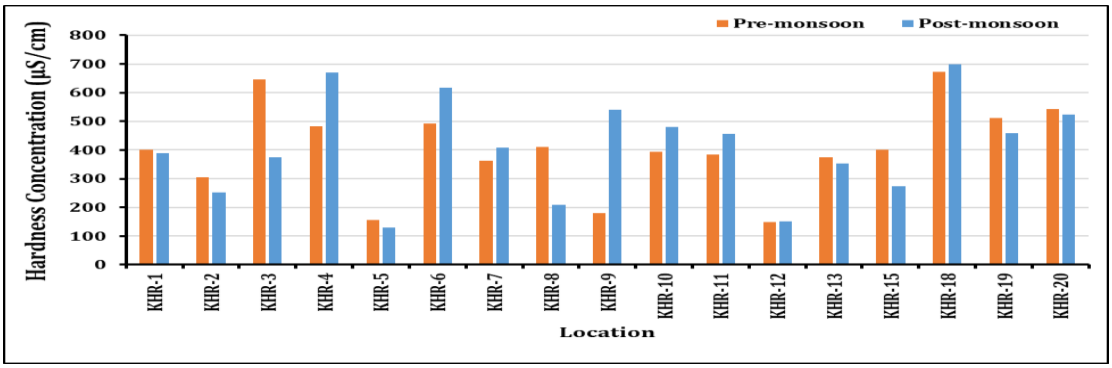


(d) TDS

Figure 40: Comparison of physical parameters of the ground waters of the study area during pre and post monsoon periods



(e) Alkalinity



(f) Hardness

Figure 40:…….Contd.

6.4.2 Major Ions

Table 12 presents the major ions as observed in the ground water samples of the study area for the pre-monsoon period of May 2022 while ***Table 13*** presents the same data for the post monsoon period of November, 2022. The major cations observed in the ground waters of the study area include Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, and NH^{4+}.

Table 19: Major ions of groundwater in the study area during May 2022

S.N.	Site Code	Na	K	Ca	Mg	HCO_3	Cl	SO_4	NO_3	F	NO_2	NH_4	PO_4
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-1	19	1.2	119	25	262	44	117	20	0.46	ND	1.40	ND
2	KHR-2	150	2.2	114	5.1	68	336	105	3.37	0.21	ND	2.91	ND
3	KHR-3	46	0.98	175	51	163	106	430	2.96	0.52	ND	2.68	ND
4	KHR-4	58	1.26	129	39	194	142	264	9	0.50	0.06	1.26	ND
5	KHR-5	93	1.1	43	12	287	27	37	0.51	0.83	ND	2.36	ND
6	KHR-6	46	3.5	113	51	450	69	53	81	0.41	0.42	1.1	ND
7	KHR-7	21	1.01	99	28	331	32	21	31	0.34	0.43	1.23	ND
8	KHR-8	53	0.69	92	44	365	66	49	55	0.31	0.41	1.45	ND
9	KHR-9	65	0.69	52	12	367	26	25	18	0.41	ND	0.44	ND
10	KHR-10	51	0.8	104	33	275	88	53	76	0.30	0.36	0.6	ND
11	KHR-11	23	0.49	98	34	337	23	23	60	0.38	ND	0.89	ND
12	KHR-12	88	0.88	49	6.7	350	34	31	29	0.61	ND	1.22	ND
13	KHR-13	80	1.04	129	13	249	62	257	15	0.45	0.45	1.53	ND
14	KHR-15	75	0.84	136	15	235	56	222	14	0.49	ND	4.08	ND
15	KHR-18	33	0.83	176	57	292	75	338	8.59	0.56	ND	5.22	ND
16	KHR-19	87	11	154	31	317	106	317	24	0.38	0.41	2.35	ND
17	KHR-20	28	1.3	152	40	315	73	92	62	0.26	0.08	5.02	ND

Table 20: Major ions of groundwater in the study area during November 2022

S.N.	Site Code	F	Cl	HCO_3	SO_4	NO_2	NO_3	PO_4	Ca	Mg	Na	K	NH_4
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	KHR-1	0.29	49.61	273.28	73.47	ND	39.94	ND	114.75	24.68	17.34	0.55	ND
2	KHR-2	0.50	120.40	277.43	67.17	1.75	32.35	ND	82.33	11.60	126.15	29.17	ND
3	KHR-3	0.54	51.53	169.82	249.19	ND	2.23	ND	98.96	30.95	35.71	0.54	ND
4	KHR-4	0.31	122.24	302.32	160.43	0.90	161.11	ND	177.87	54.90	34.06	1.40	ND
5	KHR-5	0.87	24.45	292.56	28.10	ND	0.82	ND	39.34	7.79	97.39	0.63	ND
6	KHR-6	0.35	137.50	464.09	84.14	ND	69.73	ND	138.34	66.46	74.46	8.93	ND
7	KHR-7	0.31	49.00	294.26	38.85	ND	92.76	ND	110.64	32.09	23.32	0.79	ND
8	KHR-8	0.39	23.21	262.79	18.71	ND	34.12	ND	69.08	9.07	51.43	0.30	ND
9	KHR-9	0.30	161.34	291.58	85.37	ND	187.60	ND	112.78	63.07	65.07	0.11	ND
10	KHR-10	0.30	112.34	277.43	71.66	ND	131.31	ND	107.84	51.28	84.21	0.73	ND
11	KHR-11	0.41	18.13	388.45	28.83	ND	102.52	ND	116.38	40.28	26.25	0.06	ND
12	KHR-12	0.52	39.20	248.64	32.81	ND	46.29	ND	49.54	6.79	101.59	0.53	ND
13	KHR-13	0.38	51.91	286.70	108.32	ND	63.37	ND	107.32	20.73	60.15	0.90	ND
14	KHR-14	0.41	70.88	298.66	51.73	ND	218.26	ND	174.77	34.07	23.20	0.06	ND
15	KHR-15	0.38	26.17	273.77	88.31	ND	28.88	ND	89.88	11.89	58.80	0.46	ND
16	KHR-18	0.62	21.99	299.88	352.98	ND	12.77	ND	183.06	58.58	35.16	0.13	ND
17	KHR-19	0.34	75.65	216.67	348.63	ND	6.77	ND	156.67	16.14	107.82	1.38	ND
18	KHR-20	0.26	88.17	274.99	82.30	ND	126.97	ND	144.21	39.90	26.02	0.51	ND
19	KHR-21	0.35	20.57	274.99	67.92	ND	15.87	ND	87.28	14.49	41.71	0.66	ND
20	KHR-22	0.35	67.25	255.96	64.02	ND	48.42	ND	110.05	13.15	45.98	1.26	0.20
21	KHR-23	0.30	38.90	290.36	86.97	ND	30.88	ND	98.27	3.60	78.21	0.65	ND
22	KHR-24	0.73	102.74	206.91	334.46	ND	0.23	ND	178.76	44.82	49.87	0.76	ND
23	KHR-25	0.42	49.45	249.86	211.91	0.81	15.99	ND	125.24	17.58	54.37	1.33	ND
24	KHR-26	0.36	47.42	230.09	165.10	ND	2.38	ND	109.55	29.74	19.72	0.44	ND

The concentration of sodium ions (Na^+) in the pre-monsoon period of May 2022 in the ground waters of the study area varied between the lowest of 19 mg/l for the hand pump at Dalchi (located in the house of Sh. Rai Singh on Pipalgaon to NTPC Plant road) to a highest of 150 mg/l for the hand pump in village Bhatyaan Khurd (located in Aanganwadi and School Compound Near Hanuman Mandir). The concentration of sodium ions (Na^+) in the post-monsoon period varied between the lowest of 17.34 mg/l for the hand pump at KHR-1 (house of Sh. Rai Singh on Pipalgaon to NTPC Plant road) to a highest of 126.15 mg/l for the hand pump in KHR-2 (Aanganwadi and School Compound near Hanuman Mandir, village Bhatyaan Khurd).

During the pre-monsoon period, the concentration of potassium ions (K^+) varied between the lowest of 0.49 mg/l for the hand pump located opposite house of Sh. Shivji Panwar in village Padliya Gawli to a highest of 11 mg/l for the handpump located opposite Community Centre Near Primary School, Dalchi. During post monsoon, the concentration of potassium ions (K^+) varied between the lowest of 0.06 mg/l for the hand pump KHR-14 (opp. Panchayat Bhawan, village Kheri Bujurg) to a highest of 29.17 mg/l for the handpump KHR-2 (Aanganwadi & School Compound near Hanuman Mandir, village Bhatyaan Khurd).

Ca^{2+} in the ground waters of the study area during the pre- monsoon season was found to vary widely between 43 mg/l to 176 mg/l with an average value of 115.2 mg/l for the whole study area. The highest value of 176 mg/l was observed for the open well inside the plant area. The lowest value of 43 mg/l was observed for the hand pump on road located opposite Primary School at village Badgaon. Ca^{2+} in the ground waters of the study area during the post- monsoon season) was also found to vary widely between

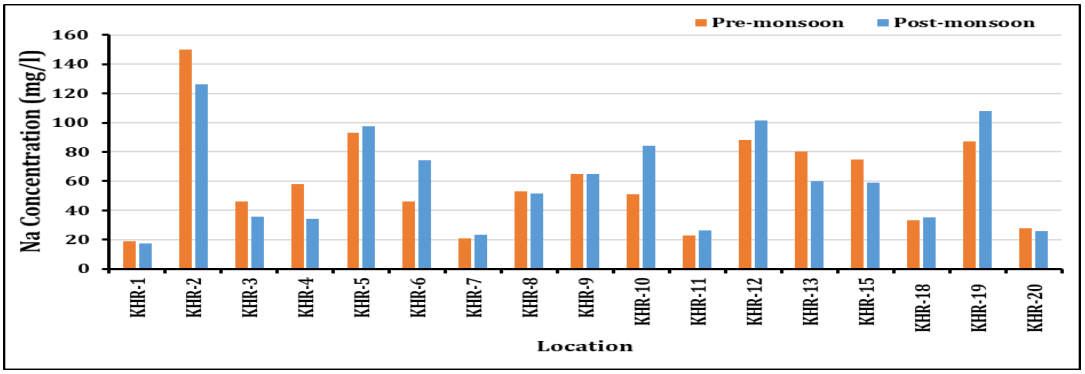
39.34 mg/l to 183.06 mg/l with an average value of 115.95 mg/l for the whole study area. The highest value of 183.06 mg/l was observed for the hand pump KHR-18 (Inside the Plant). The lowest value of 39.34 mg/l was observed for the hand pump KHR-5 (on road located opposite Primary School at village Badgaon). Calcium was found to exceed the BIS acceptable limit of 75 mg/l for drinking water at many of the locations during both the pre and post monsoon. It was, however, within the BIS permissible limit of 200 mg/l at all the locations during both the seasons.

The variation of magnesium (Mg^{2+}) in the ground waters during the pre-monsoon period ranged between the lowest of 5.1 mg/l for the handpump at Bhatyaan Khurd (located in Aanganwadi and School Compound Near Hanuman Mandir) to the highest of 57 mg/l for the open well inside the plant area. The variation during the post-monsoon period of November 2022 ranged between the lowest of 3.60 mg/l for the piezometer at KHR-23 (before pump house opp. side Near RCC-3 Poles) to the highest of 66.46 mg/l for the open well KHR-6 (opp. Madhya Pradesh Gramin Bank, opp Health Centre. village Kanapur). Magnesium was found to be well within the BIS permissible limit of 100 mg/l for drinking water at all the stations during both the seasons. However, it was observed to be above the BIS acceptable limit of 30 mg/l at some locations during both the seasons, in particular during the pre-monsoon season.

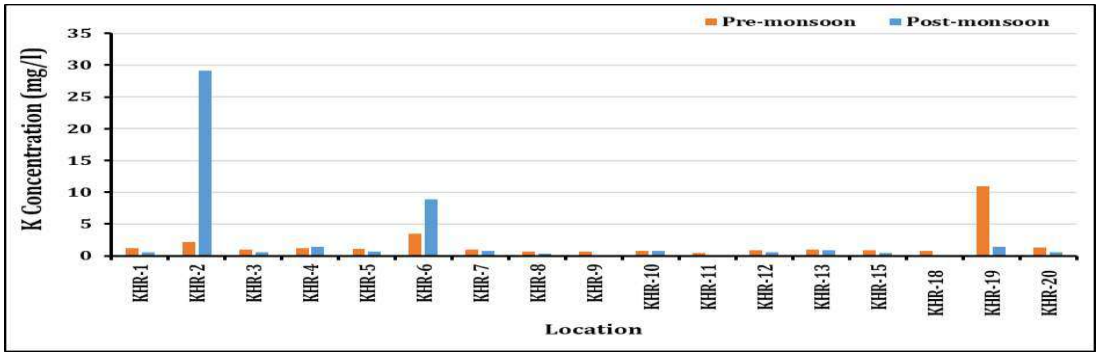
As far as the concentration of ammonium ions (NH^{4+}) in the ground waters of the study area is concerned, it ranged between 0.44 mg/l to 5.22 mg/l with an average value of 2.3 mg/l for the whole study area, during the pre-monsoon. The highest concentration of 5.22 mg/l was recorded for the for the open well inside the plant area while the lowest concentration of 0.44 mg/l was observed for the tube well adjoining Jai Bajrang Kirana, Neharu Nagar, Pipalgoan. As far as the concentration of ammonium ions (NH^{4+}) in the ground waters during post-monsoon is concerned, it was not detected any of the locations except at KHR-22 location where it was 0.20 mg/l.

As far as the newly constructed piezometers around the ash dyke are concerned, while none of the piezometers exceeded the BIS permissible limits for calcium and magnesium, all the piezometers exceeded the acceptable BIS limit for calcium and one piezometer exceeded the limit for magnesium. Ammonium was not detected in 5 out of 6 piezometers.

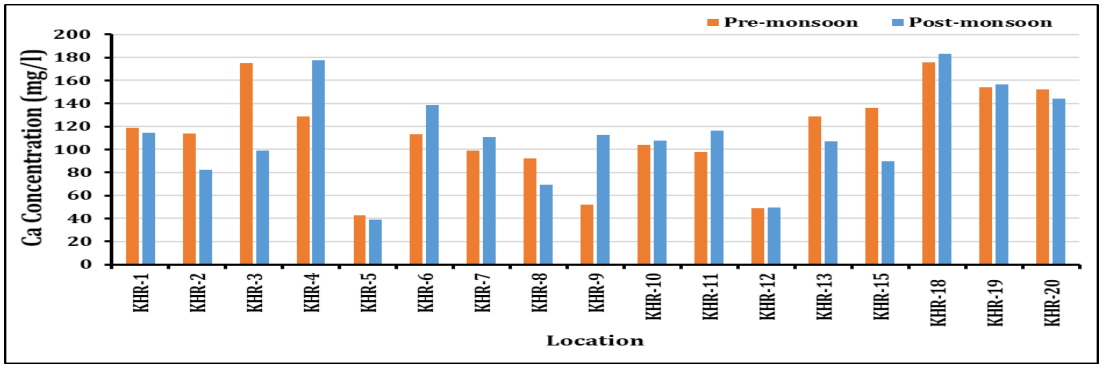
Comparison of the pre-monsoon and post-monsoon data of cations in the ground waters of the study area is shown in ***Figure 41***. It can be observed from ***Figure 41*** that though both calcium and magnesium decreased at some locations due to the dilution effect of monsoon rainfall, an increase was also observed at some locations. Similar variations were also observed for sodium and potassium ion concentration. However, a significant increase in potassium has been observed at KHR-2***.***



(a) Sodium



(b) Potassium



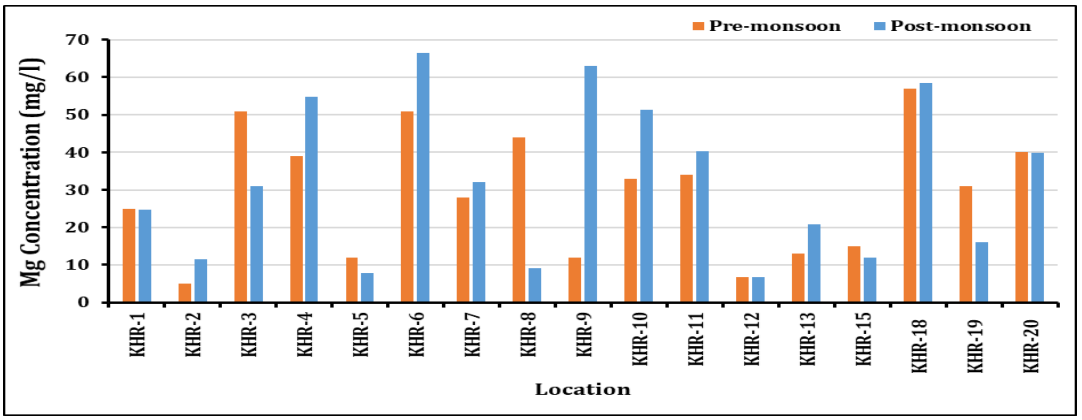


Figure 41: Comparison of the pre-monsoon and post-monsoon data of cations in the ground waters of the study area

Anions

The anion chemistry of the analyzed ground water samples of the study area shows that F^-, Cl^-, HCO^{3-}, SO_4^{2-} NO_2^- NO_3^- and PO_4^{3-} are the dominant anions in the ground waters of the study area, both during the pre and post monsoon seasons.

F^-- in the ground waters during the pre-monsoon season (May 2022) was found to vary between 0.21 to 0.83 mg/l with an average value of 0.4 mg/l for the study area. The highest value of 0.83 mg/l was observed for the Lagoon 1. Lowest value of 0.21 mg/l was observed for the raw water reservoir. F^-- in the groundwater during the post-monsoon season (November 2022) was found to vary between 0.26 to 0.87 mg/l with an average value of 0.42 mg/l for the study area. The highest value of 0.87 mg/l was observed for the hand pump at KHR-5 (opp. Primary School on road, village Badgaon). Lowest value of 0.26 mg/l was observed for the hand pump at KHR-20 (opp. Sh Mukesh House, village Jamnia). Fluoride was found to be within the BIS acceptable limit of 1 mg/l at all the locations monitored, both during the pre and post monsoon season.

The Chloride (Cl^-) concentration in the ground water during pre-monsoon was found to vary widely between 23 to 336 mg/l with an average value of 84.6 mg/l for the study area. The highest value of 336 mg/l was observed for the hand pump at Aanganwadi and School Compound Near Hanuman Mandir in village Bhatyaan Khurd while the lowest value of 23 mg/l was observed for the hand pump at village Padliya Gawli. During post-monsoon, the Chloride (Cl^-) concentration in the groundwater was found to vary between 18.13 to 161.34 mg/l with an average value of 65.42 mg/l for the whole study area. The highest value of 161.34 mg/l was observed for the hand pump at KHR-9 (adjoining of Jai Bajrang Kirana, Neharu Nagar Pipalgoan) while the lowest value of 18.13 mg/l was observed for the hand pump at KHR-11 (opp. Shivji Panwar House, village Padliya Gawli). Chloride was very much within the BIS permissible limit of 1000 mg/l at all the stations during both the seasons. Infact it was found to be very much within the BIS acceptable limit of 200 mg/l at all the stations during both the seasons, except at KHR-2 during pre-monsoon.

HCO_3^- during the pre-monsoon season was found to vary widely between 68 mg/l to 450 mg/l with an average value of 283.3 mg/l for the study area. The highest value of 450 mg/l was observed for the hand pump located opposite Madhya Pradesh Gramin Bank in village Kanapur. Lowest value of 68 mg/l was observed for the hand pump at Aanganwadi & School Compound Near Hanuman Mandir, at village l Bhatyaan Khurd. HCO_3^- in the groundwater, during the post-monsoon season (November 2022) was found between 169.82 mg/l to 464.09 mg/l with an average value of 279.23 mg/l for the study area. The highest value of 464.09 mg/l was observed for the hand pump located KHR-6 (opp. Madhya Pradesh Gramin Bank, opp. Health Centre, village Kanapur). Lowest value of 169.82 mg/l was observed for the hand pump at KHR-3 (near NTPC opp. of Bhilal Baba Temple, Gate No. 1, opp Cooling Towers, Below Bargad Tree).

Sulfate (SO_4^{2-}) ion concentration in the ground waters of the study area showed a significant variation between 21 mg/l to 430 mg/l during the pre-monsoon season of May 2022. The highest value of 430 mg/l was observed for the hand pump located opposite Bhilat Baba Temple near NTPC, Gate No. 1, while the lowest value of 21 mg/l was observed for the hand pump located at the house of Sh. Daya Ram in village Londhi.

Post monsoon concentration of Sulfate (SO_4^{2-}) ions in the groundwater was also found to vary very widely between 18.71 mg/l to 352.98 mg/l. The highest value of 352.98 mg/l was observed for the hand pump KHR-18 (inside the plant), while the lowest value of 18.71 mg/l was observed for the hand pump located at KHR-8 (opp. Sabir`s House, Sanawat-Kasravad road, opp. Baba Shree Dhaba, village Pipalgoan). Concentration of sulphate ions was found to exceed the BIS acceptable limit of 200 mg/l for 6 out of 17 stations during the pre-monsoon. During the post-monsoon, it exceeded the acceptable limit at 5 out of 24 monitoring stations. It was within the permissible limit of 400 mg/l at all the stations during both the seasons except for KHR-3 during the pre-monsoon.

Nitrite (NO_2^-) was not detected in 9 out of the 17 ground water sampling locations in the study area monitored during the pre- monsoon period of May 2022. At the nine locations where it was detected, it was observed to be highest at 0.45 mg/l at KHR-13 and lowest at 0.06 mg/l for the open well located between NTPC & Township. Nitrite (NO_2^-) was not detected in 21 out of the 24 ground water sampling locations in the study area monitored during the post- monsoon period of November 2022. At the three locations where it was detected, it was observed to be highest at 1.75 mg/l for the hand pump KHR-2 (Aanganwadi & School Compound Near Hanuman Mandir, village Bhatyaan Khurd) and lowest at 0.81 mg/l for the piezometer KHR-25 (opp. twin pole no. 8).

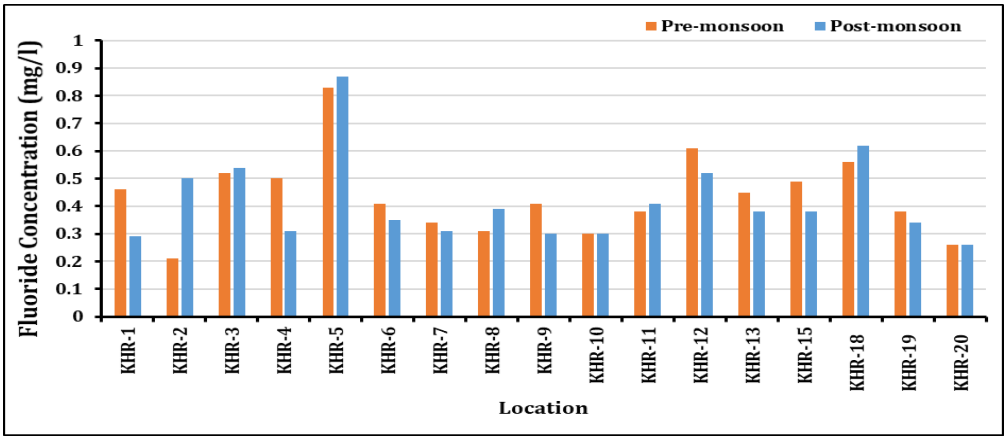
The concentration of nitrate (NO_3^-) varied between the lowest of 0.51 mg/l for the hand pump located on road, opposite Primary School, in village Badgaon to the highest of 81 mg/l for the handpump located opposite Madhya Pradesh Gramin Bank, at village Kanapur during the pre-monsoon. During the post monsoon, the concentration of nitrate (NO_3^-) varied between the lowest of 0.23 mg/l for the hand pump located on road, opposite Primary School, in village Badgaon to the highest of 218.26 mg/l for the hand pump KHR-14 (opp. Panchayat Bhawan, village Kheri Bujurg). Nitrate was found to be within the BIS acceptable limit of 45 mg/l at 12 out of 17 stations during the pre-monsoon and at 5 out of 24 stations during post monsoon. At other stations it exceeded the limit, the exceedance being significant at some of the locations, particularly during the post monsoon.

Phosphate was not detected in any of the ground water samples of the study area for the pre-monsoon period of May 2022. It was also not detected in any of the ground water samples of the study area during the post-monsoon period of November 2022.

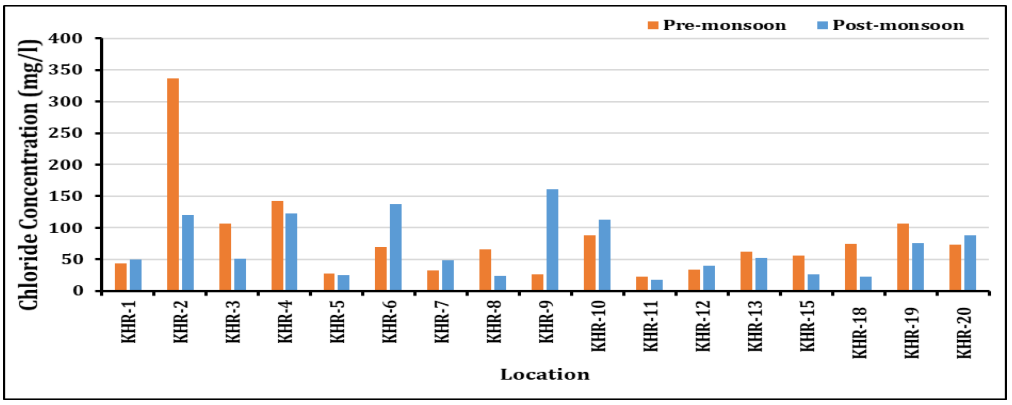
As far as the newly constructed piezometers around the ash dyke are concerned, while none of the piezometers exceeded the acceptable limit for fluoride and chloride, two piezometers exceeded the acceptable BIS limit for sulphate, although it was within the permissible limit. Only one piezometer location was found to exceed the BIS acceptable limit for nitrate. Nitrite was not detected in five out of the six piezometers.

Comparison of the concentration of anions in the ground waters of the study area during the pre and post monsoon is presented in ***Figure 42***. The comparison of fluoride ions indicates a dilution effect at some places causing a decline in the concentration during the post monsoon period. However, an increase has also been observed at some places, although it is very marginal. Similarly, the comparison of the pre-monsoon and post-monsoon data of chloride ions also indicates a significant dilution effect at most of

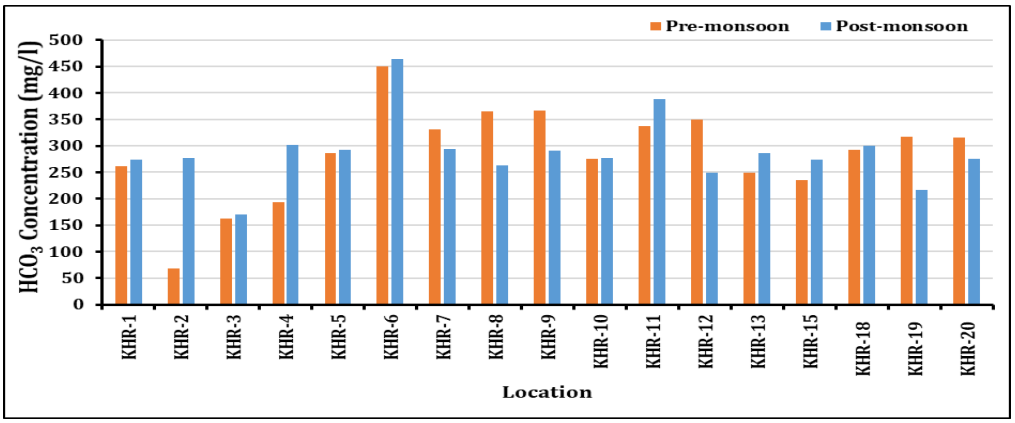
the locations. Bicarbonate ion concentration indicates a rise at a number of places and decrease at remaining places. Sulphate indicates a significant reduction in the concentration at many locations and increase at other locations. As far as nitrate ions concentration is concerned, the comparison indicates a significant rise during the post-monsoon at most locations of ground water monitoring.



(a) Fluoride

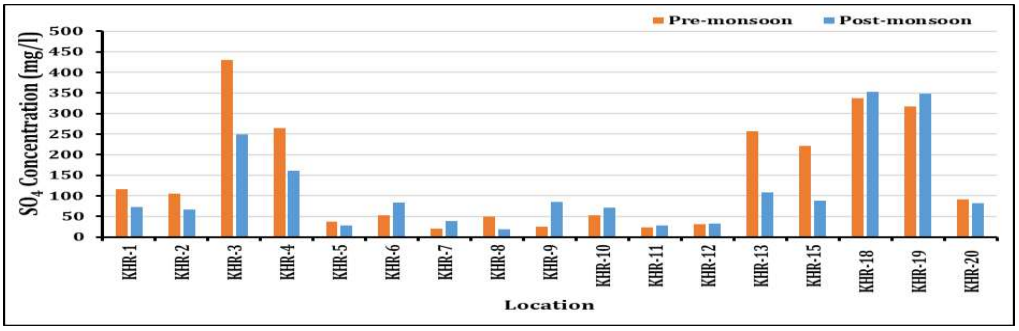


(b) Chloride

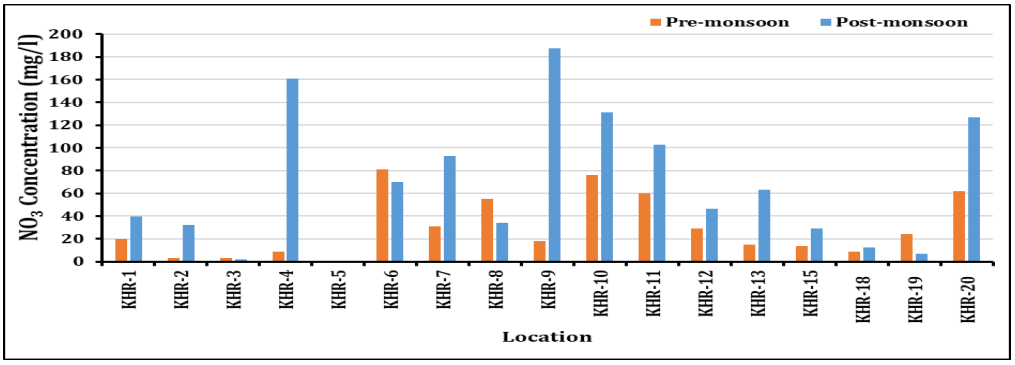


(c) Bicarbonate

Figure 42: Comparison of the pre-monsoon and post-monsoon data of anions in the ground waters of the study area



(d) Sulphate



(f) Nitrate

Figure 42:...Contd.

6.4.3 Heavy Metals

The results of analysis for heavy metals in ground waters of the study area during the pre-monsoon period of May 2022 are presented in ***Table 21***. The results of analysis for the post-monsoon period of November 2022 are presented in ***Table 22***.

Table 21: Heavy metal concentration in groundwater in the study area during May 2022

S.N.	Site Code	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1	KHR-1	11	103	8142	0.23	4.1	96	1673	0.81	0.05	ND	26
2	KHR-2	2.3	96	734	0.16	1.2	2.5	507	0.32	0.11	0.07	3.2
3	KHR-3	2.4	3.4	312	0.06	1.2	2.1	146	0.42	0.01	0.10	0.5
4	KHR-4	2.7	15	95	0.11	1.4	1.6	30	0.42	ND	0.11	0.2
5	KHR-5	2.9	40	1781	0.19	1.7	6.1	59	0.22	0.07	0.05	1.9
6	KHR-6	5.0	73	2961	0.64	3.9	85	265	1.00	0.09	0.08	49
7	KHR-7	3.3	20	1801	0.21	2.4	5.8	749	0.71	0.36	0.19	9.2
8	KHR-8	2.2	8.5	1710	0.12	1.2	15	498	0.46	0.19	0.24	15
9	KHR-9	2.4	3.6	131	0.09	1.5	1.9	49	0.48	0.01	0.36	0.7
10	KHR-10	3.3	92	944	0.38	2.8	11	162	0.27	0.08	0.37	4.9
11	KHR-11	2.3	5.5	394	0.15	1.8	7.4	128	0.37	0.03	0.33	2.5
12	KHR-12	2.8	32	541	0.21	18	11	191	0.64	0.08	0.51	8.0
13	KHR-13	2.0	1.3	42	0.07	1.6	6.9	57	0.34	0.02	0.31	0.1
14	KHR-15	1.8	1661	98	0.22	1.2	5.6	86	0.41	0.07	0.33	0.1
15	KHR-18	2.4	329	144	0.45	4.0	6.2	96	0.37	0.03	0.33	0.8
16	KHR-19	1.8	28	108	0.12	1.3	3.1	119	0.53	ND	0.32	0.0
17	KHR-20	2.1	5.9	340	0.18	2.1	5.8	105	0.30	0.01	0.26	1.9

Table 22: Heavy metal concentration in groundwater in the study area during November 2022

S.N.	Site Code	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1	KHR-1	4.54	24.11	4617.36	0.18	2.23	31.42	1872.08	0.33	0.04	0.02	14.26
2	KHR-2	1.85	19.00	803.48	0.14	1.10	4.19	981.53	0.45	0.05	0.01	5.40
3	KHR-3	1.66	2.43	176.76	0.05	0.60	1.53	54.28	0.47	0.01	0.00	0.86
4	KHR-4	1.80	4.53	54.99	0.11	0.83	2.44	9.81	0.32	0.02	0.00	0.89
5	KHR-5	2.09	15.58	1349.72	0.08	1.73	7.12	58.91	0.22	0.11	0.00	3.72
6	KHR-6	2.90	10.38	2046.72	0.16	1.46	49.98	143.97	0.83	0.01	0.00	4.97
7	KHR-7	1.45	14.80	403.26	0.14	0.74	4.60	324.53	0.29	0.09	0.00	1.21
8	KHR-8	1.39	2.92	460.41	0.06	0.94	7.45	149.28	0.27	0.07	0.00	2.08
9	KHR-9	2.05	14.62	1284.48	0.21	1.59	9.78	184.14	0.19	0.05	0.00	3.01
10	KHR-10	2.10	11.64	1505.08	0.24	1.61	34.20	247.81	0.18	0.02	0.00	2.83
11	KHR-11	2.04	5.55	888.65	0.10	0.93	13.52	40.86	0.29	0.01	0.00	2.69
12	KHR-12	1.50	1.94	101.78	0.07	0.69	3.53	9.78	0.41	0.01	0.00	0.44
13	KHR-13	1.84	3.68	60.02	0.09	0.87	4.36	12.11	0.36	0.01	0.04	0.71
14	KHR-14	2.00	4.44	379.51	0.10	1.72	32.34	368.51	0.33	0.06	0.00	2.51
15	KHR-15	2.07	4.20	221.34	0.05	0.69	4.68	38.25	0.25	0.01	0.00	0.81
16	KHR-18	2.22	121.50	91.16	0.16	1.82	4.06	11.85	0.30	0.03	0.00	0.62
17	KHR-19	1.74	10.95	93.71	0.06	0.69	1.85	134.72	0.27	0.02	0.00	0.76
18	KHR-20	2.02	6.93	1049.98	0.17	1.12	3.37	30.43	0.20	0.01	0.00	1.15
19	KHR-21	4.02	358.71	9817.33	10.34	10.54	94.26	150.56	0.27	0.04	0.00	17.24
20	KHR-22	3.44	79.79	4300.65	3.08	5.15	52.09	203.42	0.47	0.04	0.00	6.25
21	KHR-23	2.09	13.04	814.28	0.49	1.44	17.19	90.43	0.41	0.01	0.00	45.23
22	KHR-24	2.04	18.31	442.85	0.33	1.75	9.30	95.72	0.27	0.04	0.00	69.89
23	KHR-25	6.82	208.01	29884.51	25.57	14.58	866.02	263.27	5.46	0.05	0.00	61.35
24	KHR-26	2.49	33.05	1115.61	0.79	2.45	6.60	234.79	0.21	0.03	0.00	81.98

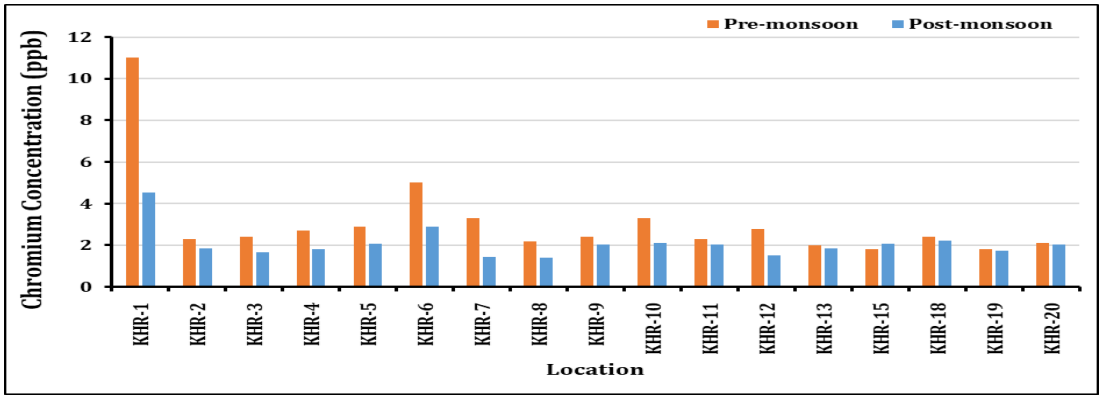
It can be seen from ***Table 21*** that during the pre-monsoon period of May 2022, chromium (Cr) ranged from 1.8 ppb to 11ppb. Manganese (Mn) varied in the range of 1.3 ppb to 1661 ppb. The concentration of iron was observed to vary in the range of 42 ppb to 8142 ppb. Cobalt (Co) varied I the range of 0.06 ppb to 0.64 ppb. The Nickel (Ni) concentration varied in the range of 1.2 ppb to 18. Copper (Cu) varied in the range of 1.6 ppb to 96 ppb. Zinc (Zn) concentration varied from 30 ppb to 1673 ppb. Arsenic (As) ranged from 0.22 ppb to 1 ppb. Cadmium (Cd) ranged from 0.01 ppb to 0.36 ppb. Hg varied in the range of 0.05 to 0.51 ppb and Lead (Pb) varied in the range of 0 ppb to 49 ppb.

It can be seen from ***Table 22*** that that during the post-monsoon period of November 2022, chromium (Cr) ranged from 1.39 ppb to 6.82 ppb. Manganese (Mn) varied in the range of 1.94 ppb to 358.71 ppb. The concentration of iron was observed to vary in the range of 54.99 ppb to 29884.51 ppb. Cobalt (Co) varied the range of 0.05 ppb to 25.57 ppb. The Nickel (Ni) concentration varied in the range of 0.06 ppb to 14.58 Copper (Cu) varied in the range of 1.53 ppb to 866.02 ppb. Zinc (Zn) concentration varied from 9.78 ppb to 1872.08 ppb. Arsenic (As) ranged from 0.18 ppb to 5.46 ppb. Cadmium (Cd) ranged from 0.01 ppb to 0.11 ppb. Hg varied in the range of 0.00 to 0.04 ppb and Lead (Pb) varied in the range of 0.44 ppb to 81.98 ppb.

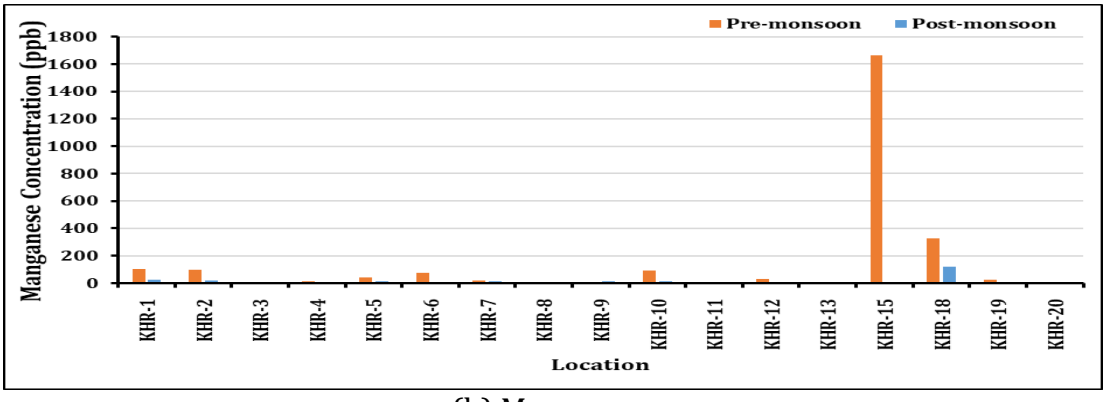
The concentration of chromium, nickel, zinc, arsenic, cadmium, and mercury was found to be very much within the BIS acceptable limits for drinking water at all the stations during both the seasons. Manganese was found to exceed the limit at 2 stations during the pre-monsoon and one station during post monsoon out of 24 monitored stations.

Similarly, two stations in pre-monsoon and three stations during post-monsoon was found to exceed the BIS limit for copper (0.05-1.5 mg/l) out of 24 monitored stations. Lead was found to exceed the BIS limit of 0.1 mg/l at two stations during the pre-monsoon and 5 stations during the post monsoon. However, iron was found to exceed the BIS limit of 0.3 mg/l at 11 stations during pre-monsoon out of the 17 monitored stations and 17 stations during post monsoon out of 24 monitored stations. As far as newly constructed piezometers around the ash dyke area are concerned, they were monitored only during November, 2022. Iron was found to exceed the limit in 4 out of 6 piezometers, copper in one piezometer and lead in 4 out of the 6 monitored piezometers. None of the other heavy metal was observed to exceed the BIS limit.

Comparison of pre and post monsoon data of heavy metals in the ground waters of the study area is presented in ***Figure 43.*** The comparison indicates a general reduction in the heavy metal concentration for most of the ground water locations in the study area in the post monsoon over the pre monsoon, for all the parameters. However, a marginal increase in some parameters at some locations is also observed.

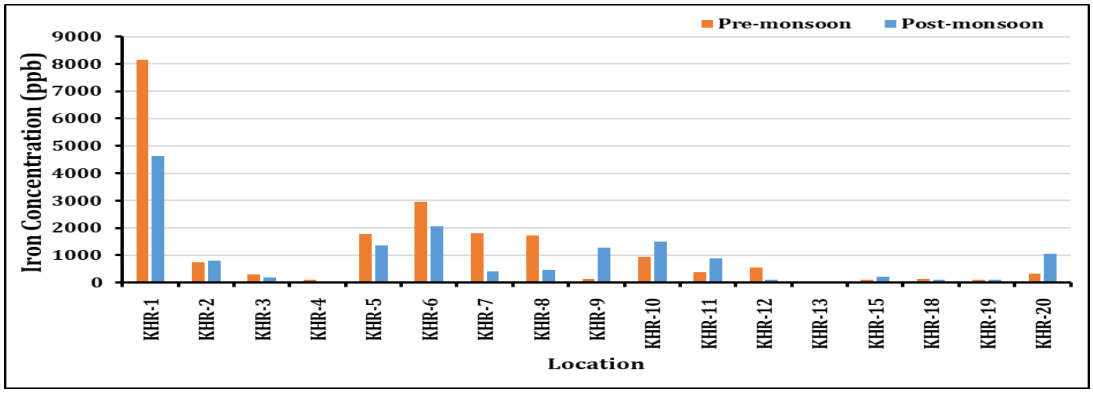


(a) Chromium

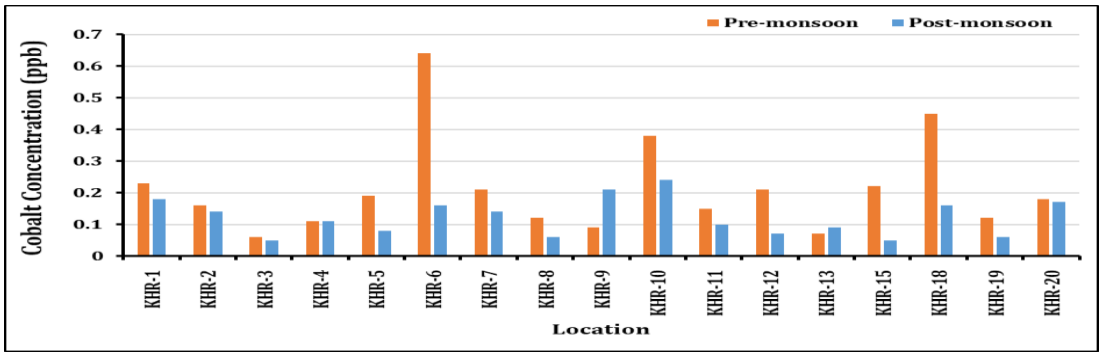


(b) Manganese

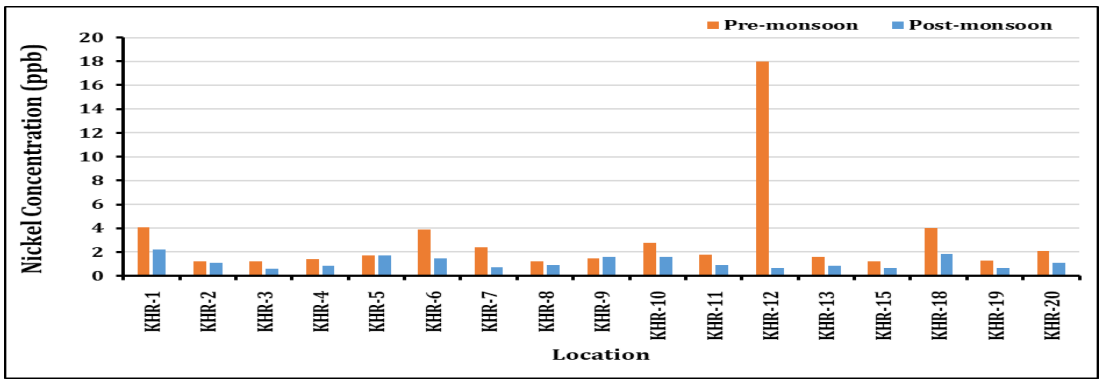
Figure 43: Comparison of the pre-monsoon and post-monsoon data of heavy metals in the ground waters of the study area



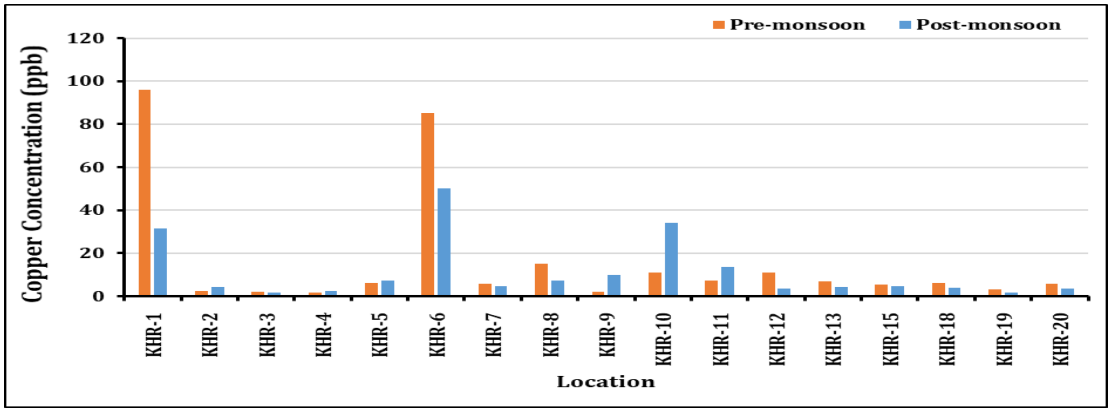
(c) Iron



(d) Cobalt

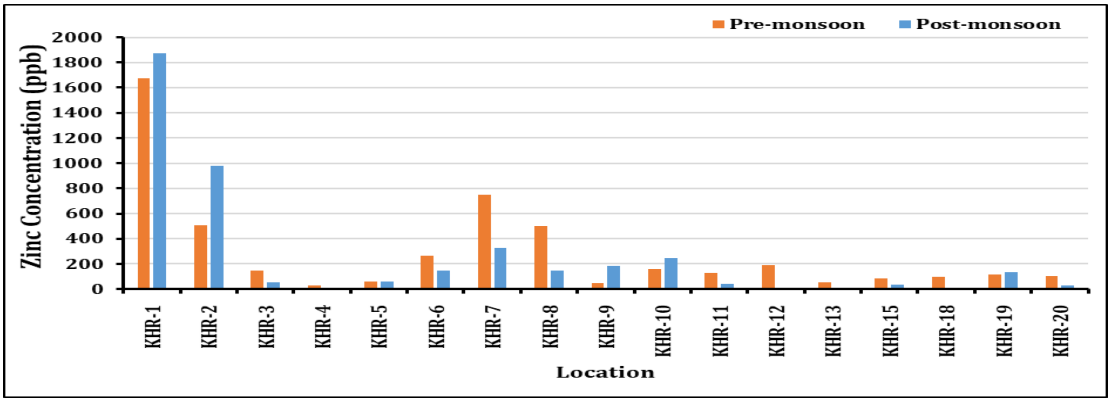


(e) Nickel

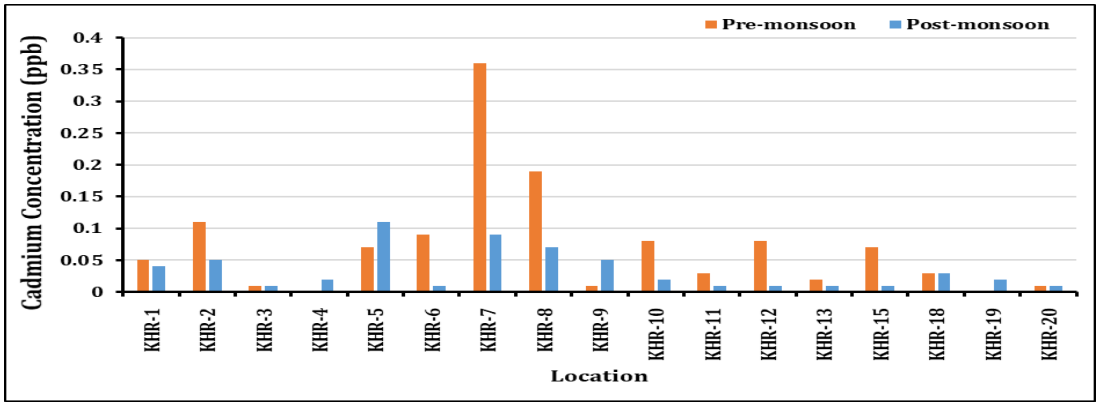


(f) Copper

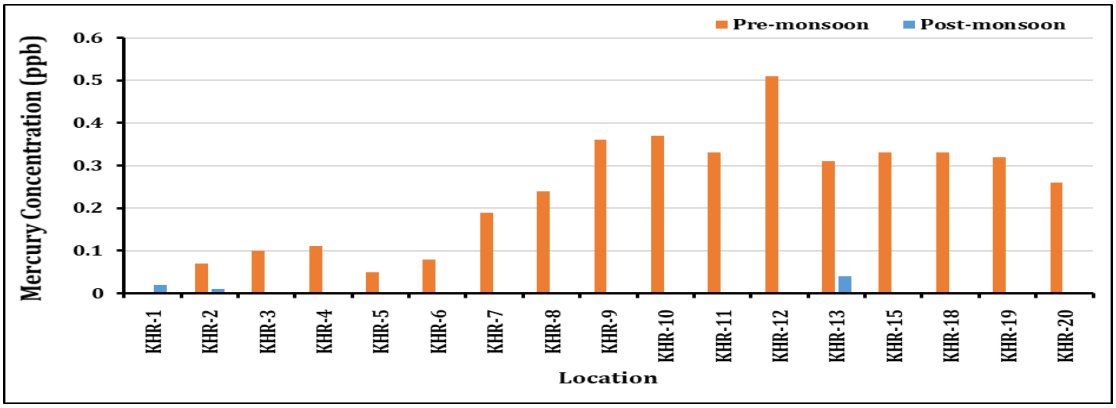
Figure 43:...Contd.



(g) Zinc



(h) Cadmium



(i) Mercury

Figure 43:...Contd.

Figure 44 presents some of the photographs of ground water quality monitoring carried out for the study area during pre-monsoon season of May 2022. Photographs of the ground water quality monitoring of post-monsoon season of November 2022 are presented in ***Figure 44.***

Figure 44: Some photographs of pre-monsoon ground water quality sampling in the study area during May 2022

Figure 45: Some photographs of post-monsoon ground water quality sampling in the study area during November 2022

Figure 45…Contd.

7.0 SOIL CHEMISTRY

7.1 General

Soil chemistry is the study of how the elements and their compounds are distributed between and within the three principal phases that comprise the soil, namely the solid, liquid, and gaseous phases. Natural soil chemistry can be changed by various natural forces such as leaching of chemical elements by water moving through the soil, chemical reactions, and biological activity. However, soil chemistry can also be altered by human impact from various land uses, including farming. These changes may be considered negative or positive impacts depending on the intended future use of the soil. Similar to natural changes, management of soils by humans can also result in positive or negative changes to soil chemistry, such as increases in soil organic matter. For example, fertilizer and manure applications to a silt loam soil may increase the percentage of water-stable aggregates of a silt loam because of increases in soil organic matter.

A knowledge of soil chemistry is fundamental in predicting the fate of contaminants in the surface and subsurface environments. For example, soil salinity problems are more closely associated with soil and water chemistry than the type of irrigation system. However, the irrigation system can accentuate salinity problems. The knowledge of soil chemistry is also useful in making sound and cost effective decisions about remediation of contaminated soils.

As per the scope of the present study, soil samples were collected from 12 locations using soil auger. Three samples were collected at each location at surface, 30 cm depth and 60 cm depth. The samples were collected in polythene bags and were properly labelled. The samples were brought to the National Institute of Hydrology where they were analyzed for their chemistry. ***Figure 46*** shows the soil sampling locations in the study area while ***Table 23*** presents the details of the sampling locations.

The results of laboratory analysis for physical parameters and major ions in the soil samples of the study area are shown in ***Table 16.***

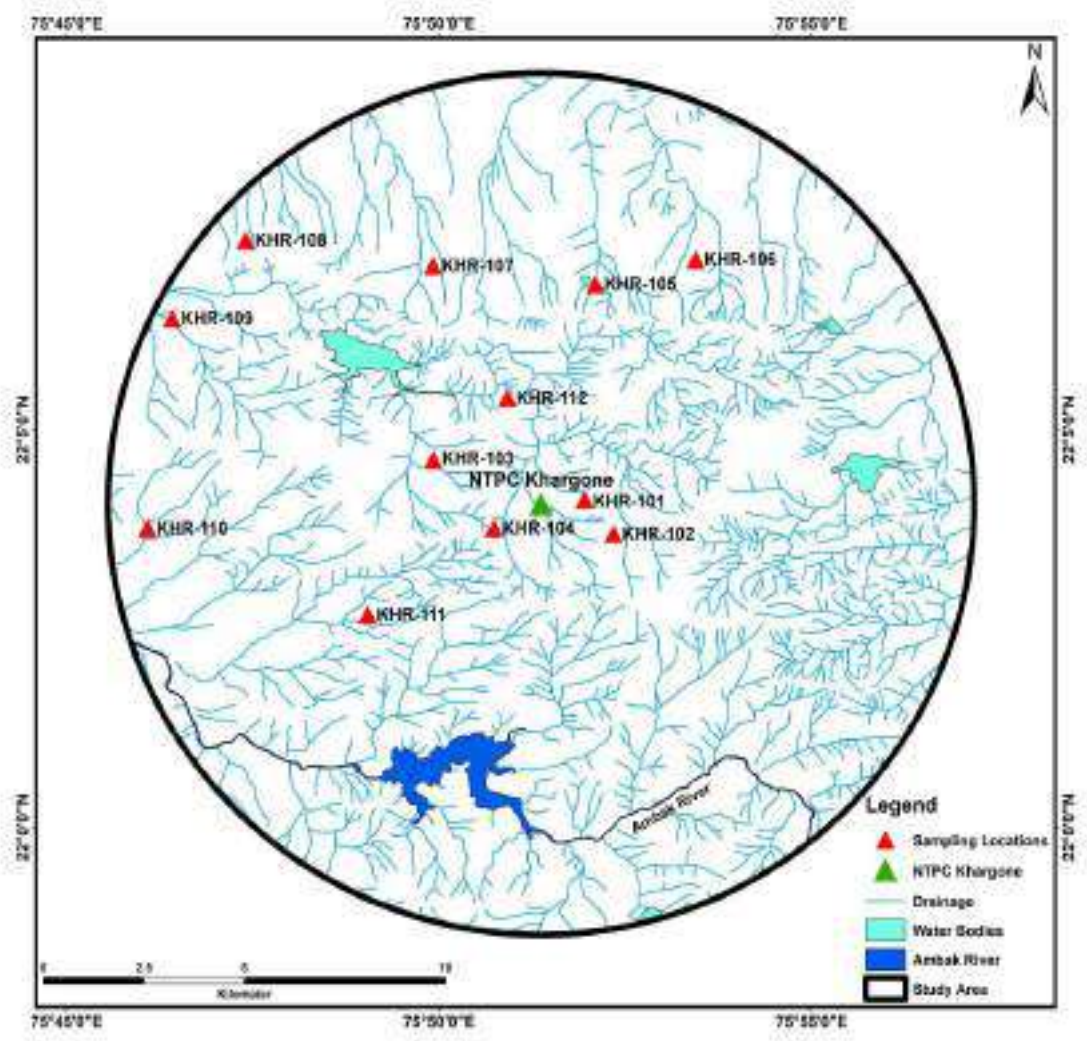


Figure 46: Location map of soil sampling locations in the study area

Table 23: Details of soil sampling locations in the study area

S. N.	Site Code	Date of collection	Location address	Latitude (Deg. Dec.)	Longitude (Deg. Dec.)
1	KHR-101	5/22/2022	NTPC Plantation Land near Shelda Village	22.068686	75.865808
2	KHR-102	5/22/2022	NTPC Plant to Kheri road along NTPC Railway line	22.061526	75.872330
3	KHR-103	5/22/2022	Near NTPC Boundry inside Dalchi along Plant ashdyke - Dalchi road	22.077065	75.832013
4	KHR-104	5/22/2022	Plant to Bhopada side single Chimney side	22.062734	75.845571
5	KHR-105	5/22/2022	opp side of Kottara Pond, Plant to Kattora Village	22.113848	75.868283
6	KHR-106	5/22/2022	Near Badgaon Village, Near Papu Dhaba	22.119023	75.890667
7	KHR-107	5/22/2022	Kanhapur- Pipalgaon Road ,Along Road site outside Kanhapur	22.117732	75.831940
8	KHR-108	5/22/2022	Pipalgaon Londi road, Londi along road side Near Hand Pump	22.123119	75.790038
9	KHR-109	5/22/2022	opp Sant Siya ram Auto Parts & Garrage	22.118459	75.757034
10	KHR-110	5/22/2022	Village Bhatiyan On Plant road Near Overhead water tank opp side	22.062688	75.768112
11	KHR-111	5/22/2022	Village Bhopada Shalda Road	22.044646	75.817312
12	KHR-112	5/22/2022	Vill Jamnia, School Compound Near Road	22.090059	75.848602

7.1 Physical Parameters and Major Ions

Most soils generally have pH values between 3.5 and 10. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas the range is 6.5 to 9. Soils can be classified according to their pH value as neutral (pH range: 6.5 to 7.5), alkaline (pH over 7.5) and acidic (pH less than 6.5). Soils with pH less than 5.5 are considered strongly acidic. In the present study the pH range of the soil samples is 6.0 to 7.2 with an average value of 7.2 for the study area, considering samples of all depths together. At many locations the soils are observed to be neutral within the pH range of 6.5 to 7.5 (10 out of 36 samples). However, at most locations (26 out of 36 samples) the soils are moderately acidic with pH values lower than 6.5 but above 6.0. Only in one sample the soil was observed to be alkaline at 60 cm depth.

Soil electrical conductivity (EC) is a measure of the amount of salts in soil (salinity of soil). It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane,

and carbon dioxide. Excess salts hinder plant growth by affecting the soil-water balance. Soils containing excess salts occur naturally in arid and semiarid climates. Salt levels can increase as a result of cropping, irrigation, and land management.

The average value of EC for soil in the study area during the post monsoon period (May 2022 2020) was found to be 260.5 µS/cm, considering all the samples at various depths. However, a wide variation was observed at different places and different depth with a minimum 75 µS/cm in the surface soil sample at Kottra village (opposite side of Kottara Pond, Plant to Kattora Village) and maximum of 803 µS/cm in the surface soil sample opp Sant Siya ram Auto Parts & Garrage. Furthermore, it has been observed that no specific trend of depth-wise increase or decrease in the EC values have been observed in most of the soil samples.

As far as major ions are concerned, F^-, Cl^-, HCO^{3-}, SO_4^{2-}, NO_3^- and PO_4^{3-} are the dominant anions while Ca^{2+}, Mg^{2+}, Na^+, K^+, and Fe^{2+} are the dominant cations in the soils of the study area from surface upto 60 cm depth. The depth-wise concentration of the various ions is shown in ***Table 24.***

Table 24: Physical parameters and major ion concentration in soils of the study area

S.N.	Site Code	pH	EC	Alkalinity	CO3	HCO3	Cl	SO4	NO3	PO4	F	Na	K	Fe
			µS/cm	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g
1	KHR 101 (Surface)	6.0	233	0.192	ND	0.234	0.06	0.02	0.000	0.004	ND	1.27	1.20	0.012
2	KHR 101 (30 CM)	6.1	140	0.282	ND	0.344	0.08	0.01	ND	0.005	0.017	1.28	1.24	0.012
3	KHR 101 (60 CM)	6.0	142	0.246	ND	0.300	0.06	0.01	ND	0.000	0.015	1.27	1.23	0.001
4	KHR 102 (Surface)	6.4	100	0.234	ND	0.285	0.08	0.11	ND	0.001	0.008	1.28	1.19	0.002
5	KHR 102 (30 CM)	6.3	144	0.336	ND	0.410	0.08	0.01	ND	0.001	0.004	1.26	1.20	0.005
6	KHR 102 (60 CM)	6.8	99	0.23	ND	0.281	0.10	0.01	0.001	0.003	0.012	1.29	1.24	0.001
7	KHR 103 (Surface)	6.0	118	0.45	ND	0.549	0.06	0.01	0.006	0.001	0.005	1.25	1.17	0.010
8	KHR 103 (30 CM)	6.0	139	0.50	ND	0.610	0.08	0.11	0.004	0.022	ND	1.17	1.21	0.645
9	KHR 103 (60 CM)	6.8	251	0.625	ND	0.763	0.06	0.13	0.001	0.006	ND	1.22	1.23	0.525
10	KHR 104 (Surface)	6.3	173	0.214	ND	0.261	0.12	0.02	0.000	0.004	0.008	1.27	1.19	0.000
11	KHR 104 (30 CM)	6.3	155	0.168	ND	0.205	0.04	0.04	ND	0.001	0.014	1.26	1.23	0.004
12	KHR 104 (60 CM)	6.3	292	0.32	ND	0.390	0.10	0.01	0.001	ND	0.014	1.25	1.27	0.000
13	KHR 105 (Surface)	6.2	75	0.094	ND	0.115	0.06	0.05	ND	ND	0.007	1.25	1.23	0.001
14	KHR 105 (30 CM)	6.7	160	0.234	ND	0.285	0.10	0.02	ND	0.000	0.027	1.27	1.23	0.000
15	KHR 105 (60 CM)	6.9	320	0.252	ND	0.307	0.08	0.10	0.000	ND	0.022	1.25	1.20	0.000
16	KHR 106 (Surface)	6.0	474	0.34	ND	0.415	0.10	0.04	0.013	0.004	ND	1.28	1.17	0.002
17	KHR 106 (30 CM)	6.0	316	0.18	ND	0.220	0.08	0.05	0.012	0.000	0.009	1.28	1.24	0.001
18	KHR 106 (60 CM)	6.0	247	0.206	ND	0.251	0.14	0.00	0.011	0.000	0.014	1.27	1.23	0.000
19	KHR 107 (Surface)	6.8	479	0.46	ND	0.561	0.12	0.01	0.007	0.001	0.014	1.27	1.28	0.000
20	KHR 107 (30 CM)	6.8	293	0.31	ND	0.378	0.14	0.15	0.005	0.002	0.014	1.24	1.58	0.000

21	KHR 107 (60CM)	6.7	254	0.346	ND	0.422	0.10	0.21	0.003	0.002	ND	1.27	1.23	0.000
22	KHR 108 (Surface)	6.1	293	0.48	ND	0.586	0.08	0.01	0.006	0.000	0.010	1.28	1.09	0.000
23	KHR 108 (30 CM)	6.2	182	0.252	ND	0.307	0.06	0.00	0.001	ND	0.016	4.49	1.14	ND
24	KHR 108 (60 CM)	7.2	136	0.272	ND	0.332	0.06	0.02	0.004	ND	0.004	1.28	1.22	0.000
25	KHR 109 (Surface)	6.4	803	0.40	ND	0.488	0.14	0.10	0.006	0.000	0.021	1.24	1.91	0.000
26	KHR 109 (30 CM)	6.6	562	0.50	ND	0.610	0.16	0.08	0.003	ND	0.018	1.10	1.18	ND
27	KHR 109 (60CM)	6.6	613	0.35	ND	0.427	0.08	0.14	0.003	0.004	0.017	4.49	1.14	0.011
28	KHR 110 (Surface)	6.1	258	0.324	ND	0.395	0.12	0.01	ND	0.000	0.004	1.29	1.09	0.000
29	KHR 110 (30 CM)	6.3	302	0.16	ND	0.195	0.08	0.05	ND	0.019	ND	0.55	0.71	0.001
30	KHR 110 (60CM)	6.3	305	0.206	ND	0.251	0.14	0.02	0.006	0.003	ND	1.29	1.07	0.001
31	KHR 111 (Surface)	6.3	216	0.398	ND	0.486	0.12	0.01	ND	ND	0.008	1.26	1.15	0.000
32	KHR 111 (30 CM)	6.3	108	0.204	ND	0.249	0.10	0.01	0.001	ND	0.012	1.27	1.20	0.000
33	KHR 111 (60 CM)	6.2	177	0.242	ND	0.295	0.10	0.04	0.000	ND	0.012	1.27	1.20	0.000
34	KHR 112 (Surface)	6.1	336	0.43	ND	0.525	0.14	0.00	ND	ND	0.037	1.27	1.14	ND
35	KHR 112 (30 CM)	6.4	245	0.098	ND	0.120	0.12	0.11	ND	ND	0.035	1.26	1.21	0.006
36	KHR 112 (60 CM)	6.1	238	0.128	ND	0.156	0.14	0.22	ND	0.000	0.097	0.71	0.58	0.006

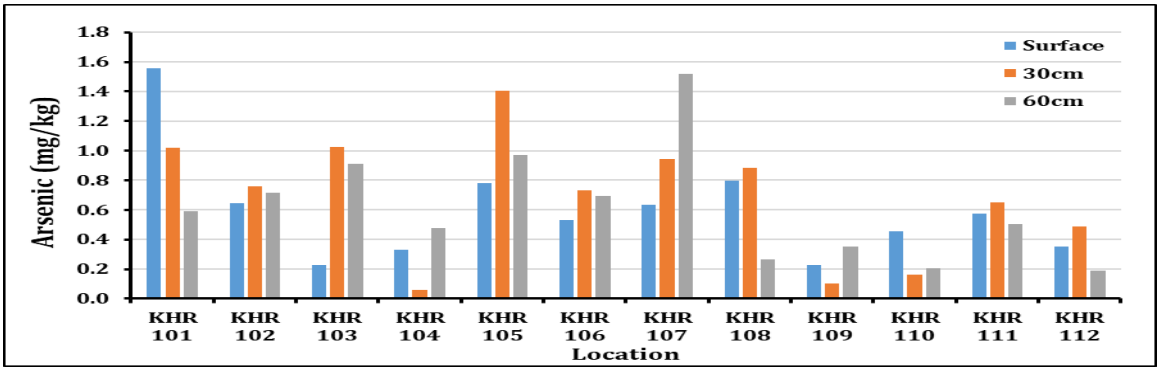
7.2 Heavy Metals

The main sources of trace elements in soil are soil parent materials (rocks), fertilizers, bio-solids, irrigation water, coal combustion residues, auto emissions, and metal-smelting industries. Even though some trace elements originate from rocks and some are essential for plant growth and development, when present in soils at elevated levels those same elements become toxic. Trace elements that have been taken up by plants, especially those grown on contaminated soils, could move up the food chain, some accumulating in the fatty tissue of animals and/or humans. Some trace elements of potential concern as soil contaminants are: arsenic (As), boron (B), cadmium (Cd), chromium (Cr), copper (Cu), fluorine (F), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

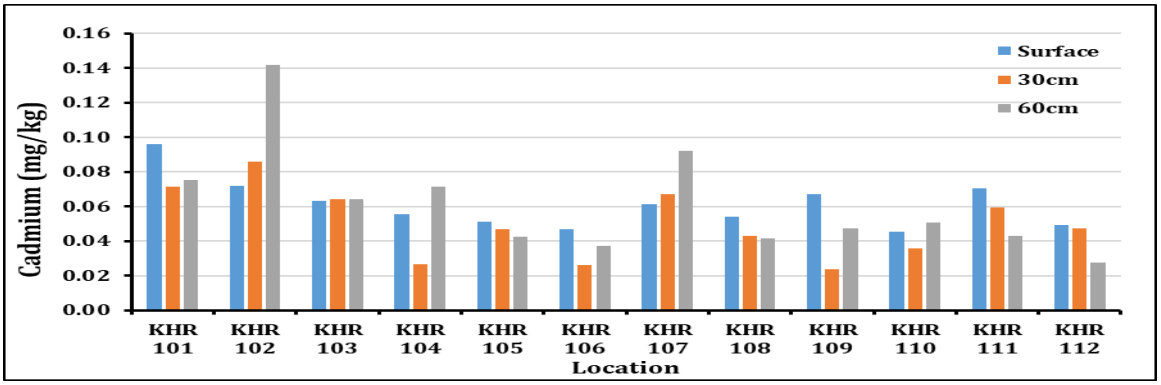
Table 25 presents the depth wise concentration of the heavy metals in the soil samples of various sampling locations. The same are also shown graphically in ***Figure 47***. A summary statistics of the data are presented in ***Table 26.***

Table 25: Depth wise concentration of heavy metals in the soil samples of study area

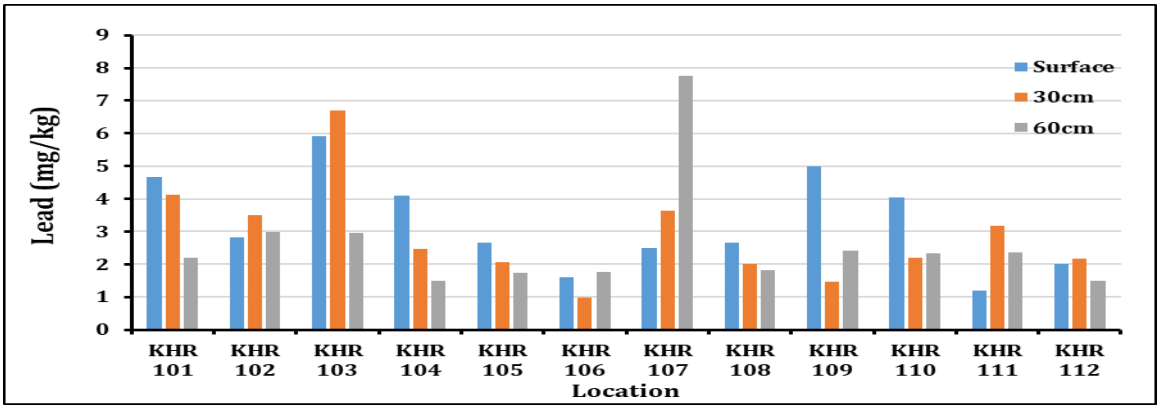
Sample		As	Cd	Pb	Cr	Mn	Cu	Zn	Hg	Fe
SN	Sample ID	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1	KHR 101 (Surface)	1.558	0.096	4.657	44.538	1323.750	156.711	91.948	31.878	78355.621
2	KHR 101 (30 cm)	1.019	0.071	4.119	30.103	571.117	135.916	61.247	26.253	67957.800
3	KHR 101 (60 cm)	0.593	0.075	2.206	32.321	573.326	160.595	57.364	40.402	80297.720
4	KHR 102 (Surface)	0.646	0.072	2.814	56.138	1253.608	177.833	90.290	24.207	88916.460
5	KHR 102 (30 cm)	0.759	0.086	3.511	63.208	1341.186	207.908	112.276	38.015	103953.837
6	KHR 102 (60 cm)	0.717	0.142	2.982	51.573	1194.848	209.892	125.582	58.132	104945.793
7	KHR 103 (Surface)	0.229	0.063	5.918	19.859	1211.809	167.588	78.701	20.456	83793.964
8	KHR 103 (30 cm)	1.024	0.064	6.706	38.282	1308.968	273.027	171.667	25.741	136513.521
9	KHR 103 (60 cm)	0.911	0.064	2.951	28.716	1237.349	200.940	75.340	21.991	100469.927
10	KHR 104 (Surface)	0.333	0.055	4.109	39.945	1524.814	231.924	167.360	15.172	115962.090
11	KHR 104 (30 cm)	0.061	0.026	2.479	4.113	468.684	50.977	40.689	13.297	25488.548
12	KHR 104 (60 cm)	0.479	0.071	1.488	7.155	906.566	65.995	13.155	16.706	32997.295
13	KHR 105 (Surface)	0.781	0.051	2.670	32.558	858.438	72.678	116.751	15.172	36338.897
14	KHR 105 (30 cm)	1.405	0.047	2.053	15.865	449.668	32.527	38.538	18.922	16263.562
15	KHR 105 (60 cm)	0.971	0.042	1.736	46.938	1024.004	100.528	94.835	26.593	50264.022
16	KHR 106 (Surface)	0.530	0.047	1.600	21.793	1112.680	119.209	137.882	22.672	59604.620
17	KHR 106 (30 cm)	0.730	0.026	0.990	10.154	491.769	42.107	62.116	16.536	21053.403
18	KHR 106 (60 cm)	0.693	0.037	1.760	33.825	1147.115	116.162	108.628	20.456	58080.851
19	KHR 107 (Surface)	0.637	0.061	2.490	25.807	795.585	108.656	99.756	17.047	54327.753
20	KHR 107 (30 cm)	0.941	0.067	3.633	42.128	1081.649	129.498	114.303	15.172	64748.862
21	KHR 107 (60 cm)	1.518	0.092	7.770	88.656	2080.996	231.857	306.796	22.502	115928.697
22	KHR 108 (Surface)	0.798	0.054	2.656	35.820	926.777	90.860	75.486	14.490	45429.855
23	KHR 108 (30 cm)	0.883	0.043	2.014	44.800	1048.180	140.928	76.109	26.603	70463.781
24	KHR 108 (60 cm)	0.266	0.041	1.827	22.625	573.731	60.791	51.946	9.546	30395.535
25	KHR 109 (Surface)	0.228	0.067	4.979	17.656	1094.031	97.774	110.746	13.637	48886.760
26	KHR 109 (30 cm)	0.104	0.024	1.475	10.166	391.654	48.933	39.234	13.637	24466.601
27	KHR 109 (60 cm)	0.355	0.047	2.421	30.782	1185.150	106.149	80.937	10.910	53074.586
28	KHR 110 (Surface)	0.457	0.045	4.049	24.429	760.789	177.333	110.068	12.615	88666.600
29	KHR 110 (30 cm)	0.163	0.036	2.208	8.809	576.630	113.559	89.328	11.422	56779.495
30	KHR 110 (60 cm)	0.206	0.051	2.346	12.796	634.220	159.804	82.457	14.149	79901.760
31	KHR 111 (Surface)	0.573	0.070	1.206	20.390	629.869	150.274	54.930	12.274	75137.149
32	KHR 111 (30 cm)	0.649	0.059	3.182	39.706	1010.952	193.789	131.534	16.706	96894.383
33	KHR 111 (60 cm)	0.506	0.043	2.357	37.980	1023.431	200.250	120.831	13.978	100125.227
34	KHR 112 (Surface)	0.352	0.049	2.007	37.164	950.737	92.057	70.797	12.785	46028.289
35	KHR 112 (30 cm)	0.488	0.047	2.173	49.213	1087.723	146.444	88.274	17.738	73222.102
36	KHR 112 (60 cm)	0.189	0.028	1.482	22.729	562.799	61.202	49.868	12.103	30600.825



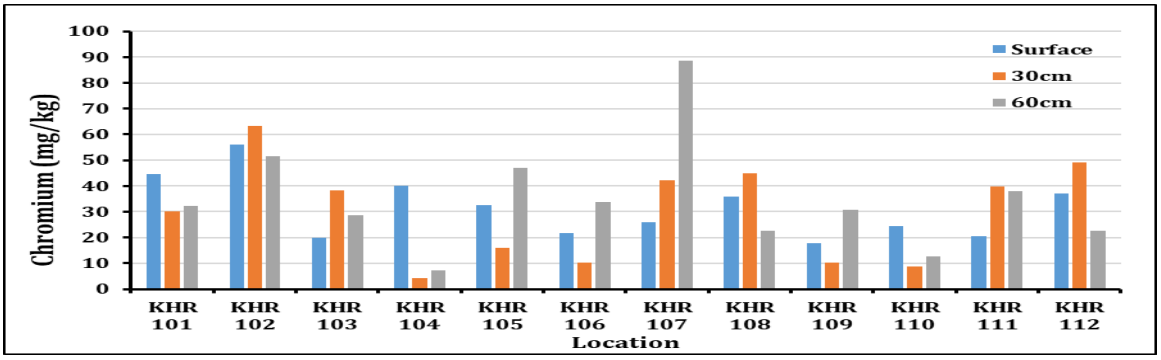
(a) Arsenic



(b) Cadmium

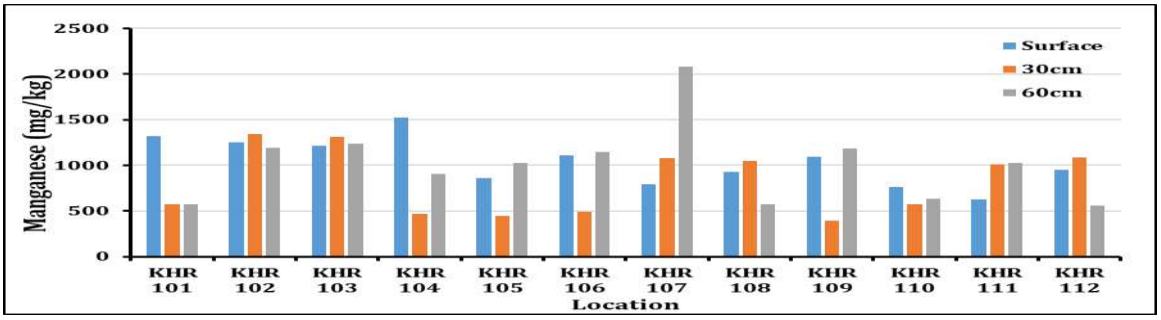


(c) Lead

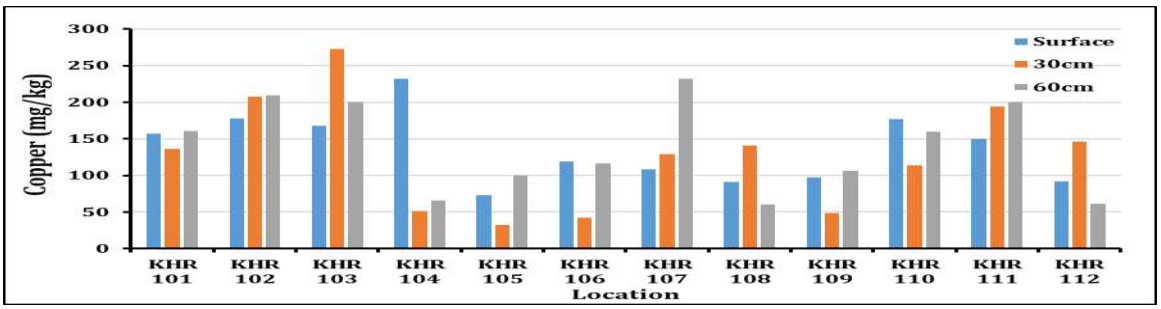


(d) Chromium

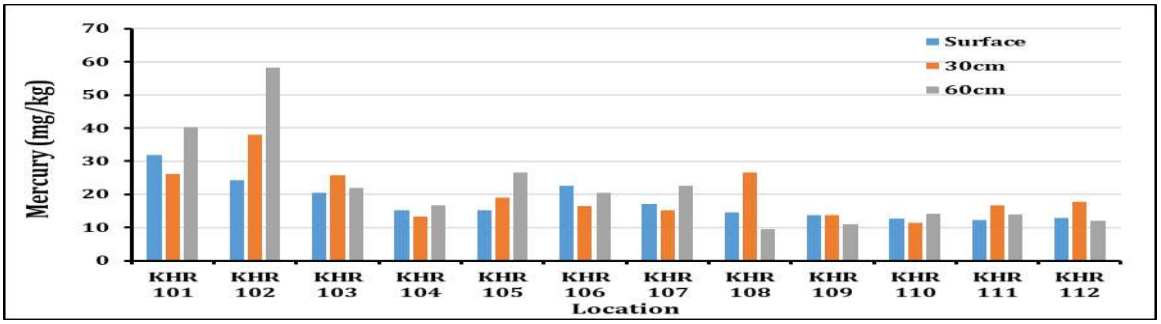
Figure 47: Depth wise concentration of the heavy metals in the soil samples of study area



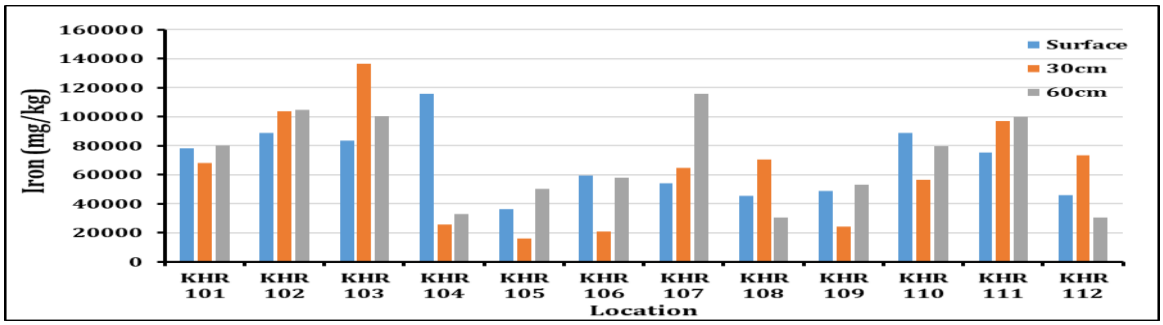
(e) Manganese



(f) Copper



(g) Mercury



(h) Iron

Figure 47:…….Contd.

Table 26: Summary of data on heavy metals in the soil samples of study area

Parameter	As	Cd	Pb	Cr	Mn	Cu	Zn	Hg	Fe
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Maximum	1.558	0.142	7.770	88.656	2080.996	273.027	306.796	58.132	136513.521
Minimum	0.061	0.024	0.990	4.113	391.654	32.527	13.155	9.546	16263.562
Average	0.632	0.057	2.917	31.909	955.961	134.241	94.382	19.998	67120.450

Figure 48 presents some of the photographs of soil sampling carried out for the study area during May 2022.

Figure 48: Some photographs of soil sampling in the study area

Figure 48:….Contd.

8.0 REVIEW OF HYDRO-GEOLOGY

Hydro-geology involves interaction of the movement of ground water with the geology. The main concerned of hydro-geology is the groundwater contamination, conservation of supplies, and water quality. The interaction of ground water and geology is very complex and not always easy to comprehend, because factors like rainfall can significantly affect the hydro-geology. Nevertheless, water lever variations, ground water flow direction and water quality studies can help to throw much light on the hydrogeology of an area and changes occurring it in over the time.

Ground water flow direction has been studied under the present study for both the pre-monsoon and post monsoon period. Ground water flow direction was also studied for the two seasons by NIH during the hydro-geology study carried out during 2015-2017. A comparison of the ground water flow direction during the Pre-monsoon (May 2022) and post–monsoon (November 2022) clearly indicates that there is no variation in the flow direction during the two seasons. The ground water flow direction is observed to follow the surface water topography in general. Similar ground water flow direction for the study area was recorded by NIH during the hydro-geological study carried out earlier**.** Thus, no change in ground water flow direction has been observed for the study area over the years.

Analysis of ground water level variation carried out under the present study indicates that there is increase in groundwater level in post monsoon over the pre-monsoon for 13 out of 15 ground water level monitoring stations, for which the data of both the stations are available. For the remaining two stations there is a decline in water level. Even the decline is not of similar order, it is 0.85 m for one station and 11.34 m decline for the other station. Even the rise at different station show a wide variation. It ranges

from a minimum of 0.15 m to a high rise of 17.47 m. The average rise in water level per station is 4.83 m. Data of many of these stations was also monitored during the previous study by NIH. The average ground water level during the pre-monsoon season, for these lakes was 25.93 m during May 2016. During the monitoring of May 2022 the average pre-monsoon water level has been observed to be 11.92 m.

The significant variation in ground water levels at different stations as observed in the present study (or for that matter in any study) is due to variable recharge at these stations due to monsoon rainfall as well as due to variation in withdrawl of water at these stations. Further, it has been observed that while ground water is very close to ground surface in some areas it is very deep in some areas. Generally, areas which are located near to canals are seen to have shallow water tables while those away from any recharge structures are having deep water levels. The recharge from canal also acts as additional factor influencing the ground water levels. As such, it is difficult to infer about the changes in hydro-geology of an area based on limited data of ground water level variation. A long term data about all the influencing parameters may be needed to draw any specific conclusion. As far as soil chemistry is concerned, no comparable historical data related to soil chemistry are available with the investigators. As per the EIA report of NTPC Soil samples from ten (10) different locations were collected and analyzed. The soil pH varied from 7.37 to 8.12. The EC was observed in the range of 83.8 to 284.39 µs/cm. Under the present study soil samples have been collected from 12 locations within 10 kms radius from the plant at three depths of surface, 30 cm and 60 cms. The pH of the soil was found to vary in the range of 6.0 to 7.2 with an average pH of 6.4. The EC ranged between 75 mg/l to 803 mg/l with an average value of 260 mg/l. However, since the details of the sampling location of the EIA report are not available, the two data cannot be compared, as they may be belonging to totally different locations.

For the purpose of understanding the changes in ground water quality of the study area data from the present stud has been compared with the data of the previous study of NIH. ***Table 27*** presents the comparison of minimum, maximum and average value of different parameters of surface water during pre-monsoon of year 2016 and 2022. Data for ground waters are presented in ***Table 28***. The data for the post monsoon period are presented in ***Table 29*** for surface waters and ***Table 30*** for ground water.

Table 27: Comparison of minimum, maximum and average value of different water quality parameters of surface waters for pre-monsoon of year 2016 and 2022

Parameters	Unit	Pre-monsoon May-2016			Pre-monsoon May-2022		
		Min	Max	Avg	Min	Max	Avg
Physical Parameters							
Tem	**C°**	NA	NA	NA	23.9	31.5	29.1
PH		7.1	7.4	7.3	6.0	6.7	6.3
EC	**µS/cm**	320	642	480	350	2810	1042
TDS	**mg/l**	205	411	307.25	224	1798	667
Alkalinity		102.0	209.0	160.3	22.0	490.0	154.1
Total Hardness		95	202	149.25	127	985	368
DO		NA	NA	NA	3.1	7.2	6.1
BOD		NA	NA	NA	8.0	17.0	10.8
COD		NA	NA	NA	32.0	115.0	55.3
Major Ions							
F^-	**mg/l**	NA	NA	NA	0.19	14.00	1.87
Cl^-		2.0	22.0	8.5	6.60	158.00	64.12
HCO_3^-		124.0	255.0	195.5	27.00	598.00	188.00
SO_4^{2-}		6.0	23.0	12.5	6.80	1192.00	227.26
NO_3^-		16.0	22.0	18.5	0.01	8.70	2.26
NO_2^-		NA	NA	NA	0.05	8.70	2.74
PO_4^-		NA	NA	NA			
Ca^{2+}		20.0	38.0	31.0	31.00	301.00	84.50
Mg^{2+}		11.0	26.0	17.5	12.00	99.00	38.09
Na^+		14.0	31.0	19.0	14.00	86.00	50.50
K^+		1.2	4.4	2.6	2.10	45.00	11.01
NH_4^+		NA	NA	NA	0.28	5.90	2.11
Heavy Metals							
Cr	ppb	NA	NA	NA	1.90	15.00	3.71
Mn		NA	NA	NA	10.00	785.00	181.42
Fe		NA	NA	NA	93.00	1532.00	684.25
Co		NA	NA	NA	0.10	26.00	2.96
Ni		NA	NA	NA	1.30	100.00	11.42
Cu		NA	NA	NA	1.50	20.00	6.33
Zn		NA	NA	NA	10.00	203.00	104.67
As		NA	NA	NA	0.41	34.00	4.66
Cd		NA	NA	NA	0.00	1.47	0.15
Hg		NA	NA	NA	0.27	0.54	0.34
Pb		NA	NA	NA	0.10	3.90	1.13

Table 28: Comparison of minimum, maximum and average value of different parameters of groundwater for pre-monsoon of year 2016 and 2022

Parameters	Unit	Pre-monsoon May-2016			Pre-monsoon May-2022		
		Min	Max	Avg	Min	Max	Avg
Physical Parameters							
Tem	**C°**	NA	NA	NA	27.5	34.1	30.4
PH		7.4	8.5	7.9	6.6	7.2	6.8
EC	**µS/cm**	485	1427	863	788	1642	1167
TDS	**mg/l**	310	913	552	504	1051	747
Alkalinity		102.0	400.0	236.1	55.6	369.0	234.2
Total Hardness		37	407	236	150	673	404
Major Ions							
F^-	**mg/l**	NA	NA	NA	0.21	0.83	0.44
Cl^-		2.2	136.0	53.0	23.00	336.00	80.29
HCO_3^-		124.0	488.0	288.1	68.00	450.00	285.71
SO_4^{2-}		8.0	112.0	51.3	21.00	430.00	143.18
NO_3^-		8.2	26.0	18.6	0.06	0.45	0.33
NO_2^-		NA	NA	NA	0.51	81.00	29.97
PO_4^-		NA	NA	NA	NA	NA	NA
Ca^{2+}		10.0	99.0	54.3	43.00	176.00	113.76
Mg^{2+}		3.0	48.0	24.4	5.10	57.00	29.22
Na^+		11.0	110.0	57.6	19.00	150.00	59.76
K^+		0.1	12.0	2.6	0.49	11.00	1.75
NH_4^+		NA	NA	NA	0.44	5.22	2.10
Heavy Metals							
Cr	ppb	1.80	259.70	25.20	1.80	11.00	3.10
Mn		14.00	2901.60	285.99	1.30	1661.00	148.07
Fe		416.80	13262.80	2345.15	42.00	8142.00	1192.82
Co		0.30	3.00	0.98	0.06	0.64	0.21
Ni		11.40	81.10	30.28	1.20	18.00	3.02
Cu		3.10	139.20	22.29	1.60	96.00	16.06
Zn		180.70	2336.50	504.86	30.00	1673.00	289.41
As		0.00	1.20	0.22	0.22	1.00	0.47
Cd		0.50	2.90	1.08	0.01	0.36	0.08
Hg		0.20	1.00	0.53	0.05	0.51	0.25
Pb		3.10	20.60	8.63	0.00	49.00	7.29

Table 29: Comparison of minimum, maximum and average value of different parameters of post-monsoon in surface waters of year 2016 and 2022

Parameters	Unit	Post-monsoon Non-2015			Post-monsoon Non-2022		
		Min	Max	Avg	Min	Max	Avg
Physical Parameters							
Tem	**C°**	NA	NA	NA	24.3	28.8	26.6
PH		6.9	7.6	7.2	6.9	8.3	7.7
EC	**µS/cm**	298	602	413	281	900	573
TDS	**mg/l**	187	378	264	222	605	409
Alkalinity		87.0	170.0	131.4	29.0	210.4	128.2
Total Hardness		89	191	132	131	318	234
DO		NA	NA	NA	4.4	7.2	6.6
BOD		NA	NA	NA	4.0	50.0	14.2
COD		NA	NA	NA	8.7	61.0	19.6
Major Ions							
F^-	**mg/l**	NA	NA	NA	0.13	8.62	1.19
Cl^-		2.80	15.00	6.38	5.75	63.87	32.77
HCO_3^-		103.00	215.00	153.40	35.38	256.69	156.38
SO_4^{2-}		4.80	19.00	9.28	8.63	337.90	89.41
NO_3^-		NA	NA	NA	1.99	10.52	5.57
NO_2^-		NA	NA	NA	0.20	0.20	0.20
PO_4^-		NA	NA	NA	153.58	153.58	153.58
Ca^{2+}		17.00	40.00	26.80	35.60	91.86	58.06
Mg^{2+}		10.00	19.00	13.40	10.24	31.54	21.74
Na^+		9.20	20.00	13.44	10.83	38.12	25.52
K^+		1.00	2.30	1.84	0.68	24.68	5.40
NH_4^+		NA	NA	NA	0.22	0.28	0.25
Heavy Metals							
Cr	**ppb**	NA	NA	NA	1.50	4.83	2.80
Mn		NA	NA	NA	4.38	489.93	129.31
Fe		NA	NA	NA	131.06	1543.63	590.78
Co		NA	NA	NA	0.10	13.21	1.75
Ni		NA	NA	NA	0.76	47.73	6.53
Cu		NA	NA	NA	2.11	42.67	8.26
Zn		NA	NA	NA	4.62	83.92	26.79
As		NA	NA	NA	0.27	9.40	2.31
Cd		NA	NA	NA	0.01	0.84	0.11
Hg		NA	NA	NA	0.00	0.28	0.08
Pb		NA	NA	NA	0.79	4.61	1.70

Table 30: Comparison of minimum, maximum and average value of different parameters of post-monsoon in groundwater of year 2016 and 2022

Parameters	Unit	Post-monsoon Non-2015			Post-monsoon Non-2022		
		Min	Max	Avg	Min	Max	Avg
Physical Parameters							
Temp	**C°**	NA	NA	NA	26.5	31.5	29.4
PH		7.2	7.8	7.5	6.7	8.2	7.2
EC	**µS/cm**	493	1822	891	590	1652	984
TDS	**mg/l**	316	1166	571	469	967	706
Alkalinity		150.0	358.0	227.9	139.2	380.4	228.9
Total Hardness		120	549	283	130	698	410
Major Ions							
F^-	**mg/l**	NA	NA	NA	0.26	0.87	0.42
Cl^-		2.20	194.00	51.87	18.13	161.34	65.42
HCO_3^-		183.00	437.00	277.07	169.82	464.09	279.23
SO_4^{2-}		8.00	85.00	38.86	18.71	352.98	120.89
NO_3^-		NA	NA	NA	0.23	218.26	61.31
NO_2^-		NA	NA	NA	0.81	1.75	1.15
PO_4^-		NA	NA	NA	NA	NA	NA
Ca^{2+}		30.00	141.00	73.14	39.34	183.06	115.95
Mg^{2+}		8.00	48.00	24.00	3.60	66.46	29.32
Na^+		11.00	164.00	45.64	17.34	126.15	55.75
K^+		0.10	19.00	2.90	0.06	29.17	2.18
NH_4^+		NA	NA	NA	0.20	0.20	0.20
Heavy Metals							
Cr	**ppb**	1.70	250.30	20.16	1.39	6.82	2.42
Mn		8.90	2205.60	226.09	1.94	358.71	41.25
Fe		369.20	12041.90	1887.46	54.99	29884.51	2581.82
Co		0.30	3.20	0.92	0.05	25.57	1.78
Ni		9.30	64.80	28.15	0.60	14.58	2.39
Cu		2.40	114.20	17.01	1.53	866.02	52.75
Zn		131.20	2336.50	448.98	9.78	1872.08	237.96
As		0.40	2.40	0.81	0.18	5.46	0.54
Cd		0.00	1.50	0.17	0.01	0.11	0.03
Hg		0.20	1.00	0.43	0.00	0.04	0.00
Pb		2.30	20.60	7.63	0.44	81.98	13.79

It must be noted that the data presented in ***Tables 27 to 30*** for the years 2015 and 2016 do not pertain to the same stations as 2022, as all the stations monitored during the year 2015 and 2016 have not been included in the sampling for the present study in 2022. Moreover, certain new locations have been added in the present study for example the piezometers. Nevertheless, the data are presented to get some idea about the general changes in water quality in the area.

Comparison of the pre-monsoon data (***Table 27 and Table 28***) brings out that while some of the parameters show an increase, others vary in similar range while decline is observed in some parameters. For example, general decline is observed in pH of both surface and ground waters during pre-monsoon of 2022 compared to pre-monsoon 2016. However, no significant variation is seen in alkalinity for both surface and ground waters during pre-monsoon of 2022 compared to pre-monsoon 2016. Heavy metals in ground water in general indicate lower values in pre-monsoon of 2022 compared to

pre-monsoon of 2022. Parameters like TDS and hardness indicate a rise in pre-monsoon of 2022 when compared with pre-monsoon of 2016. No significant variation is, however, seen in the ions during the pre-monsoon of both 2016 and 2022. Both the data are in more or less similar range.

As far as post monsoon data are concerned (***Table 29 and Table 30***) comparison brings out that physical parameters of surface waters are higher in 2022 compared to 2015. Similar observation can also be made for the ions. As far as water quality of ground waters during post monsoon is concerned, most physical parameters and ions show higher values during post monsoon of 2022 compared to post monsoon of 2015. But heavy metals in general show lower values in post monsoon of 2022 compared to post monsoon of 2015.

From the above observations it is clear that there is no specific increasing trend in the water quality parameters of either the surface water or ground waters of the study area from 2015-16 to 2022. There are variations which could be due to various reasons such variable recharge during different years on account of variation in rainfall, variation in recharge at different locations within the same year, variation in amount of polluted substances reaching the surface and ground water bodies locally etc. ***Table 31***, for example, provide data on rainfall at NTPC Khargone and surrounding area for the years 2015 and 2022. The grid data have been taken from Power Larc, NASA website. It can be seen that rainfall in 2022 was almost 100% more than that of 2015 during the period of June to November. There is particularly significant amount of rainfall during October 2022 than in 2015. Such a magnitude of rainfall can cause significant recharge and runoff consequently causing significant leaching to groundwater or runoff to surface water bodies, which could be one of the reasons of high variability in ground water or surface water quality.

Table 31: Variation in rainfall at NTPC Kharone and surrounding area

Month	Rainfall (mm)	
	2015	2022
June	232.18	183.09
July	399	677
August	300.955	743.43
September	83.14	206.62
October	7.015	262.66
November	0.115	0.09
Total	**1022.405**	**2072.89**

In view of the above observations it is important that for a detailed investigations of change in hydro-geological conditions, particularly through analysis of trends in concentration of various ions and heavy metals in surface and ground waters of any area, a long term data is needed for which regular monitoring of some selected monitoring stations is required, along with collection of other related data. It is therefore recommended that regular monitoring of the surface and ground water (particularly the newly constructed piezometers) for atleast about a decade or so, should be carried out for NTPC Khargone plant area and nearby areas, so that changes in hydro-geology can be detected.

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Annexure-I

NTPC Limited

(A Government of India Enterprise)

CPG-2,Sipat Project

PO Ujwal Nagar
District Bilaspur
Chhattisgarh- 495555, India
Telephone No. : 07752-246552 Fax No. : 07752-246507

Service Purchase Order

PAN No. : AAACN0255D
CIN No. : L40101DL1975GOI007966

Purchase Order No. : 4000268090-037-1019 **Date** : 30.11.2021 **(version : 0)**

To
NATIONAL INSTITUTE OF HYDROLOGY
A GOVT.OF INDIA SOCIETY,UNDER M/O
WATER RESOURCES
ROORKEE
Uttarakhand
India - 247667
E-Mail : DIRECTOR.NIHR@GOV.IN

Vendor Code : 1013420

Subject: : Review of Hydrogeology to assess impact on surface water and ground regime (especially around ash dyke) and propose specific mitigation measures NTPC Khargone.
NIT NO. : 9900228483/037/1019 Dated 30.11.2021
Your Offer No. : Online Offer
Your Reference :

Dear Sir,

This has reference to our above mentioned NIT, Your offer and subsequent discussions. We are pleased to accept your offer opened on 03.11.2021 and confirm having awarded on you the work of Review of Hydrogeology to assess impact on surface water and ground regime (especially around ash dyke) and propose specific mitigation measures NTPC Khargone. of total value INR 1,722,600.00 (Rupee SEVENTEEN LAKH TWENTY-TWO THOUSAND SIX HUNDRED ONLY) mentioned in the scope of works, special terms & conditions, Bill of quantities etc.

The duration of the service period shall be from 15.12.2021 to 14.12.2022. Though the duration of contract shall remain same, the actual date of commencement of the contract shall be as per the direction of EIC. Sh Ashish Dubey, DGM (EMG) shall be EIC for this work.

This service purchase order along with its annexure is being issued to you in duplicate .We request you to return the duplicate copy of this service purchase order, duly signed on each page by your authorised signatory in token of your unequivocal acknowledgment of the same within 15 days from the date of this service purchase order. If no communication is received within 15 days of receipt of Purchase Order, it will be treated that order has been accepted in entirety.

We thank you for the interest shown by you in our project and the cooperation extended to us. We expect to receive your continued cooperation in future also.

Thanking You,
For & on behalf of NTPC Limited.

Imran Naqvi, Sr Mgr (C&M)

Enclosures :

ANNEXURE-3

भारत सरकार
परमाणु ऊर्जा विभाग
विकिरण एवं आइसोटोप प्रौद्योगिकी बोर्ड

Government of India
Department of Atomic Energy
Board of Radiation & Isotope Technology

Certificate Tracking ID / CTID : 2203875
Date of Issue / DOI : 13-Dec-2022
Certificate Serial No. / CSN : ULR-TC666522000002614F

TC-6665

RADIOACTIVITY TEST CERTIFICATE

Ref : BRIT/RAL/DOM/804-815/MISC/629-640/22-23

To :
M/S NTPC LIMITED
KHARGONE SUPER THERMAL POWER PROJECT,
NTPC LTD, KHARGONE, (M.P.)

This is regarding the sample of "COAL & ASH" sent for radioactivity analysis vide your letter ref. no. NTPC/KGN/EMG/BRIT/2022 dated 09.11.2022 as shown in italics:

SAMPLE DESCRIPTION	:	***1) COAL (DRY POWDER)*** ***2) FLY ASH (DRY POWDER)*** ***3) BOTTOM ASH (DRY POWDER)***
QUANTITY (IN GM)	:	***500 GM EACH***
SAMPLING DATE	:	***08/11/2022***
SAMPLE LOCATION	:	***NTPC LTD, KHARGONE, (M.P.)***

DATE OF RECEIPT OF SAMPLE: 17.11.2022 **DATE OF COMPLETION OF TEST: 10.12.2022**

The samples were analysed for U-238, Ra-226 , Th-232 and K-40 radioactivity content by HPGe gamma spectrometry and the values obtained are as follows:

Sr. No	NAME OF THE PRODUCT	U-238 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
1	COAL (DRY POWDER)	23 ± 1.0	20.7 ± 2.0	32.7 ± 4.0	35.1 ± 2.8
2	FLY ASH (DRY POWDER)	57.1 ± 1.5	54.7 ± 3.5	70.6 ± 6.7	127 ± 7.1
3	BOTTOM ASH (DRY POWDER)	42.9 ± 1.3	31.5 ± 2.5	67.4 ± 6.8	140 ± 7.7

Opinion: The measurement values are below the clearance level for radionuclides of natural origin in bulk solid materials, as per AERB directive 01/2010 (table-3) dated 26/11/2010.

Note: (i) The report pertains to the given sample only. (ii) The sample will be retained in this laboratory for a period of 3 months from certificate date and thereafter it will be disposed off. (iii) This report shall not be reproduced except in full, without written approval of the laboratory. (iv) The sampling is not done by this laboratory.

Checked by:
SUMAN C
Assistant

Authorized Signatory:
AJAY NANA THAMKE
OIC, RAL

********** End of Report **********

विआप्रौबो/ बीएआरसी परिसर, सेक्टर २०, वाशी, नवी मुंबई – ४०० ७०३ (महाराष्ट्र)
BRIT/ BARC Vashi Complex, Sector 20, Navi Mumbai – 400 703 (Maharashtra)
वेबसाइट/ Website: www.britatom.gov.in; दूरभाष/ 022 2788 7002/ 7006

ANNEXURE-4

Community Work by NTPC-Khargone STPP

October 2022 to March 2023

Girl Empowerment Mission (GEM)- Admission of 10 meritorious girls to NTPC Township school-Bal Bharti Public school (BBPS), NTPC Khargone on 01.10.2022



Rural Sports: Block Level Kabaddi Tournament at NTPC Township Date:14.10.2022 & 15.10.2022 and Block Level Athletics Competition on 18.11.2022 in which more than 700 students of various schools participated.


रविवार, 20 नवंबर 2022

एनटीपीसी परियोजना सेल्दा के संयोजन में जिला स्तरीय ऐथेलेटिक्स का आयोजन

खरगोन निप्र। जिला स्तरीय ऐथेलेटिक्स का आयोजन एनटीपीसी परियोजना सेल्दा के संयोजन में शौर्य क्रीड़ा प्रांगण में किया गया। अंडर 14, 17 व 19 आयु वर्ग में जिले भर से 50 विद्यालयों के 600 खिलाड़ियों ने जोश और जुनून के साथ प्रतियोगिता में सहभागिता की। प्रतियोगिता का शुभारंभ राजेश कुमार कनोजिया सी.जीएम. एनटीपीसी एवं जिला शिक्षा अधिकारी के.के. डोगरे ने किया।

इस अवसर मुख्य अतिथि श्री कनोजिया ने शुभकामना देते हुए कहा कि खेल हमारे शरीर को

Coaching for class 10th in Selda High School in association with BBPS. It directly benefitted 43 students of 5 villages.

Skill Development trainings: Commencement of Tailoring and beautician Training to Local Women benefitting 47 women to generate livelihood

Celebration of World Disability Day and distribution of sports items at Aasthagram Trust Khargone on 4.12.2022 with 120 tribal, orphan and specially – abled children.

GEM Winter Follow-up Workshop from 20th December to 27th December 2022. 29 girls participated in the workshop from nearby villages. Various academic and extra-curricular activities were organized for them.

Commencement of Skill Development training through CEDMAP of Electrician and Solar Panel Installation on 30.01.2023 in which No of Participants are 15 students of 3 villages.


Health: Organization of Blood donation camp, Mega eye-checkup camp directly benefitting 503 villagers followed by facilitation by NTPC Khargone in 14 Cataract operations of needy.

Organization of Sickle cell anemia for people of Dalchi, Selda and Lallyachapad was conducted on 21 and 22 February 2023 in which 343 children were screened. Out of which 40 were found positive, for these children Disability Evaluation was arranged at District Hospital Khargone via District Medical Board. 34 Children attended for the same.


Teaching by Ahilya Mahila Mandal (AMM) at Dalchi Primary school for educational support and building confidence.

Distribution of 635 Uniform at 12 PAV schools on 21.02.2023

ANNEXURE-5

एनटीपीसी NTPC

एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

Ref: KGN/EMG/MOEF/Ann. Return/ACR 2022-23

Date: 11.04.2023

To
Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest, and Climate Change,
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3, Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in
moefcc-coalash@gov.in

Sub: Submission of Annual Compliance Report for Ash Utilization for FY 2022-23

Ref: MOEF&CC, Notification S.O.-5481(E), dated 31.12.2021: Annual Compliance Report

Dear Sir,

With respect to the above-mentioned subject & reference, we are submitting Annual Compliance Report (ACR) of Ash Utilization in prescribed performa as **Annexure-1,** in soft copy vide email for the period **01.04.2022 to 31.03.2023** at NTPC-Khargone STPS.

Submitted for your kind information and perusal please.

Thanking you,

Yours Sincerely,

(Ashish Kumar Agarwal)
AGM (Ash & Environment Management)

Enclosure:
1. Annexure-1: ACR of AU for FY 2022-23

Copy to (Email) :-
1. Member Secretory, CPCB, Delhi (mscb.cpcb@nic.in)
2. Member Secretory, MPPCB, Bhopal (ms-mppcb@mp.gov.in)
3. Regional Officer, MPPCB, Indore (ropcb-indore@mp.gov.in)

Ash Compliance Report

(for the period 1st April'2022 to 31st March'2023)

(to be submitted on or before 31st May)

Ref.-MoEFCC Notification S.O. 5481(E), Dated-31.12.2021

S. No.	Details	Status
1	Name of Power Plant	**Khargone Super Thermal Power Project**
2	Name of the company	**NTPC Ltd.**
3	District	Khargone
4	State	Madhya Pradesh
5	Postal address for communication:	Village-Selda, PO-SPO NTPC-Selda, SO-Bediya, Tehsil-Barwah, District-Khargone, Madhya Pradesh, PIN-451113
6	E-mail:	emgkhargone@ntpc.co.in aukhargone@ntpc.co.in
7	Power Plant installed capacity (MW):	1320
8	Plant Load Factor (PLF %):	48.61
9	No. of units generated (MWh):	560125
10	Total area under power plant (ha): (including area under ash ponds)	554.42
11	**Quantity of coal consumption during reporting period MTPA (Metric Tons Per Annum):**	**3619651**
12	**Average ash content in percentage (percent):**	**36.18**
13	**Quantity of current ash generation during reporting period MTPA (Metric Tons Per Annum):**	**1309698**
	Fly ash MTPA (Metric Tons Per Annum):	918248
	Bottom ash MTPA (Metric Tons Per Annum):	391450
14	Capacity of dry fly ash storage silo(s) (Metric Tons) :	HCSD SILOS: 1500 (500 x 3) FLY ASH SILOS: 4000 (1000 x 4) **Total Capacity: 5500**
15	Details of utilisation of current ash generated during reporting period-	
a	**Total quantity of current ash utilised (MTPA) during reporting period:**	**1344515**
b	Quantity of fly ash utilised (MTPA):	
i	***Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels)***	**1403**
ii	***Cement manufacturing:***	**664228**
iii	*Ready mix concrete:*	Nil
iv	*Ash and Geo-polymer based construction material:*	Nil
v	*Manufacturing of sintered or cold bonded ash aggregate:*	Nil
vi	*Construction of roads, road and fly over embankment:*	Nil
vii	*Construction of dams:*	Nil
viii	*Filling up of low lying area:*	Nil
ix	*Filling of mine voids:*	Nil
x	*Use in overburden dumps:*	Nil
xi	*Agriculture:*	Nil
xii	*Construction of shoreline protection structures in coastal districts;*	Nil
xiii	*Export of ash to other countries:*	Nil
xiv	*Others (please specify):*	Nil
c	Quantity of bottom ash utilised (MTPA):	Nil (approach road is not ready for BA Lagoons)
i	*Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):*	Nil
ii	*Cement manufacturing:*	Nil

iii	*Ready mix concrete:*	Nil
iv	*Ash and Geo-polymer based construction material:*	Nil
v	*Manufacturing of sintered or cold bonded ash aggregate:*	Nil
vi	*Construction of roads, road and flyover embankment:*	Nil
vii	*Construction of dams:*	Nil
viii	*Filling up of low lying area:*	Nil
ix	*Filling of mine voids:*	Nil
x	*Use in overburden dumps:*	Nil
xi	*Agriculture:*	Nil
xii	*Construction of shoreline protection structures in coastal districts:*	Nil
xiii	*Export of ash to other countries:*	Nil
xiv	*Others (please specify):*	Nil
	a) Fly Ash to Traders	**83887**
	b) Pond Ash to NHAI & Others	**594997**
	Total quantity of current ash Unutilised (MTPA) during reporting period:	(-) 34817
16	**Percentage utilisation of current ash generated during reporting period (per cent):**	**102.7**
17	**Details of disposal of ash in ash ponds**	
a	Total quantity of ash disposed in ash pond(s) (Metric Tons) as on 31st March (excluding reporting period):	0
b	Quantity of ash disposed in ash pond(s) during reporting period (Metric Tons):	(-) 34817
c	Total quantity of water consumption for slurry discharge into ash ponds during reporting period (m^3):	2595409
d	Total number of ash ponds:	1 Ash pond (with 03 Lagoons)
i	*Active:*	1
ii	*Exhausted (yet to be reclaimed):*	Nil
iii	*Reclaimed:*	Nil
e	Total area under ash ponds (ha):	132
18	Individual ash pond details *Ash pond-1,2, etc (please provide below mentioned details separately, if number of ash ponds is more than one)*	
a	Status: Under construction or Active or Exhausted or Reclaimed	Active
c	Date of start of ash disposal in ash pond (DD/MM/YYYY or MMYYYY):	01/08/2019
c	Date of stoppage of ash disposal in ash pond after completing its capacity (DD/MM/YYYY or MM/YYYY): (Not applicable for active ash ponds)	NA
d	Area (hectares):	132
e	Dyke height (m):	Variable height 15-18 m
f	Volume (m^3):	5990000
g	Quantity of ash disposed as on 31st March (Metric Tons):	(-) 34817
h	Available volume in percentage (percent) and quantity of ash can be further disposed (Metric Tons):	81.38 % and 5859604 MT
i	Expected life of ash pond (number of years and months):	03 Years

j	Co-ordinates (Lat and Long): (please specify minimum 4 co-ordinates)	22°04'36.8"N 75°50'52.2"E 22°04'26.4"N 75°49'59.9"E 22°04'42.4"N 75°50'18.2"E 22°04'20.3"N 75°50'23.6"E		
k	Type of lining carried in ash pond: HDPE lining or LDPE lining or clay lining or No lining	L1-HCSD: Fly ash lining L2-BA & L3-BA: Bentonite clay lining		
l	Mode of disposal: Dry disposal or wet slurry (in case of wet slurry please specify whether HCSD or MCSD or LCSD)	Wet and HSCD mode of disposal		
m	Ratio of ash: water in slurry mix	HCSD-55:45 & BA-20:80		
n	Ash water recycling system (AWRS) installed and functioning: Yes or No	Yes		
o	Quantity of wastewater from ash pond discharged into land or water body (m3):	Nil		
p	Last date when the dyke stability study was conducted and name of the organisation who conducted the study:	15.12.2021 by IIT-Hyderabad		
q	Last date when the audit was conducted and name of the organisation who conducted the audit:	08.07.2022 done Internal Audit		
19	**Quantity of legacy ash utilised (MTPA):**			
i	*Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):*	NA		
ii	*Cement manufacturing:*	NA		
iii	*Ready mix concrete:*	NA		
iv	*Ash and Geo-polymer based construction material:*	NA		
v	*Manufacturing of sintered or cold bonded ash aggregate:*	NA		
vi	*Construction of roads, road and flyover embankment:*	NA		
vii	*Construction of dams:*	NA		
viii	*Filling up of low lying area:*	NA		
ix	*Filling of mine voids:*	NA		
x	*Use in overburden dumps:*	NA		
xi	*Agriculture:*	NA		
xii	*Construction of shoreline protection structures in coastal districts;*	NA		
xiii	*Export of ash to other countries:*	NA		
xiv	*Others (please specify):*	NA		
	a) For Dyke Protection Layer	NA		
	b) To Traders	NA		
20	Summary:			
	Details	Quantity generated (MTPA)	Quantity utilised (MTPA) and (per cent)	Balance quantity (MTPA)
	Current ash during reporting period	1309698	1344515 & 102.7 %	Nil
	Legacy ash	0	0	0
	Total	**1309698**	**1344515 & 102.7 %**	**Nil**
21	Any other information: Soft copy of the annual compliance report, and shape files of power plant and ash ponds may be e-mailed to:- **moefcc-coalash@gov.in**	Noted		
22	Signature of Authorised Signatory	Priyabrata Mondal		

ANNEXURE-6

FGD Progress Status at NTPC-Khargone Super Thermal Power Project

S. No.	Description	Status as on Mar'2023
1.	**Package description**	Awarded to M/s L&T Ltd. on 31-07-2018
2.	**Status of Front Handover**	All the work front required to complete the entire scope of civil & architectural works have been handed over to L&T.
3.	**Total Excavation**	Completed
4.	**U#1 & Common facilities RCC**	28866 / 28866 Cum completed.
5.	**U#2 RCC**	9315/ 9315 Cum completed
6.	**Structure Erection U#1**	5431 / 5431 MT done. All the erection works pertaining to Unit-1 & common facilities are completed.
7.	**Structure Erection U#2**	5431 / 5431 MT done. All the erection works pertaining to Unit-2 are completed. Commissioning and pending defects is in progress.
8.	**U#1 & 2 Chimney shell**	Chimney Unit-1 Completed and taken into operation during Flue Gas-In activity. Unit-2 erection completed and taken into operation during Flue Gas-In activity. Painting, lighting ,lift, rain water drain and tiling work is in progress.
9.	**Likely Date of Commissioning**	U#1:- **Commissioning done -Feb'2023** U#2:- May'2023

Photographs:

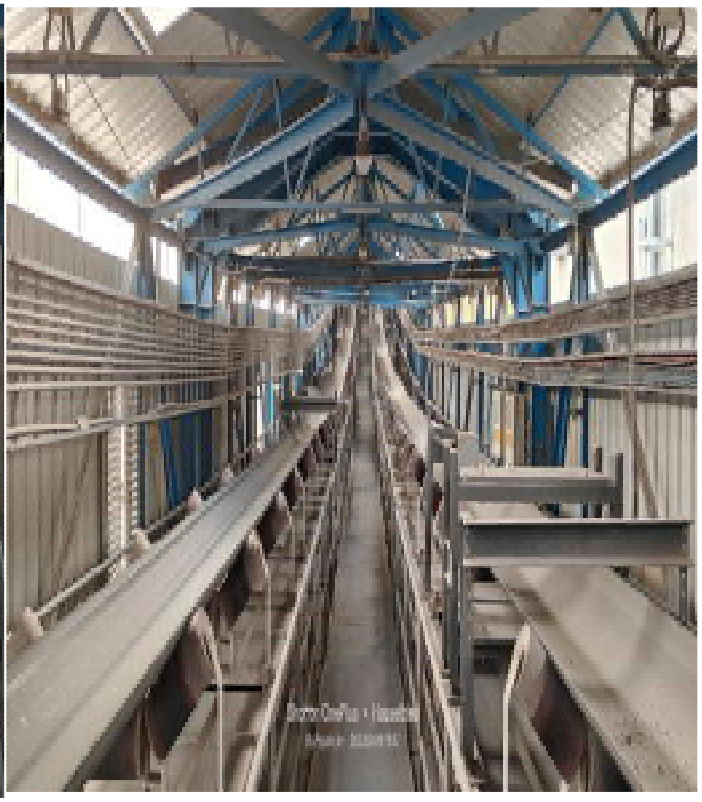
FGD Overview

DM and Process Water

Unit # 1 Absorber

Wet Ball Mill A and B

Lime Stone Conveyor

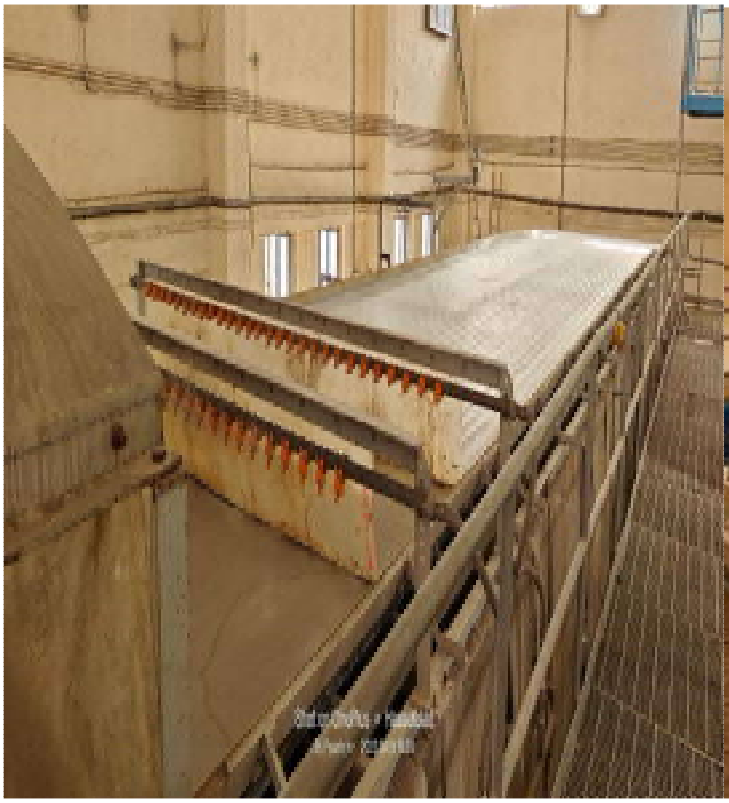


Lime Stone Silo

Lime Stone Truck Tippler

Lime Stone Slurry Tank

Gypsum Conveyor



ANNEXURE-7

Water withdrawal data at NTPC-Khargone STPS from Omkareshwar Dam on Narmada River

Water withdrawal data (for Oct22-Mar'23)				
Month	**Start date**	**Finish date**	**Days**	**Water Drawn, M3**
Oct-22	01-10-22	31-10-22	30	641612
Nov-22	01-11-22	30-11-22	31	1383020
Dec-22	01-12-22	31-12-22	30	1443918
Jan-23	01-01-23	31-01-23	31	1590151
Feb-23	01-02-23	28-02-23	31	1255241
Mar-23	01-03-23	31-03-23	31	1316767
Total Water Drawn, M3				**7630709**