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Institutional Report

Environmental Geoscience Research at CSIR-NEERI, Nagpur India

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Institute Profile

CSIR-NEERI is a constituent laboratory of the Council of Scientific and Industrial Research under the Ministry of Science and Technology, Government of India. The Institute was started in the year 1958, and the Institute was created to provide solutions to Public Health issues following the outbreak of Cholera in the National Capital in the 1950s. It started as the Central Public Health Environmental Engineering Laboratory in 1958. It evolved with time, and since 1972, it is the National Environmental Engineering Research Institute (NEERI). The Institute has different working areas covering the land, water, and Biological environment. Geoscience is an integral part of the research program of the Institute.

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Major Focus

CSIR-NEERI have been working on Geophysical aspects in the last two decades with a significant focus on environmental sustainability (Figure 1). The activities span a broad spectrum from providing solutions to Industries to societal benefits like providing clean drinking water to advisory to Government, Regulatory authorities, and the Judiciary.

The principal activities carried out from 2015-19 are reported.

Use of Artificial Recharge for *in-situ* Dilution of Fluoride

Fluoride is an important constituent in the drinking

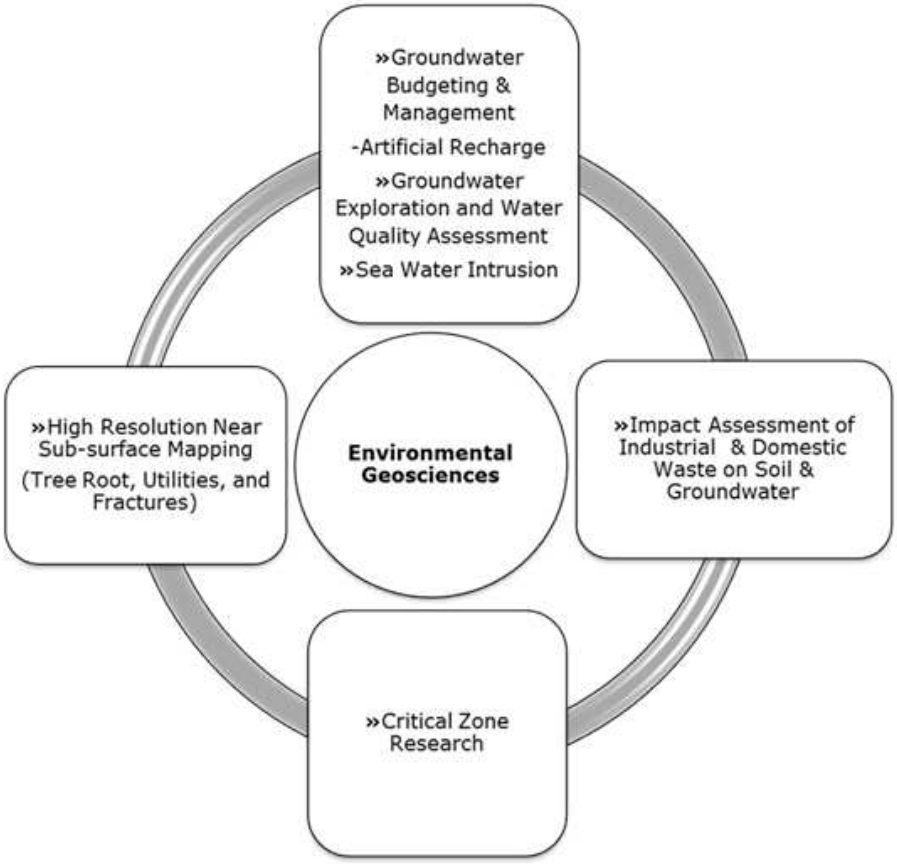

Fig. 1: Environmental Geosciences in CSIR-NEERI

water, and although required for health, it is harmful when it exceeds the permissible limit. The CSIR-NEERI have conducted a systematic study on the efficacy of artificial recharge structures in dilution of fluoride concentration in a fluoride affected village (s) in Central India during 2014-19. The village namely Shivlaldhana was selected near Chindwada in Madhya Pradesh after detailed discussions with the Government agencies and local authorities, and extensive fieldwork, where Fluoride levels in the groundwater range from minimum of 0.2 mg/l to maximum of 6.4 mg/l. The local villagers are depending on fluoride-rich groundwater drawn by existing hand pumps. During summer crises, groundwater being transported by water tanks nearby agricultural bore wells. No pipeline water system in the village.

The study quantified the efficacy of the natural recharge as well as artificial recharge in fluoride dilution. Though the artificial recharge approach to address the scarcity of groundwater is used very extensively in the Indian conditions in different states, its potential for fluoride mitigation has not been attempted on a large scale. Successful implementation requires extensive study, which should lead to the appropriate method for recharge best suited to the site-specific hydrogeological conditions.

The study area is covered by the Deccan trap of Cretaceous age. Understand the hydrochemical changes with depth or water yielding zones, conductivity, and temperature logging were done in representative four bore wells by bore well camera in the study area. Based on available information, it is revealed that the possible source of high fluoride concentration in the village wells is maybe the granite, which is in the basement. The method involves artificial recharging of the groundwater with roof water rainwater recharge through recharge pit in bore wells. It is a process in which water from surface water seeps and mixes with groundwater and dilutes the fluoride content. This process would help only in diluting and not removing the contaminant. Besides,

we can also achieve an important objective by these interventions is that – ensure sustainable availability of water by providing a source to replenish the groundwater. By this groundwater recharge, higher fluoride concentration bringing down up to the BIS permissible limits (1.50 mg/l) and to provide safe drinking water to school children (100 Nos.) as the well same number of households in local village people.

Assessment of Bearing Capacity and Sustainability around Nainital, Bhimtal, Khurpatal, Naukuchiyatal and Sattal Lakes in Nainital District of Uttarakhand State:

CSIR-NEERI carried out a comprehensive study incorporating the hydrological aspects, biological aspects, and the impact of urbanization on the lake through Remote Sensing Analysis. The carrying capacity of all the lake catchment areas has been attempted by taking into account the available space, population, land use pattern, etc.

Remote Sensing Analysis

The Remote Sensing Analysis was carried out for Nainital, Bhimtal, Naukuchiyatal, Sattal, and Khurpatal Lakes to identify the changes in the land use and land cover pattern over last 20 years (i.e., 1997-2017). Further, slope analysis was done to determine the developmental activities on different slope categories. Available space for the scope of further expansion of the built-up area is also quantified.

The results for Nainital Lake show that the built-up cover throughout 1997-2017 on gentle slope class (0-5 degree) has increased from 1.51 to 1.69%, and for moderate slope class (5-15 degree), it has increased from 8.66-11.68%. At the same time, the built upon strong (15-26.5 degree) and steep slope class (26.5-62.5 degree) has increased from 8.66 to 11.68% and 7.91 to 12.24%, respectively. The highest percentage increase of built-up is observed on the steep slope class. This should be an immediate matter of concern as development activity on the slope beyond 26.5 degrees is not permitted as per by-laws for Nainital 2011. The significant built-up area has come up in the last 20 years on different slope categories. The Built-up area on different slope categories indicates that no barren land below 26.5-degree slope (as per building by-laws) is left in the Nainital catchment area. It suggests that no further expansion of built-up should be allowed in the Nainital catchment.

Water and Wastewater Study

In the recent past, the lake water level has been significantly affected during the critical period of February to June. This reduction in lake level during the period of February to June is an alarming situation and may be attributed to the substantial decrease of non-monsoon rainfall.

The Physico-chemical and heavy metal concentration in the lake water were well within the BIS 10500:2012 drinking water specifications. As the water samples were collected during the post-monsoon period, the water samples contained significant amounts of Biochemical Oxygen Demand (BOD) Chemical Oxygen Demand (COD), and Total Kjeldahl Nitrogen (TKN) which represents bulk organic pollution in the lakes. Aquatic component analysis (Zooplankton and Phytoplankton) also indicates that the organic pollution of Nainital Lake is high as compared to other lakes. It was found that sewage quality being treated at different STPs varies widely. The inlet COD concentration is quite variable, thereby affecting the performance of STPs. Since different technologies are applied at these STPs, a study to equalize sewage and optimize performance is highly desirable. The review should also target the reuse of treated sewage for various applications. The sludge generated from STP operations also requires scientific management.

Biological Component: Terrestrial

The analysis of data from terrestrial components indicates that there has been the loss of deciduous forest in the catchment of Nainital Lake and is gradually replaced by evergreen forest (pine trees). It has repercussions on the hydrological regime of the study area. The detailed study on loss of ecosystem services, especially regulating and provisioning due to infrastructure development, the concretization of the catchment area, increased commercial tourism, emigration, and its impact on the local economy, need to be carried out. The broadleaf forests need to be expanded, and water conservation pits need to be created in Nainital. There is an urgent need to utilize an integrated approach that combines various ecological aspects to design better management on

invasive species that are introduced intentionally or unintentionally.

Understanding Critical Zone Structure: Critical Zone Observatory (Narkhed)

The objective of the project is to characterize the critical zone structure (geomorphic, hydro-geological, geochemical, and terrestrial features like leaf area index, root zone mapping, and Spatio-temporal variations of soil moisture) using Remote Sensing, high-resolution geophysical mapping, field observation, and laboratory analysis.

For setting up the Critical Zone Observatory (CZO) watershed approach was adopted, and the study area of the CZO is delineated. It partly covers the WRJ-1 watershed of the Nagpur district and part of the Pandhurna district of Madhya Pradesh, covering a total area of 137 sq. Km.

Groundwater Level Monitoring

The monthly monitoring of groundwater level at 47 observation wells is being conducted since February 2018. During the monitoring period, the minimum groundwater level was in the range of 0 m to 37.2 m bgl (September 2018), whereas the maximum groundwater level in the study area was in the range of 3.4 m to 57.0 m bgl (June 2018).

Groundwater Budgeting

Groundwater budgeting of the study area was conducted, and the stage of groundwater extraction in the study area is calculated to be 96.14 %.

Groundwater and Surface Water Quality

The groundwater quality for the post-monsoon season and the pre-monsoon season is carried out for all the observation wells. Elevated concentration of Nitrate and Phosphate in groundwater during post-monsoon was detected, indicating excessive use of fertilizer.

Soil Chemistry and Soil Morphology

To understand the soil characteristics of the study area, soil sampling was done at different land use and land cover classes. The soil texture analysis conducted for the whole study area shows that the soil of the study area comprises 50% of clay, 30% of silt, and 20% of sand. The average soil organic carbon in the study area is 1.1 %, with a C/N ratio of 15.

Surface Soil Moisture

Surface soil moisture for the entire study area is being monitored for the different land use and land cover classes at the temporal resolution of the 15 days.

Petrological Study

A petrological study for the collected rock samples of the study area is done. The overall results of the petrographic analysis of rocks show that all the rocks are Igneous Rock (Basalt) mainly composed of feldspar, pyroxene along with iron.

Vegetation Type and Leaf Area Index

The investigation of different types of vegetation is being carried out. The Leaf Area Index calculation for the Orange Orchards and other vegetation in the study area is being assessed.

Rat Hole Mining

CSIR-NEERI was directed by the Honourable National Green Tribunal to assess the impact of the rot hole mining in Meghalaya on the water bodies and the damage to the ecology. Based on the report submitted by CSIR-NEERI, a pilot study for the restoration of the water bodies is being initiated.

Environmental Management Plan for the Sambhar Lake in Rajasthan

The objective of the project was to assess the present status of the hydrogeological and hydrochemical conditions of the sambhar lake catchment area and to assess the impact of the industrial withdrawal of groundwater in sambhar lake on the groundwater of the catchment area. Based on the results of the study, an environmental management plan for the Sambhar lake catchment area was proposed. The Sambhar Lake is situated in the state of Rajasthan, which is in the eastern part of the Thar Desert (Rajasthan) and southeast of the Aravalli mountain ranges comprising rock formations of early and middle Proterozoic age. The lake is elliptical and shallow in shape and covers an approximate area of 225.69 sq. Km. Networks of observation wells (46 nos.) have been established in the delineated watershed area for the study. The water level (bgl-m) in pre-monsoon season ranged from 1.7m

to 32.55m and in post-monsoon season ranged from 1.11m to 30.85m. The present stage of groundwater development in the study area is about 158%, which indicates that the scope of groundwater development is already exhausted and it comes under the "Over-exploited" category / "Critical" category (CGWB, 2007, 2008, 2009). However, it does not take into account the saline areas, the stage development for the study area was calculated by considering the industrial draft and it is found to be 560%. The water quality results show that all the samples of pre-monsoon and 98% samples of the post-monsoon season were found above acceptable limits of drinking water specifications of the BIS 10500:2012. TDS in samples was in the range of 768 to 300700 mg/L in pre-monsoon, 380-298080 mg/L in post-monsoon season and the Nitrate in the study area was in the range of 0.8-180 mg/L in pre-monsoon and 0.6-298 mg/L in the post-monsoon season. The groundwater quality results show that the nearby groundwater of the lake catchment area is contaminated by sodium and chloride due to the reversal of hydraulic gradient as a result of large scale indigenous groundwater withdrawal in Sambhar Lake.

The overall results show that large tract of the area is covered by saline areas with Sambhar Lake covering 225.69 sq. Km, Many groundwater sources, namely SW15 (in Khardia village), SW27 (Bhadun village), SW 29 (Sinodia village), and SW 30 (Nousal village) in the vicinity of the lake are characterized by very high salinity. Because of the high salinity, bore wells, hand pumps are not installed by the villagers for potable purposes. Nitrate is a major concern, and suitable intervention measures need to be initiated for treatment. There is no perennial flow to the river and the major streams, i.e., Mendha River and Rupangarh River, are dry except a lean flow in the monsoon season. The study area has scant rainfall (400-600mm annual rainfall) and there is a large scale withdrawal of groundwater by industries as well as agricultural purpose causing a lowering of water table often below 50m and leading to drying of many shallow wells. The yield is also reduced in many wells. The pumping by the Sambhar salt and the private operators far exceeds the groundwater availability in the study area as determined by extensive primary data generated in the field during the project period. The heavy pumping from the production wells leads to the lowering of the lake water level as well. The recharge potential of the aquifer needs to be augmented in the study area which can be addressed by reducing the pumping from the production wells and ensuring sufficient flow in the inflow channels to the lake. Because of the area coming under the arid zone, suitable measures like drip/sprinkler irrigation, rainwater-harvesting need to be promoted in the study area. Also, the groundwater legislation should be implemented for the regulation and control of groundwater in the study area.

Seawater Intrusion Study for Narmada Cement Jafrabad Works (NCJW), Gujarat

Seawater intrusion in the coastal aquifer is a severe problem of Groundwater management. In coastal areas, the magnitude of seawater intrusion depends on the balance between freshwater flow and saltwater from the sea. The factors such as geology, hydrogeology, groundwater heads, and groundwater well-pumping rates are influencing the interface between freshwater and saline water. CSIR-NEERI, with CSIR-CIMFER, conducted a study to evaluate the seawater intrusion status in a coastal aquifer in the Jafrabad area of the Gujarat state of India. This report deals with Seawater intrusion (SWI) investigation for the Narmada limestone mine of Narmada Cement-Jafarabad Works (NCJW), which is located in Amreli district of Gujarat state and owned by M/s UltraTech Cements Limited of Aditya Birla Group. The study area covers mine lease area of Narmada Cement mine (NCM) which is an open cast mine. The mining of limestone is being carried out at this mine in combination with conventional mining and 'Surface Miner' above the mean sea level. Due to restricted depth, the horizontal expansion of mine is large. The deposit has a very negligible overburden.

A multidisciplinary approach has been adopted for this investigation as the problem has multiple dimensions that involve geological/geophysical (Electrical Resistivity Tomography) / hydrological / laboratory and modeling results based on different parameters.

The Electrical Resistivity Tomography (ERT) has been employed to characterize the seawater intrusion in a coastal aquifer of Jafrabad (District Amreli) in Gujarat. A total of 9 numbers of ERT were

performed for this purpose. As the presence of seawater strongly reduces the resistivity values, obtained resistivity data were then classified into three groups as Very low (0-3 ohm-m) Low (3-45 ohm-m) Intermediate (45-250 ohm-m) High (250 ohm-m). Very low resistivity zones were termed as most seawater intruded zone. The zones characterized by low and intermediate resistivity values are considered as 'possible zone' of intrusion and this zone possesses a mixture of freshwater as well as seawater in the rock pores. The presence of seawater in the high resistivity zone (i.e., > 250 ohm-m) is considered as the zone free from SWI, but its possibilities are very less. The total absence of SWI in such zones cannot be ruled out as it lies in the close proximity of the inflicted area. The inverted resistivity sections in the east pit and north pit indicated that the SWI/very low resistivity zone (0-3 ohm-m) is present at 20-22 m depth below ground level (mainland). Almost all ERT profiles are showing less resistivity (< 3 ohm-m) which increases the possibility of seawater intrusion.The study area is modeled considering three boundaries of the watershed namely ridge on the west (Raidi), the Dhatarwadi River on the east and the Arabian Sea on the south. Predictive assessment for future scenario has been done for 05 years and 20 years.

From both the methods, it is found that groundwater in most of the area around Jafarabad town is severely affected by saltwater. Very low resistivity zone has been demarcated from ERT profiles conducted in North block pit and south block pit of NCJW mines, Mitiyala village, Lunsapur,Vand village at a depth of 33 m, 12 m, 40 m, 37 m, 24 m respectively. Hydro Chemical analysis of nearby sampling locations shows High concentrations of TDS as well as Na, cl. Besides Cl/HCO3 ratio is high.

It is recommended that aquifer must be recharged to avoid further seawater intrusion. The recommended recharge structures for the particular study area are either through 'mined out pits' or through injection wells. Installation of Piezometers to monitor the groundwater level and TDS concentration is necessary. Intrusion control measures like maintaining freshwater head above seawater should be taken to prevent further SWI into the mainland.

Integrated Hydrogeological, Geophysical, Hydrochemical, and Groundwater Flow and Solute Transport Modelling Studies Around the Ash-filled South Balanda Mine Voids in Angul District, Odisha

The power sector is one of the fastest-growing sectors in India, and it supports the economic growth of the nation. The present installed capacity of power plants is about 302087.84 MW and thermal power plants account for approximately 61.29% of the total installed capacity. The TTPS is a coal-based power station of 4×60 MW. The unused ash is mixed with water and the resultant slurry is disposed of in abandoned south Balanda mine void spread over 92.82 ha. Given the intervention by MOEF & CC in 2011, NTPC has engaged CSIR-NEERI to undertake various studies related to environmental impacts of ash filling in mine voids. Different aspects have been studied since 2012 and the present report integrates all the findings.

A network of observation wells has been set up, and monitoring of the wells and piezometers installed by TTPS has been carried out in the pre-monsoon and post-monsoon seasons for the major cations, anions and trace elements.

The study based on the groundwater level (above mean sea level) contours indicates that the groundwater flow direction is towards the Brahmani River. All the parameters (major cations/anions) were well within the permissible limits of BIS standards except for fluoride and nitrate, which showed elevated concentrations in three samples. Petrographic studies carried out by NEERI in 2014 had established the presence of fluoride and aluminum bearing minerals in the study area. The remote sensing and land use land classification study had found the elevated concentration of nitrate to the proximity of the samples to the built-up areas and agricultural fields.

The water extraction tests and Water elution tests show that the leaching of metals may occur only under extremely acidic conditions in the laboratory. Under normal environmental conditions, the leaching of the heavy metals and trace elements is insignificant. This explains the low concentration of trace elements in the Supernatant in the Mine Void.

The drilling at the ash void indicates that the top unconfined aquifer at the site is now occupied by poor permeable ash column. The Modelling of solute transport of the supernatant (with TDS 210 mg/L) indicates that the high concentrated plume (210 mg/

L) will move 280 m, 568 m, 852 m and 1140 m distance in 5 years, 10 years, 15 years and 20 years respectively.

The results of all the studies indicate that the disposal of ash from the TTPS in the voids of South Balanda Mine has no adverse impact on groundwater quality. The reduced permeability of the ash deposits in the Mine void prevents the movement of ash water into the adjoining aquifers and prevents groundwater contamination. It is recommended that TTPS should monitor the trace elements in the supernatant and the Piezometres every quarter.

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List of Reports

Integrated Hydrogeological, Geophysical, Hydrochemical, and Groundwater flow and solute transport modelling studies around the ash-filled South Balanda Mine Voids in Angul District, Odisha

Submitted to: NTPC Limited, Talcher, Angul, Odisha

Seawater intrusion study for Narmada cement Jafrabad works (NCJW), Gujarat

Submitted to: UltraTech Cement Limited, Jafrabad, Gujrat

Assessment of Bearing Capacity and Sustainability around Nainital, Bhimtal, Khurpatal, Naukuchiyatal and Sattal Lakes in Nainital District of Uttarakhand State

Submitted to: Lake Development Authority, Nainital, Uttarakhand.