# भूजल संवाद

Govt. of India
Ministry of Jal Shakti
Dept. of WR, RD & GR
Central Ground Water Board

*Bhujal Samvad, The Quarterly Magazine of Central Ground Water Board*

*Jan to March, 2021, Vol.12*



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The Quarterly Magazine of Central Ground Water Board
Dept. of Water Resources, River Development and Ganga Rejuvenation,
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**Vol. 12 (Jan to March, 2021)**



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**Cover Photo:** Pristine White beach Sands of Kavaratti Island, Lakshdweep

# MESSAGE

I am pleased to introduce a new volume of Bhujal Samvad. It has been three years since the magazine was started by CGWB.

This issue of Bhujal Samvad, is a special issue on our Islands, covering articles on both Andaman & Nicobar Islands and Lakshadweep. State Government Initiative Section includes Initiatives by Andaman and Nicobar Island Administration for Sustainable Urban Water Supply, whereas a report on Ground Water Scenario in Lakshwadweep Island is also included. The Achievements of Central Ground Water Board during 2020-21 are highlighted in our In Focus section. A special article on promising solution to Ground Water Management through Atal Bhujal Yojana by Arghyam has also been included in the newly created NGO Column Section. Public Interaction Programmes by CGWB is a part of our Cover Story. We are grateful to our avid readers for providing us with excellent feedback and thoughts towards improving the magazine. Do share your ideas with us through our social media pages or send email to our editorial office (mediacell-cgwb@nic.in).

We are eager to hear from you.

G.C.Pati
Chairman CGWB

# IN FOCUS

## Achievements 2020-21

01

**NAQUIM:** NAQUIM studies for aquifer mapping and management plan formulation have been taken up by CGWB. The programme was initiated in 2012 as a component of the ground water mangaement and regulation scheme. Of the total geographical area of nearly 32 lakh sq km, and area of nearly 25 lakhs sq km has been identified to be covered under NAQUIM studies. Till March 2020, an area of 13 lakh sq km was covered.
During 2020-21 total target was 3 lakh sq km against which an area of 3.33 lakh sq km has been covered taking the cumulative coverage 16.33 lakh sq. km.

02

**PIP:** Public Interaction Programmes (PIP) were introduced in the year 2018 as a medium to disseminate NAQUIM information with stakeholders at grassroots level. During 2018-20 total 446 programmes conducted with 46000 participants. In addition to this, during 2019-20, CGWB carried out 298 awareness programmes in schools in which nearly 35000 students and teachers participated.

During 2020-21, we had a target of conducting 248 PIPs against which 254 PIPs were conducted through the Regional Offices of the Board in which nearly 18000 persons participated.

03

Capacity Building: Rajiv Gandhi National Ground Water Training and Research Institute since its establishement in the year 1997 till the end of XI plan (2011) had conducted 221 training programmes in which 4500 professionals were trained. Since XII plan (2012-17) RGNGWTRI is implementing a three tiered (Tier 1: National Level, Tier 2: State Level, Tier 3: Block Level). During 2012-20 total 982 trainings conducted with 78000 participants.

During 2020-21 RGNGWTRI conducted 59 training programmes (Tier 1: 34. Tier 2: 19 and Tier 3: 6) with a total participation of 3163 persons.

04

**MoU:**

- MoU between CGWB and Manav Rachna International Institute of Research and Studies (MRIIRS) was signed on 20th June 2020 for "Academic Collaboration for education and research in ground water"


- CGWB, DoWR,RD&GR, Ministry of Jal Shakti and CSIR-NGRI, Hyderabad have signed an agreement for use of advanced heli-borne geophysical survey and other scientific studies in parts of the States of Rajasthan, Gujarat and Haryana under the Aquifer Mapping Programme. Under phase- I of the project, an area of nearly 1 lakh sq km is targeted to be covered. The MoA was signed on 21st December 2020. Shri G.C Pati chairman, CGWB and Dr. V Tiwari, Director, CSIR-NGRI signed the MoU in the august presence of Hon'ble Minister of Science and Technology and Hon'ble Minister of Jal Shakti.

05

**Exploratory Drilling:** CGWB carries out exploratory drilling to obtain subsurface information on disposition and characteristics of aquifers. As a par t of the NAQUIM programme till the end of March 2020, CGWB had constructed nearly 11200 wells for ground water exploration that included nearly 5850 through the inhouse drilling rigs and the remaining through outsourcing.

During the year 2020-21 CGWB as a part of the NAQUIM studies has constructed 686 boreholes through inhouse rigs and 1083 boreholes through outsourcing.

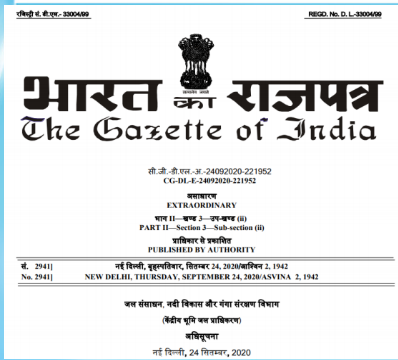
06

**Geophysical Studies:** Geophysical investigations provide indirect information about disposition and characteristics of the subsurface formations. Vertical Electrical Sounding (VES) and Transient Electromagnetic Surveys (TEM) are two of the most predominant surface geophysical techniques used by CGWB for study of subsurface formations and groundwater.
As a part of NAQUIM studies during he period 2012-20 CGWB has carried out more than 24000 (in house 17600, outsourcing 6000) such studies.
During the period 2020-21 a total of 3757 such studies (VES + TEM) were carried out, of which nearly 3311 were carried out using inhouse resources and the remaining through out sourcing.

07

**Water Quality Analysis:** As a part of the NAQUIM studies, during the period 2012-20, 232760 sample have been analyze (inhouse) & 5046 have been analysed through outsourcing
During 2020-21, 29456 samples have been analysed inhouse.

# IN FOCUS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भारत का राजपत्र
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EXTRAORDINARY

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जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

(केंद्रीय भूमि जल प्राधिकरण)

अधिसूचना

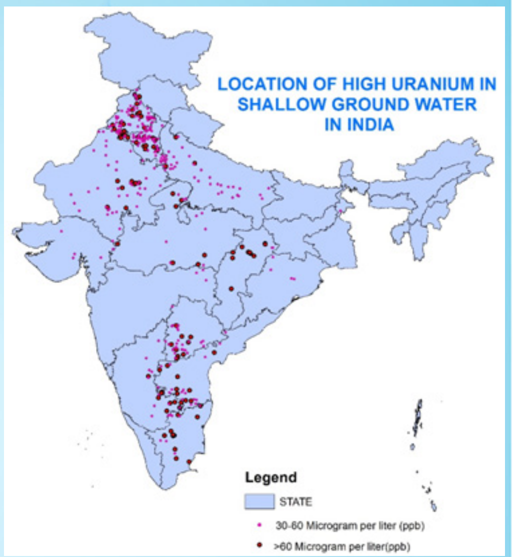
नई दिल्ली, 24 सितम्बर, 2020

**CGWA:** Guidelines to regulate and control ground water extraction in India has been issued.

08

09

**Study on Uranium:** A special study on Uranium contamination in ground water was taken up by CGWB. Nearly 3.0 % samples found to have Uranium >30 ppb (permissible limit by WHO). The report is available on CGWB website.




10

**Artificial Recharge projects** Implemented innovative Aquifer Rejuvenation interventions in three aspirational districts of the States of Maharashtra, Telengana and Andhra Pradesh.

Construction of innovative Bridge-cum-Bandhara was undertaken at five sites in the State of Maharashtra to Conserve surface water & base flows available in the stream channel. Existing bridges were improvised as water retaining structure.


Bridge cum Bandhara

# Groundwater scenario of Lakshadweep- an archipelago in Arabian Sea

## INTRODUCTION

The Union Territory of Lakshadweep is a group of 36 tiny islands,which are scattered in the Arabian Sea,covers an area of 32 sq. km. with Kavaratti as its capital. These islands form the northern part of the Chagos-Laccadive Ridge, which is a prominent volcanic ridge and oceanic plateau, extending between the Northern and the Central Indian Ocean. Even though the land area is restricted, these islands possess a vast lagoon area, which covers about 4,200 km2.The main islands are Andrott, Amini, Agatti, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy. Apart from these ten inhabited islands, Bangaram, the only island open to international tourists, is seasonally inhabited.Total population of Lakshadweep is 64473 (2011 Census) with a population density of 2015 persons per sq.km.

Satellite Imagery of Lakshadweep Islands

Lying well within the tropics and extending to the equatorial belt, these islands have a tropical humid, warm and generally pleasant climate with average annual rainfall of 1640 mm with average monthly rainfall of more than 40 mm for eight months in a year, from May to December. Evapotranspiration is very high in most of the months, except in high rainfall season and it exceed the rainfall making the water scarcity. The islands are made of coral reefs, which are 100 million years old, and the soils derived from these coral limestone,which are highly permeable, allow rainfall to readily infiltrate, with the result that surface run-off does not occur except in isolated areas characterized by compact soils. Some islands are saucer shaped that are either oval or elliptical in shape with the highest elevation on their periphery/rim. While some islands are elongated narrow, either the shape of baseball stick or sole, with a steep shoreline having an elevated centre. Most conspicuous feature of all islands is the western lagoon side, characterized by wide sparkling white beaches with shallow slope and narrow stony beaches with steep slope on the eastern side. The islands are generally flat with localized depressions and sand mounds, which are largely man-made.

## Groundwater as floating lens: Spatio-temporal variation

The coral sands and the coral limestone form the principal aquifer in all the islands and exploratory drilling elucidated the different episodes of diagenes isand lithification. The continuity, thickness and lateral extent of these aquifers vary from place to place in each island. The delicate ecosystem of Lakshadweep islands possess very limited freshwater resource that occurs as lenses floating in hydraulic continuity over the sea water satisfying the Ghyben-Herzberg relation. The fresh-sea water interface is a transition zone and the thickness of freshwater lens is highly influenced by diurnal tidal fluctuation, seasonal water level fluctuation, groundwater recharge and draft, and molecular dispersion apart from the shape and elevation of the islands. The freshwater lens continues to expand laterally as well as vertically corresponding to draft and recharge, and the groundwater flow is mostly vertical while horizontal flow is relatively insignificant. Contrasting to the mainland, the diurnal as well as seasonal variation in groundwater quality of lens is more evident. Since a fragile relation exists between the fresh water and seawater, the quality variations in the island are high and swiftly reversible.

Large diameter wells are the most common and traditional groundwater abstraction structure sand 75% of wells are fitted with small capacity (normally 0.5 HP) electric pumps. In most of the wells, the hard coral limestone is exposed near the bottom and caving is very common.The depth to water level in the islands varies from a few centimetres to about 5 m below ground level and the depth of the wells vary from less than a metre to about 6 m.The groundwater in the island is generally alkaline with pH ranging from 7.16 to 8.61 and electrical conductivity (EC) ranges from 500 to 15,000 µS /cm at 25°C. Higher concentrations of dissolved solids are generally seen along the periphery of the island, and also close to pumping centers. Wells from which water is drawn using bucket and pulley retain more or less the same quality over a long period when compared to pump fitted wells. It is also seen that a trend towards sea water composition is observed with increasing electrical conductivity in and around pumping centers. This acts as a conduit for up-coning of seawater. Quality of groundwater in the islands varies with time too. Similarly, brackish water is seen along topographic lows and in areas where coarse pebbles and corals are seen.

Location map

The freshwater lens occurs as a continuous body wherever the land is broad but the narrower area is mainly characterized by brackish water where freshwater is seen as minor lenses.  The contact between the fresh and brackish water in the lens during monsoon depends upon the size and shape of the island. Generally, the wells located in the peripheral area exhibit maximum fluctuation in groundwater quality. The small freshwater lens in the broad brackish zone disappears in extreme summer and it widens during monsoon. Similarly, the small brackish water lens in the freshwater zone shrinks during monsoon, while in summer it widens. Generally, the ground water level fluctuation due to tidal influence is in the range of 0.10 to 0.37 m. During monsoon, a major part of the recharged water gets readjusted below mean sea level by expansion of the lens. Hence, there will not be any significant rise in water level, and only a small fraction of the water that continues for succeeding 2-3 months will be above mean sea level. The effect of rainfall is evident in improvement in the quality of freshwater lens, which is very well elucidated in various studies.

The stage of groundwater development for the group of islands is of the order of 65.99 % (March, 2017). Based on the stage of development, Agatti, Amini and Kavaratti Islands have been categorized as 'Semi-Critical', whereas the remaining islands have been categorized as 'Safe'.

## Speckled Groundwater Issues:

Physiographically, all the islands are devoid of any major topographic features. Additionally complete absence of streams and surface water bodies resulted in the high dependence on fragile groundwater lens, which is the sole source of freshwater in these islands. The tidal effects on the shallow fresh water lens are ubiquitous while a major threat to groundwater in these islands is the pollution mainly by septic tanks and sewerage disposal.Tidal influence on quality variation is very prominent in the peripheral area than the central part of the island. However, it is seen that best quality of water is available during high tide. As majority of the wells in the island is fitted with low capacity pumps, continuous pumping affects the delicate equilibrium existing between the freshwater-salt water results in the up-coning of the saline water from beneath and the quality deterioration due to pumping is evident even on limited pumping.

Sewerage disposal, use of detergents for washing, presence of soak pits/ septic tank, livestock wastes, oil spills and other kinds of human interference with the eco-system are causes of concern as far as the quality of ground water in these islands is concerned.The traditional burial grounds also contribute to groundwater contamination to some extent. Another auxiliary factor that brings in the quality variation is the marine aerosols.


Sparkling white Beaches

## Concerns on Groundwater Management

The thin floating groundwater lens constitutes the conventional source of fresh water in islands apart from rain. Absence of surface water bodies and increasing demand for drinking and domestic uses in the highly populated tiny islands is putting more stress on the limited groundwater resources.As the thickness of fresh water lens shrink during summer, the quality of groundwater becomes brackish that results in water scarcity in the islands. And the situation is exacerbated by continuous pumping and unscientific waste disposal. All these dynamics make fresh water a prime commodity. Hence rainwater harvesting and storage is the most suitable and cost effective solution to the water scarcity problems in the Lakshadweep islands in view of the limited sub-surface storage available and the shallow water table conditions. Further, most of the buildings are tiled roof or RCC roofs and hence ideal for roof water harvesting.

Lakshadweep administration has widely recognized the role of rain water harvesting (RWH) as most suitable and adoptable way in supplementing the water supply very long back and it was widely implemented in all islands by building tanks of various capacities ranging from 5 m3 to 10 m3 or some places up to 70 m3. Apart from these, low temperature thermal desalinization plants (LTTD) have been established in three islands of Lakshadweep and a Reverse Osmosis plant at Bitra Island. Commissioning of LTTD for 6 islands is expected by this year. Roughly, water supply can be supplemented exclusively for 21 days from RWH and LTTD in a year.

## Sustainable Development Measures

No single solution exists to provide sufficient water supply to all the islands. Water supply must resort to a combination of groundwater, desalinated water and rainwater harvesting. Groundwater extraction through collector wells should be promoted, which envisages extraction through radial perforated pipes. This mechanism prevents excessive extraction from a point source, but is distributed over a large area. Hand drawn wells to be encouraged over energized wells. Pumps above 0.25 hp should not be allowed. With the advent of LTTD plants, maintenance of RWH should not be ignored. Abandoned wells and pond are to be rejuvenated and protected and wells should not be converted into garbage disposal pit. Water supply through desalination plants is not to be taken as alternate source but it should be taken as supplementary source. Real-time monitoring of water levels and water quality are found to be essential. Establish decentralized garbage/waste treatment systems to prevent further contamination of available fresh water resources.Finally, sensitization and capacity building of stakeholders at all levels on the importance of water conservation and ways and means for its judicious management should be imparted.

*Ms. Rani V.R.*

# INTER-ISLAND TRANSFER OF SPRING WATER FROM RUTLAND ISLAND TO PORTBLAIR, ANDAMAN AND NICOBAR ISLAND, FOR SUSTAINABLE URBAN WATER SUPPLY

## Introduction

Port Blair, the capital of A&N Islands, located in South Andaman Island, often suffers from acute water scarcity due to various hydrogeological, climatological, and demographic reasons. Surface and ground water potential of the city is inadequate. During extreme water scarcity in early 2002, CGWB (Kar, 2002) discovered number of potential springs in the contiguous Rutland Island and advocated the feasibility of interisland transfer of water to Port Blair through undersea pipelines. To mitigate the crisis, the transfer immediately started from the Chain Nala spring through ships and barges. Following CGWB recommendation, a long-term monitoring study of spring discharge was undertaken, and a Detailed Project Report was submitted. The water crisis has been continuing till date. However, in the wake of another serious water crisis in 2007, few major options of water supply including the inter-island transfer of spring water were adopted by A&N Administration. In 2009, Govt. of India had approved the proposal. Partial pipeline connection was completed in both the Islands during 2011 when few of the springs were tapped. The interisland transfer from chain nala spring continued till 2011. However, it was shifted to Rifle Man point jetty after the pipeline connection of few of the springs. Till March, 2021 a sum total of 840756 metric ton of spring water has been transported to Port Blair. Detailed studies by CGWB in 2017-18, reconfirmed the potential of the springs. Following a looming crisis in 2020, A&N Administration embarked upon the implementation of undersea pipeline work. To upscale the sustainable supply, all the left-out springs need to be connected. The work of undersea pipeline of the reported world's largest interisland spring water transfer is underway.

The Rutland Island also popularly known as Kalapahar, is in the South of South Andaman Island and the islands are separated by a narrow strait, called the Macpherson strait. The pristine lush green Island is covered by dense forestry. It supports a meagre population of 688 (2011 census). Most of the population in Rutland are the descendant of the labourers who were brought by the Britishers for cutting of trees. The island is endowed with adequate fresh water. Considering the hydrogeology of Port Blair, Britishers constructed few dug wells, number of ponds to harvest copious rainfall as also harnessed the springs to fulfill the water requirement of the handful population. Many such ponds still exist in and around Port Blair. The population of the city considerably declined after the tsunami and earthquake in 2004. However, the population gradually started rising since 2005 and the steep rise in population was noted after 2010-11 with the successive boom in tourism industry in the post Tsunami . Currently the demand of water for the city is mostly catered through the supply of water from Dhanikhari dam, inter island transfer of Spring water from Rutland island by ships and barges, few

**Dr. Amlanjyoti Kar**
**Former Regional Director, CGWB**

ponds, dug wells and few borewells located in the contiguous areas in and around the city. In absence of concerted city planning with proper water management policies, the water supply related miseries went on aggravating till 2007-08. However, by 2007-08 few major options of water supply were finally adopted by A&N Administration to mitigate the water crisis in Port Blair keeping in view of marked rise in floating population due to boom in tourism industry. The options also conjectured to fill up the huge gap of demand and supply of existing water to a great extent. Consequently, the role of ground water from the available resources and especially through the Inter Island transfer of spring water from Rutland Island has been considered pivotal in sustainable urban water supply. Hence after keen persuasion of A&N Administration, Govt. of India accorded the sanction of a part of the Inter-island transfer project of spring water as submitted by the A&N Administration, worth about 70 crores, in the year 2009. To execute the Interisland transfer project, in the first phase few springs flowing enroute Bada khadi village were connected through pipeline and extended up to Rifleman Jetty in Rutland Island. On completion of the project , this will be the world's biggest interisland transfer project of spring water through undersea pipe line.

## Springs in South Andaman and Rutland Island, their Origin and role in Rural and Urban Water Supply

Springs form the main water supply sources in hilly terrain and Himalayas. Plethora of scientific studies are undertaken on springs in India and abroad. The ongoing climatic change is hitting hard on the sustainability of springs and several measures are opined by the workers. The characteristic geological and geomorphological conditions of the South Andaman and Rutland Islands have facilitated the origin of numerous springs in all the three major geological formations (i.e Marine sedimentary group of rocks, Ophiolite (an assemblage of igneous rocks) and coralline limestone). The rural drinking water supply in the entire South Andaman Island is maintained either directly from the springs or spring fed perennial streams.

It is also worth mentioning that in the entire A&N Islands including the Rutland Island, the most potential Springs are formed in Ophiolites i.e. the igneous rocks comprising the fractured mafic, ultramafic igneous rock, Pillow lava and other Acid and Intermediate volcanic rocks. The springs in Rutland Island had been adjudged potential to mitigate the perennial crisis of urban water supply in Port Blair.

## Management of Urban Water Supply to Port Blair City from Springs in Rutland Island

Prior to commissioning of the main water supply source of Port Blair city, i.e., the Dhanikhari Dam in 1974, the Water supply to the city of Port Blair used to be catered from various ponds and wells. The dam is located nearly 15 Km west of Port Blair. The dam is constructed on the catchment of Dhanikhai at a relatively higher topography so that the rainwater harvested in the catchment through the dam can come to Port Blair under gravity. Generally, the A&N Islands receive monsoon rainfall during May to September through North-West monsoon and during October-December through South-East monsoon. Consequently, facilitated with the copious rainfall received round the year, the dam remains generally filled up. However, with the climatic aberration, if the monsoon is receded, the water level in the reservoir at Dhanikhari remains at the lowest level if withdrawal is not regulated. Every year stringent curtailment is imposed on urban water supply which brings lot of miseries to the inhabitants and the tourism industry. Generally, thrice in a week water is supplied to the populace by the Port Blair Municipal Council. However, during the stress the supply is even curtailed to once in a week. This system has been prevailing even in normal monsoon or even excess rainy years since the serious water supply lapses in 2002.

From the case study, it was found that in the previous year i.e., 2001, the rainfall was close to normal rainfall. So, to fulfill the demand of the urban populace everyday water supply was maintained till October-November anticipating some shower from North-East monsoon. Unfortunately, in November-December it did not rain. Consequently, the dam dried up in December itself.

To mitigate the crisis, regular urgent meetings were being convened by Hon'ble Lt. Governor of A&N Islands at Rajniwas, Port Blair to review the water scarcity issue and its solution. There were even proposals to carry water from water abundant islands like Car Nicobar, Little Andaman etc. through ships and barges. Meanwhile as per the information of the local inhabitants, it was learnt by A&N Administration that, there were many mighty springs in contiguous Rutland Island (Kala Pahar). In a meeting at Rajniwas Hon'ble Lt. Governor, A&N Islands desired that CGWB should carry out a hurried study in the Rutland Island to verify the feasibility of water supply source.

Immediately the study was carried out by CGWB (Kar,2002) in the Island during February 2002. The intensive short term reconnaitory study revealed that a major part of the island is underlain by fractured ultramafics (Ophiolite). Several highly emanating springs are developed in the high hills especially in the ultramafics and it is flowing to the sea as small first-second order streams. The quality of the water was found very good and free from coliform bacteria.

The intensive study revealed that nearly 36,54,722 Gallons of water per day could be available from the Spring sources as also through tapping the subterranean flow can be obtained from the Rutland Island which are flowing to the sea. During the time of study in 2002, the daily shortage to Port Blair town was estimated as 31 lakh Gallons. The study revealed that 36.5 lakh gallons of water can be obtained from Rutland Island which itself could give sustainability to the water supply arrangement and along with other water supply potions a long-term sustainability could be achieved. It was recommended that the entire water, what could be collected through pipelines along the coast into a central aqueduct may be sent along the narrowest part of the strait through under sea or over sea pipe lines near Rifleman point to the Pongibalu Jetty in South Andaman Island and the same may be added to the pipeline of Dhanikhari Dam near Naya Sahar so that the entire water can be brought to the filtration Plant at Lambaline,Port Blair for its supply inside the urban area. This was termed by the A&N Administration as a "Long-Term "option and it was conjectured as a potential source which can give sustainability to the Port Blair city for at least for 50 years. Prompted with the studies and recommendation of CGWB(Kar,2002) , in view of extreme scarcity of drinking water, the transportation of spring water to Port Blair initiated forthwith from Chain Nala through ships and barges on 28.4.2002. Based upon the recommendation of CGWB, the A&N Administration, entrusted the work of preparation of DPR of the Inter island water supply Project to ALHW who in turn appointed M/S WAPCOS to prepare the DPR. Based upon the studies on sustainability as observed by WAPCOS during 2003-04, the DPR was submitted.

Following a subsequent crisis in urban water supply in Port Blair during 2007,the propsal was sincerely persuaded by the A&N Administration and Govt. of India approved a part of the inter-island transfer propsal of the spring water to Port Blair in the year 2009 for an estimated cost of rupees 70 crore. Subsequently the pipeline connection in both the Islands started and in the first phase the good springs enroute Bada Khari nala were connected. A 40-lakh litre capacity big reservoir was constructed near by the coast at Pongibalu to store the water from Rutland and its intermittent pumping to Port Blair. Consequently, the pipeline connection from Pongibalu to Naya sahar was completed during 2011. In absence of undersea pipeline, the interisland transfer of spring water through ships and barges from Chain Nala spring source continued till 2011. The water supply from Chain nala used to be maintained by Andaman Lakshadweep Harbour works (ALHW), Govt. of India. Soon after the inter-connection of few of the springs enroute Bada Khadi Nala spring up to Rifleman point Jetty in 2011, the spring water transportation from Rutland Island since 2012 was shifted to Rifle Man point jetty. The water supply from Rifle Man jetty is being maintained by Andaman Public works Department (APWD), A&N Admn. The work of submarine pipeline work could not be undertaken in want of an expert bidder. However, the need for entire water from Rutland Island was further felt during the recent unprecedented water shortage in 2020. However, through keen initiative of A&N Administration, the work of undersea pipeline has been initiated recently by an expert agency. Special quality pipelines are imported to the site. The water shortage in Port Blair could be solved through completion of the undersea pipeline work forthwith as also through interconnection of all the springs.

## Sustainability studies on springs for submission of the DPR

In the study report, CGWB (Kar,2002) opined long term monitoring of springs to adjudge the sustainability of the springs, before undertaking the implementation of inter-island transportation work. Consequently, after assuming the assignment of submission of DPR, M/S WAPCOS had installed gauzing point on each spring in discussion with CGWB and the monitoring in each spring was undertaken during 2003-04. During the entire period, no significant decline in the yield of each spring was noted. Accordingly based upon the long-term monitoring, WAPCOS had submitted the DPR attesting the feasibility and potential of the springs for its interisland transportation through undersea pipeline.

## Recent CGWB study on sustainability of Springs and demarcation of Recharge and Discharge areas

A thorough study was undertaken by CGWB during 2016-18 to find out the nature of sustainability of the springs (Kar,2019) and to demarcate the recharge and discharge area in order to adjudge the impact of Defence Research and Development organisation (DRDO) infrastructure project on the spring yield. The CGWB recommendation was desired by A&N Administration to allot the land of 50 acres to DRDO, as the Union Territory Administration apprehended that the infrastructure project of DRDO might impact heavily on the spring yield. Accordingly, a thorough in-depth study was undertaken and the spring yields at various points of select springs were measured along the spring trajectory. From a GIS based studies coupled with DGPS facilitated the demarcation of run-off recharge and discharge areas. The study revealed that the infrastructure project has been contemplated in run-off zone and not intercept the recharge and discharge areas. Thus, it may not be jeopardising the spring yield. Based upon the CGWB recommendation, the 50-acre land was handed over to DRDO by A&N Administration. The thorough study further corroborated the sustainable yield of springs in the Island. From the study is was found that the average spring yield were virtually the same as it was observed during the maiden CGWB studies in the island in February,2002.

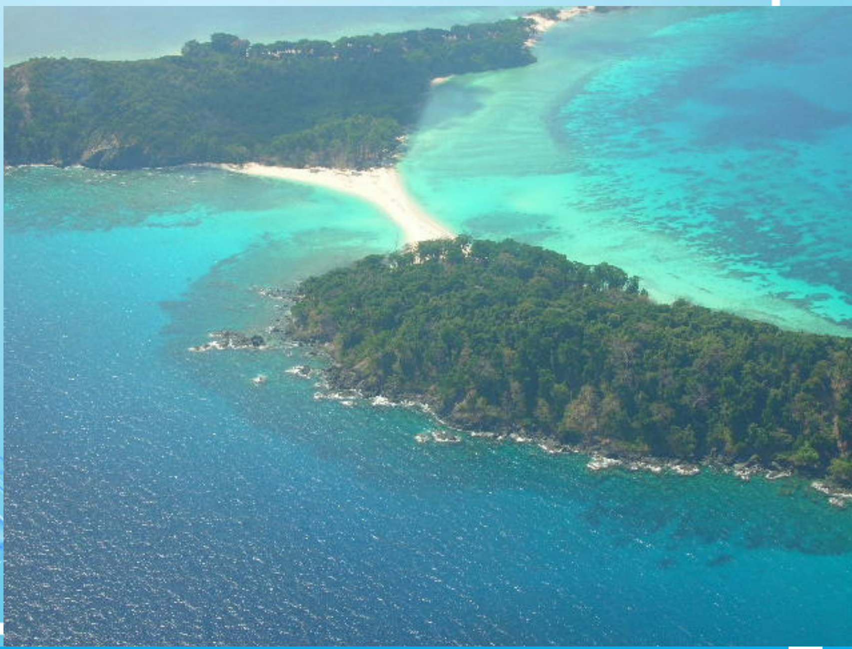
### Inter-Island transfer of spring water through ships and barges

To mitigate the severe scarcity of Port Blair the water transportation through ship and barges immediately started since 28.4.2002 and it's continuing till date. Regularly a sizable quantity of water is supplied to the interisland and mainland ships and boats at various jetties and Haddo port by Port Management Board (PMB). As a part of management, it was decided that the water to from Rutland can be utilized for supply at the Port and jetties so that the similar quantity of water can be used in Port Blair city and environs. Formerly the water supply was being met from the Chain nala source which is occurring in the North-Eastern side of the Island. A temporary jetty was constructed which was continued till 2011. The water supply from Chain Nala was being managed by Andaman & Lakshadweep Harbour Works (ALHW). After connection of few spring sources in the west enroute Bada Khadi nala (Spring) source, the pipelines connection was done up to Rifle Man Point jetty.

From 2012 the water supply through ships and barges are continuing till date. So far, the Spring sources in the West in Rutland Island are connected by the pipelines while the mighty sources in the North-east and North like Meetha Nala, Chain Nala, Komio nala etc. are yet to be tapped. For ensuring the sustainability, all the sources are required to be tapped. Till 2017 8,40,756 metric tons (1 ton is equivalent to 1000 liters) of water has so far been transported to Port Blair from Rutland.

### Conclusion and recommendation

Port Blair is the capital of A&N Islands is now a smart city, has been suffering from acute shortage of water since long due to various hydrogeological, climatological, environmental, and demographic reasons. Both surface and ground water potential are undependable. The urban populace faced unprecedented water scarcity during 2002, 2007 and of late 2020. CGWB had discovered mighty spring sources in February,2002 in the Rutland island in contiguity of South Andaman Island incorporate the city of Port Blair. CGWB study observed that a major part of the island is underlain by ultramafic ophiolites. The study revealed the source as a long-term option to mitigate the scarcity of urban water supply and the from the study the interisland transfer of water to Port Blair through undersea pipeline was advocated. The interisland transfer of spring water immediately started from Chain Nala spring source in the east in 2002, April. Based on the recommendation, a long-term study on spring sustainability was undertaken during 2004-05 and a DPR was submitted. The CGWB study during 2005, in the aftermath of earthquake and tsunami also found the unaltered sustainable yield of the springs. Recent CGWB studies for land clearance from A&N Administration to develop DRDO infrastructure project also attested the spring sustainability in ophiolite. During 2007-08 A&N Administration adopted few major options to solve the water crisis in Port Blair where the proposal of Interisland transfer of spring water was significant. In the year 2009, Govt. of India approved a part of the Inter-island transfer of spring water, as submitted by the A&N Administration, worth Rs 70 crore. The pipe line connection of few of the western springs enroute Bada Khadi spring source up to Rifle Man point jetty in Rutland was completed by the end of 2011. During the same period, a 4.0 million litre capacity concrete reservoir was constructed nearby the coast at Pongibalu in South Andaman Island. Subsequently in 2011 the pipeline work from Pongibalu reservoir to Dhanikhari pipeline at Naya Sahar was completed. This interisland transfer of spring water through ships and barges continued from Chain Nala source till 2011 and it was shifted to Rifleman Point from 2012 and continuing till date. Since inception to March, 2021 a sum of 840756 metric ton of spring water has been transported to Port Blair. The undersea pipeline work remained suspended in want of an expert contractor. However, recently in 2020 the work has been entrusted to an expert group and the work has been initiated. However, it may finally be recommended that the spring source is undoubtedly a proven sustainable source, and it will mitigate the urban water crisis as a long term solution for further 30 years. The submarine pipe line works need to be completed forthwith. To tap the entire water from the Rutland Island, all the springs as studied by CGWB should be connected and needful techniques need to be adopted to harness the subterranean water flowing to the sea.Studies on sustainability of springs may be undertaken from time to time. In case of any steady decline, needful artificial measures are required to be undertaken.



## OUTREACH PROGRAMMES OF CGWB

Ground water remains the predominant source of drinking water in the Country. Groundwater based irrigation has been expanding at a very rapid pace in India and now accounts for more than 60 percent of the total irrigated area in the country. Access to groundwater allows farmers to diversify their cropping systems, improve household food security, and shield against droughts. Overexploitation results in falling groundwater tables, deteriorating water quality, environmental degradation, rising pumping costs, and lower crop yields. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.A comprehensive micro-level picture of groundwater in India through aquifer mapping in different hydrogeological settings will result in forming groundwater management plans. This will in turn help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India, and many parts of urban India as well. The aquifer mapping program is also important for planning suitable adaptation strategies to meet climate change.

PIP conducted by CGWB, North Eastern Region and Division VII, Guwahati at Udainagar Panchayat, Tinsukia district, Assam

In order to share the findings of National Aquifer Mapping studies (NAQUIM), Central Ground Water Board organizes several public interaction programmes (PIP) all through the year for dissemination of groundwater related information at grassroots level with a broader objective to create an awareness regarding sustainable utilization of groundwater.

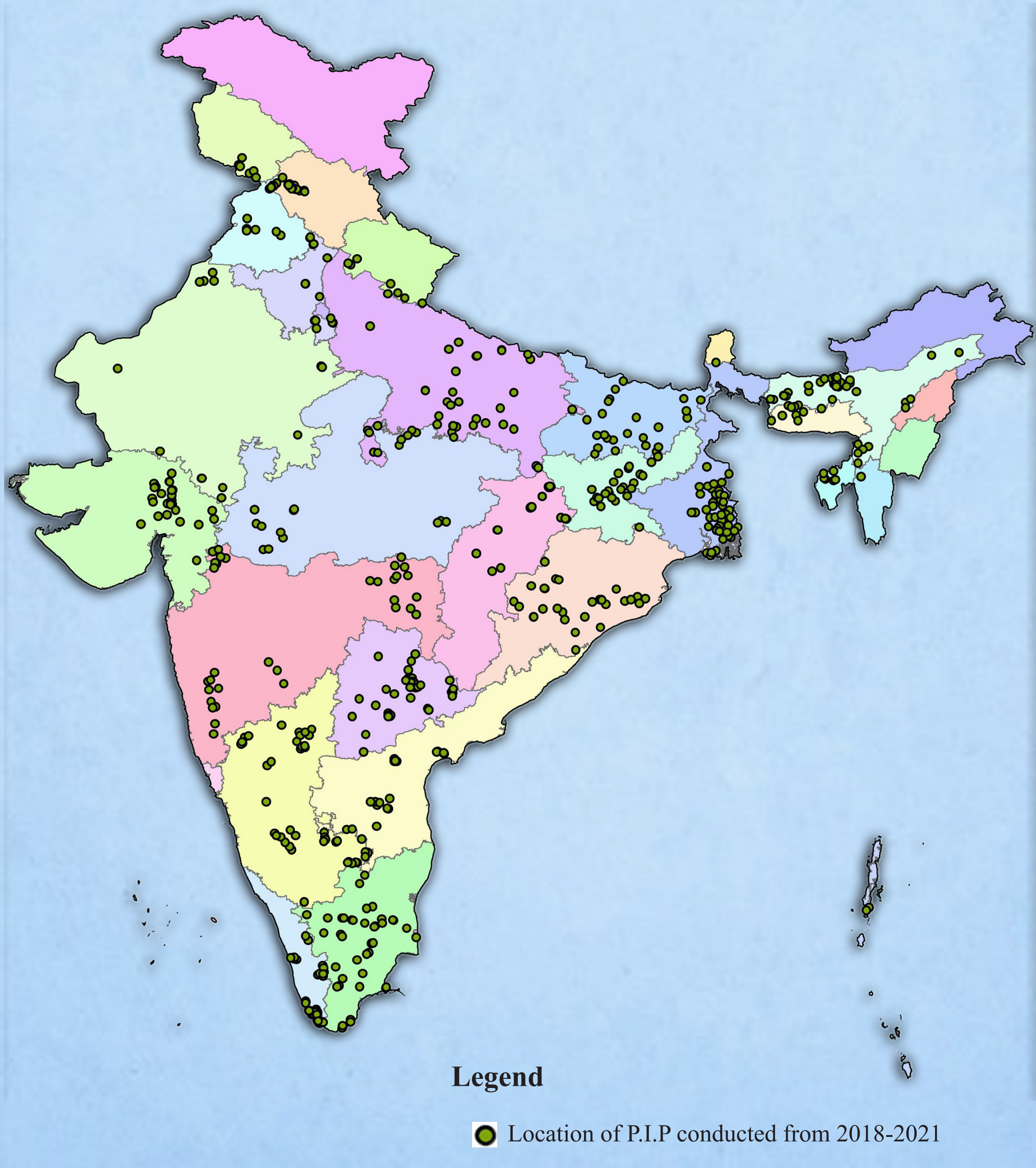
The purpose of these programmes is to share the findings of CGWB in the form of Aquifer Maps and Management Plans with the primary end-users of groundwater.

The PIPs are conducted by the regional, divisional and state unit offices of CGWB in different blocks/ gram panchayat units. The programmes are mainly targeted towards the farmers, teachers, agricultural scientists, administrators of the gram panchayat and allied stake holder departments such as engineers from PHED or state water resource departments.


Public interaction programme conducted by CGWB, Div.XIV , Bangalore at Doddindavadi site, Kollegala, Chamarajanagar district, Karnataka.

A total of 446 PIPs have been organized by CGWB during 2017-2020 and 254 PIPs have been conducted during 2020-2021, wherein around 63,000 people have participated out which 1/3rd are females. A map showing the locations of PIPs conducted by CGWB till date is given below.

## PUBLIC INTERACTION PROGRAMMES (P.I.P)



# Cover Story

## PIP in collaboration with NGOs

CGWB has taken up a new initiative for collaborating with NGOs conducting Public Interaction Programmes(PIP) in different parts of the country to sensitize communities regarding groundwater conservation and management. Three NGOs which are having Pan India presence expressed their willingness to build sample contents based on NAQUIM reports.

As a first step, PIPs were conducted in association with the NGOs in the states of Odisha, Karnataka, Maharashtra and Uttarakhand. The NGOs have developed innovative content in the form of videos/ powerpoint presentations/pamphlets/speaking walls based on the NAQUIM reports of CGWB and shared the same with local stakeholders.The content were mostly shared in local languages for easier understanding of the common people. Around 260 people had participated in these PIPs.

## Awareness Programmes for school students

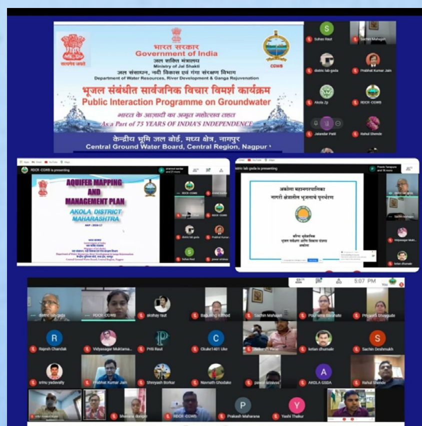
Glimpses of School Awareness Programmes by CGWB, NR Officers during February 2020

As an initiative to educate the school students about the need for Rainwater Harvesting and Artificial recharge, CGWB had conducted school level mass awareness programmes during the year 2019-20. In total, 303 school level awareness programmes were carried out by CGWB across 22 states and UTs of the country during 2019-20.

Around 36185 students had participated in these mass awareness programmes. A few glimpses of these events are shared.

## PIP commemorating 75 years of Independence

As per the directive of Ministry of Jal Shakti, CGWB has recently started conducting district wise public interaction programmes for commemorating 75 years of India's independence. Public interactions are to be conducted in each district of India over a period of 18 months i.e. from March 2021 to August 2022.



## Tier-III Training Programmes

Tier-III training courses are conducted by Rajiv Gandhi National Ground Water Training and Research Institute (RGNGWTRI) through 18 Regional Offices of CGWB across different states of India to impart training on local ground water related issues and participatory ground water management. Tier-III trainings are imparted to the grass root level stake holders on basic skills of ground water and for assistance in data collection and field studies.

A total of 463 Tier-III trainings have been conducted by CGWB since inception under which 66162 people have been trained, out of which 17850 were female participants.





Glimpses of Tier-III Trainings conducted by RGNGWTRI through different regions of CGWB

Public Interaction Programmes (PIP) are a significant activity of CGWB in sensitizing the local communities and stakeholder departments about the groundwater scenario of their areas, ground water issues and possible solutions. A total of 446 PIPs have been organized by CGWB during 2017-2020 and 254 PIPs during 2020-2021, in which around 63,000 persons have participated. Though 463 Tier-III (block level) trainings, CGWB has been able to disseminate the groundwater knowledge among 66000 people at the grass- roots levels. Conducting 303 school-level awareness programmes across 22 states and UTs of the country has been another important step during 2019-20 to educate the school students about the importance of water conservation and rainwater harvesting. The journey continues as CGWB proposes to conduct 2000 such programmes during the next five years to empower the stakeholders at ground level with usable information for sustainable management of ground water resources.

*Ms. Ankita Bhattacharya*

# Redefining capacity building to help sustain development and generate livelihoods under Atal Bhujal Yojana

*Sh. Abhishek Srivastava, ARGHYAM*

## Atal Bhujal Yojana- A promising solution to ground water management

To promote community-led groundwater management, the Government of India through the Ministry of Jal Shakti launched Atal Bhujal Yojana (Atal Jal). The central sector scheme aims to facilitate sustainable groundwater management practices across seven pre-identified states in the country over a period of five years. The scheme is unique in several ways, such as focus on demand side interventions and supply side interventions, increased community involvement in planning and implementation, improved monitoring and disclosure of groundwater related data, and introduction of incentive components to reward the best performers. Introduction of these unique aspects makes Atal Bhujal Yojana a promising scheme to improve the groundwater management in the country.

## Capacity Building under Atal Bhujal Yojana

The Atal Bhujal Yojana consists of two major components viz., institutional strengthening and capacity building component, and incentive component. The incentive component focuses on rewarding best performing states/ districts/ GPs whereas the former focuses on building capacities of different stakeholders to enable community led sustainable groundwater management. For the success of the Atal Jal scheme, it is vital to ensure that the first component i.e. capacity building and institutional strengthening is implemented in an efficient and sustainable way. And to get the capacity building right in Atal Jal, it is important to learn from the experiences of past programmes on sustainable ground water management. Following learnings from the past programmes can be utilised for improving the capacity building approach in Atal Jal:

- Implementing capacity building activities as a continuous process throughout the scheme tenure to achieve sustainability.
- Utilising all forms of existing resources (content, resource persons, etc.) to increase efficiency and expedite the capacity building process.
- Leveraging digital technologies to overcome the drawbacks of traditional capacity building and making the model easily replicable and scalable

A capacity building framework document has been developed to aid the Atal Jal implementation agencies successfully include all these aspects in their capacity building strategy. The National Project Management Unit (NPMU) of the Atal Jal scheme was supported by expert agencies to draft the framework document. It attempts to provide relevant suggestions for capacity building in Atal Jal based on their experience of implementing the groundwater management activities through a participatory approach.

## The Capacity Building Framework document suggests following sustainable and scalable approaches:

community resource person attending training session through virtual interaction.

- Demand-driven and community focused capacity building

The focus of capability building should be to look at the scheme from the lens of the community. The capacity building plan must empower them; institutionalize and build the right capabilities through all the phases - planning, funding, implementation, operations, and maintenance (O&M) at the GP level.

- Using a blended training approach (online of line) for increased frequency of trainings

A blended (online/in-person) training approach for training and capacity building allows increase in the training frequency and reduces the intensity of each session. Virtual interactions also allow discussions and mentoring sessions in peer groups which might be difficult to organise in an in-person setting. Adoption of a mixed training approach allows to organize low-dose, high frequency training to increase overall efficiency and engagement of the trainees.

- Generating livelihood opportunities for the community members through longer engagements

Providing certificates to the attendees can help engage them on a long-term basis with the groundwater management landscape. When a CRP/FLW gets trained on multiple aspects of groundwater management, s/he can act as a groundwater paraprofessional in that area with an opportunity to generate a permanent livelihood through it.

- Curating available content, customising, and making it accessible

At the very beginning of a programme, already existing relevant training content should be curated and repurposed for the planned training. This saves time and effort as well as improves the quality of the content as it gets reiterated. The existing content can be converted in a suitable format like video or presentation with voiceover which will help the trainees revisit specific parts of the training even after the session. Content pieces which are atomic i.e. covering a very specific topic, learner centric, and interactive provide best learning outcomes. Smartphone based learning management systems can be used to disseminate digitised versions of the training content and also keep the trainees posted about the content updates.

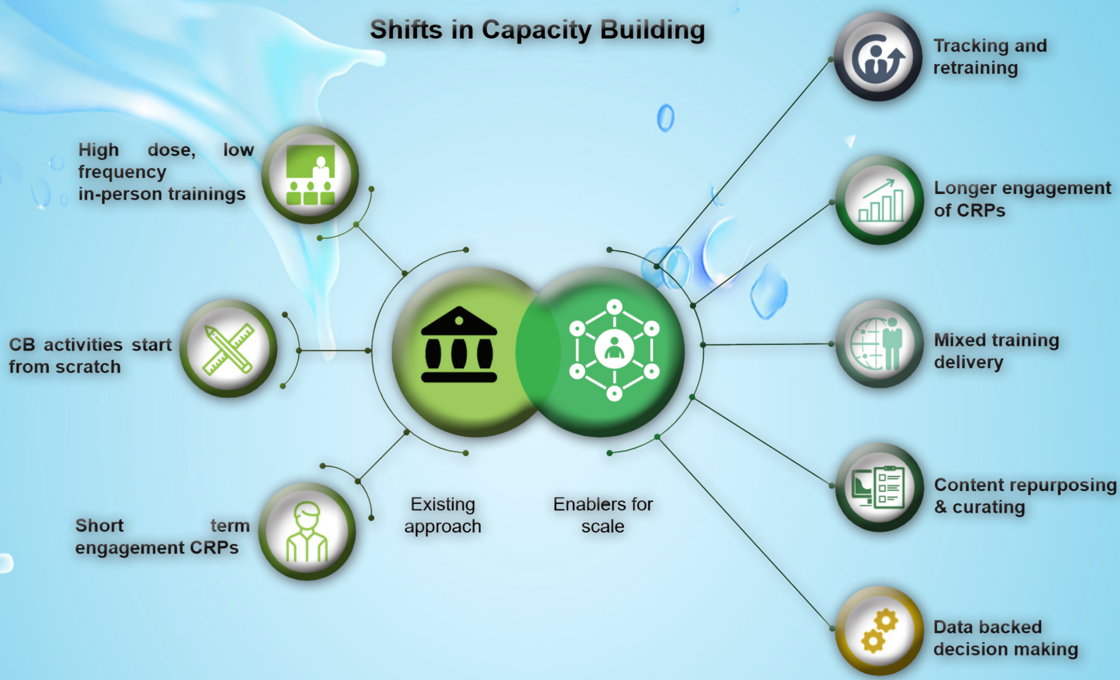
Community resource persons referring to digital content on their mobile devices to perform technical tasks in the field.

- Leveraging digital technologies to generate better insights

Technology has made it possible to record attendance, issue digital certificates and disseminate training content through a simple QR code scan, simultaneously generating insightful data for the implementing agency

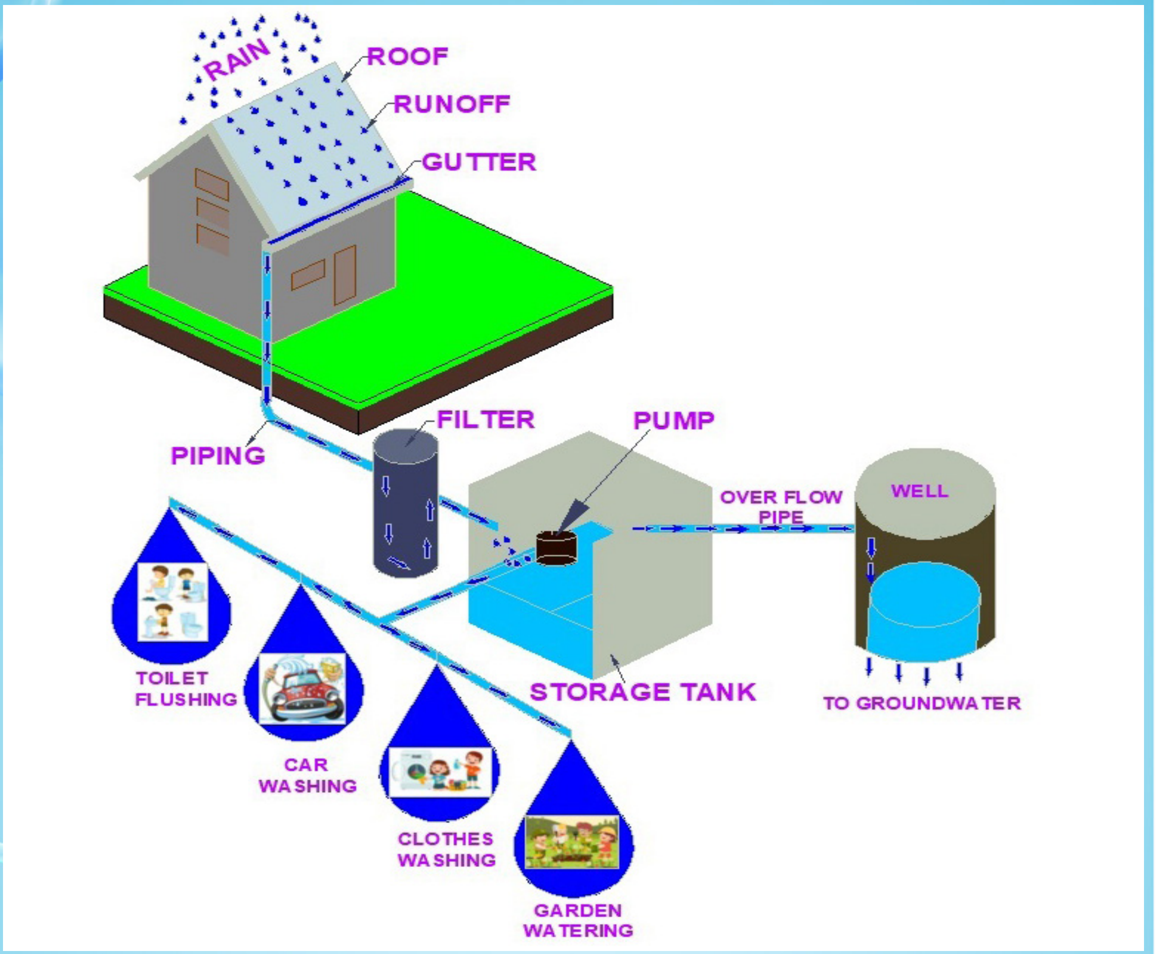
An efficient tracking tool which captures details of training sessions conducted and individuals trained with the topics, geographical areas, individuals trained, feedback, etc. can be introduced through the AtalBhujal Yojana to help create a central database. The tracking of training and trained individuals can address two of the limitations of the existing training process. Data generated from tracking can help reach out the already trained individuals for newer groundwater management programmes/ schemes and also enable data-based decision making for better resource allocation and planning. Additionally, the same tool could be leveraged to issue training certifications to the attendees and to disseminate the training material. The tracking-cum-attestation tool will help overcome multiple limitations of traditional capacity building.

## Reforming capacity building through Atal Bhujal Yojana




Atal Bhujal Yojana scheme's innovative way of doing capacity building will act as a guide for all the future programmes to achieve scale and sustainability. Upcoming programmes involving capacitybuilding of individuals can use the trainee database generated by the Atal Bhujal Yojana, refer to the training content through an online repository, and adopt the mixed training approach for low-dose, high-frequency training sessions. This will help all the future programmes with a capacity building component to optimise their strategy, irrespective of the sector. The Capacity Building Framework document is purposed to act as an initial guiding point to orient capacity building in Atal Jal in the right direction.

## Roof Top Rain Water Harvesting




Rooftop Rain Water Harvesting is the technique through which rain water is captured from the roof catchments and stored in reservoirs. Harvested rain water can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks. The Main Objective of rooftop rain water harvesting is to make water available for future use. It mainly involves

- Collection
- Transportation and
- Storage/recharge

Collecting rainwater from the roof catchments is simple, economical and eco-friendly. Rainwater otherwise flows through sewers and storm drains and is wasted. It helps in reducing the frequent drainage congestion and flooding during heavy rains in urban areas where availability of open surfaces is limited and surface runoff is quite high. Also, the losses from roof catchments are much less when compared to other catchments. The water, thus collected in the storage tanks on surface can meet the immediate domestic needs and if connected to groundwater then it improves the quality of ground water through dilution. The main components of rain water harvesting system are

- A roof
- Gutter and down pipes to transport the waterfrom the roof
- First flush system to divert the dirty water
- A filter and a storage tank.
- A collection sump and the pump unit to distribute the water for usage.
- Recharge structure that can augment the groundwater.

*Ms. Priya Kanwar*

# Research Publications by CGWB officers in reputed International Journals (as per Scopus database)

## 01 Investigation of Geochemical Characterization and Groundwater Quality with Special Emphasis on Health Risk Assessment in Alluvial Aquifers, South Africa

*International Journal of Environmental Science and Technology (2021)*

***P. P. Mthembu, V. Elumalai, M. Senthilkumar & J. Wu***

**Abstract:** The Maputaland coastal plain of KwaZulu-Natal is one of the popular tourist areas in South Africa. Groundwater is the major source for drinking and irrigation purposes which is abstracted from unconsolidated aquifers having higher infiltration rate possibly increases the risk of aquifer contamination. Comprehensive study was conducted in 53 groundwater monitoring wells to identify the characteristic of water quality and processes controlling groundwater chemistry using multiple methods. Rock-water interaction and Na/Ca ion exchange are the dominant processes. Water quality index (WQI) varies from 18.9 to 157.1 with an average value of 45.55. Majority of the samples are classified as good, 22% as poor, 2% as very poor and 7% under unsuitable category, which are spatially distributed towards southern and western part of the study area. Health risk assessment of trace elements via ingestion and dermal absorption pathways was carried out. Hazard quotient through dermal absorption (HQdermal) and hazard index (HI) for Co and Mn are above 1 in adults, children and infants. HQdermal and HI for Cd are greater than 1 in children and infants. HQdermal and HI for As and Pb are greater than 1 in infants. This implies that these metals pose serious to adverse health risk on people while infants are more vulnerable than children and adults. This study provides the baseline data on hydro geochemistry that can be utilised for further studies in future. This study recommends that groundwater in this region should be treated before utilisation and suggest that further extended studies should be conducted to explore more on groundwater resources in this area.

## 02 Geo-spatial distribution of arsenic contamination of groundwater resources in intricate crystalline aquifer system of Central India: Arsenic toxicity manifestation and health risk assessment

*Human and Ecological Risk Assessment: An International Journal Volume 27, 2021 - Issue 6,pp. 1588-1612*

***Rambabu Singh, Anadi Gayen, Suresh Kumar & R. Dewangan***

***Abstract:*** The behavior of As in aqueous media in the complex crystalline aquifers like that of the present study area is not yet understood properly. To that end, groundwater and river water samples from two different seasons are analyzed for As and physicochemical parameters. The groundwater in the area is evolved by simple dissolution or mixing of two or more different facies (Ca2+–Mg2+–Na+–SO42–). However, the majority of samples with the base-exchange indices (85%) and meteoric genesis indices (77%) value less than unitary (<1) divulges that Na+– SO42– type water and deeper meteoric percolation. The estimation of As in groundwater (<0.1–202 ppb) shows the spatial and temporal inconsistency with 17.31% (pre-monsoon) and 11.67% (post-monsoon) of the samples surpassed the permissible limit of 10 ppb. Furthermore, health risk associated with As in terms of hazard quotient (HQ) values > 1 (pre-monsoon: 21.15% and post-monsoon: 20%) for children and carcinogenic risk values >1.00 × 10−6 for different seasons (44.25% and 33.33% of samples) represents a serious health risk. Furthermore, the different stages of Keratosis and Melanosis diseases reported in the study area establish the severity of As toxicity on the local populace. The study concludes geogenic arsenic contamination in the study area is primarily associated with Rhyolite and its comagmatically formed Dongargarh granite batholith emplacements.

## 03 Fluoride Geochemistry and Exposure Risk Through Groundwater Sources in Northeastern Parts of Rajasthan, India

*Archives of Environmental Contamination and Toxicology volume 80, pages294–307 (2021)*

***Tirumalesh Keesari, Diksha Pant, Annadasankar Roy, Uday Kumar Sinha, Ajay Jaryal, Manveer Singh & S. K. Jain***

**Abstract:** Exposure to fluoride concentrations above a threshold of 1.5 mg/L can cause joint pains, restricted mobility, skeletal and dental fluorosis. This study aims to determine the hydrochemical evolution of the fluoride-rich groundwater and estimate the risk of fluoride exposure to the residents of semi-arid northeastern part of Rajasthan, India. The methodology involves measurement of fluoride and other ionic concentrations in groundwater using ion chromatography, followed by an estimation of the cumulative density function and fluorosis risk. The fluoride concentration in water samples varied from 0.04 to 8.2 mg/L with 85% samples falling above the permissible limit. The empirical cumulative density function was used to estimate the percentage and degree of health risks associated with the consumption of $F^-$ contaminated water. It is found that 55% of the samples indicate risk of dental fluorosis, 42% indicate risk of deformities to knee and hip bones, and 18% indicate risk of crippling fluorosis. In addition, instances of high nitrate concentrations above the permissible limit of 45 mg/L are also found in 13% of samples. The fluoride rich groundwater is mainly associated with the Na–HCO3–Cl type water facies while low fluoride groundwater shows varied chemical facies. The saturation index values indicate a high probability of a further increase in $F^-$ concentration in groundwater of this region. The calculated fluoride exposure risk for the general public in the study area is 3–6 times higher than the allowed limit of 0.05 mg/kg/day. Based on the results of this study, a fluorosis index map was prepared for the study area. The northern and northeastern parts are less prone to fluorosis, whereas the south-central and southwestern parts are highly vulnerable to fluorosis. The inferences from this study help to prioritize the regions that need immediate attention for remediation

## 04 Seasonal variation of mountain-valley wind circulation and surface layer parameters over the mountainous terrain of the northeastern region of India

*Theoretical and Applied Climatology volume 143, pages1501–1512 (2021)*

***Nilamoni Barman, Arup Borgohain, Shyam S. Kundu & N. V. P. Kiran Kumar***

**Abstract:** Mountainous topography and solar elevation angle have a significant influence on the wind circulation and energy exchange over a complex region. Here, the seasonal variation of mountain-valley wind circulation (MVWC) and surface layer parameters have been presented over a hilly station of northeastern India. For the study, quick-response sonic anemometer data have been utilized. The solar elevation angle varies from 85° to 43° in different seasons and controls the MVWC over the terrain. MVWC was dominated in winter (WN), pre-monsoon (PM), and post-monsoon (PMN) seasons, while the synoptic wind predominates the wind direction over the terrain in monsoon (MN). In WN and PM, nighttime heat transmission from the atmosphere to the ground was −10 to −20 W m−2, while the minimum in MN and PMN was −3 to −7 W m−2. The net seasonal daily mean sensible heat flux (H) values from the surface to the atmosphere were 42 W m−2, 58 W m−2, 35 W m−2, and 34 W m−2 in WN, PM, MN, and PMN. In MN, the average daytime temperature was 8 °C, 0.5 °C, and 3 °C higher and at night was 9.5 °C, 2 °C, and 4.5 °C higher than the WN, PM, and PMN. In WN, PM, and PMN, the momentum flux had a higher value of about 2 to 3 h after the maximum value in H was attained at the 6-m and 10-m levels. The daytime turbulence kinetic energy was higher by 99%, 56%, 72%, and 93% than the nighttime during WN, PM, MN, and PMN.

## 05 Simulation of groundwater flow under the influence of groundwater abstraction in parts of Narmada River basin in Gujarat State, India

*Groundwater for sustainable development 2021 v.12 pp. 100534*

***Anil Kumar Jain, Laxmi Prasad Chorasia, Senthil kumar Mohanavelu***

**Abstract:** An area between Narmada and Heran rivers in Gujarat State, India forms an excellent potential aquifer system wherein the surface water and groundwater are well interconnected. A conceptual model of the study area was developed and was calibrated for transient state for 48 stress period for 16 years between 1986 and 2002. During the calibration, it was observed that model is very sensitive to conductance applied to General Head Boundary (GHB) and some extent of aquifer parameters and recharge.The model developed was used to forecast the groundwater flow for 13 years from June 2002 to June 2015. Three categories of scenarios have been simulated in order to reflect a combination of different parameters/variables which are likely to influence the behavior of groundwater in future. In forecasting scenario, a major design objective of groundwater extraction was tested to site the additional tube wells in alluvium area. Quantify possible increase in groundwater withdrawal from these tube wells in such a way to induce the recharge from the river to the aquifer or to reduce the base flow to river.The various scenarios formulated for devising better aquifer management plan for this aquifer system clearly showed that this aquifer system is safe under the present hydrological stresses. The developed model also indicated that increase or decrease in the stress will have substantial impact on the subsurface flow to stream or rivers bordering the modeled area. Considering the natural base flow in the rivers, the study showed that there is large scope for groundwater development in this area, which can be augmented by additional tubewells.

## 06 Spatial variability of hydrochemical characteristics and appraisal of water quality in stressed phreatic aquifer of Upper Ganga Plain, Uttar Pradesh, India

*Environmental Earth Sciences volume 80, Article number: 185 (2021)*

***Puthiyotil Nijesh, Kossitse Venyo Akpataku, Abhinav Patel, Prashant Rai & Shive Prakash Rai***

**Abstract:** The present study deals with the characterization of hydrochemical parameters and their spatial variability, and suitability for drinking and irrigation purposes of groundwater from unconfined aquifer of Western Uttar Pradesh, India, encompassing an area of 57,342 km2. The results confirm that groundwater is predominantly hard and exhibits neutral to alkaline nature. Groundwater were dominated by Na+ (6–5060 mg/L) followed by Ca2+, Mg2+, and K+ for cations, while Cl−, HCO3−, and SO42− were the dominating anions. The water facies belong to fresh (Ca–Mg–HCO3 Na–HCO3) to very saline (Na–Cl, Ca–Mg–Cl) water types, representing both geogenic and anthropogenic controls on groundwater chemistry. The spatial distribution pattern of the ions (Cl−, SO42−, F−, Ca2+, HCO3−, Na+, and Mg2+) showed an increasing trend from the source to downstream. The correlation coefficients between hydrochemical parameters show a strong positive correlation of EC and TDS with all major ions, including NO3− and K+. This finding corroborated that chemicals originating from geogenic and anthropogenic causes contribute substantially to groundwater mineralization. Except for the unsuitability due to excessive salinity (9.2%) and hardness (19.2%), the main human-health-related concern is the high concentrations exceeding the permissible limits for NO3− (15.6%) and F− (7.8%). The irrigation water quality parameters such as % Na, MH, TDS, RSC, SAR, PI, and KR revealed excellent to permissible quality. The unsuitable samples were derived mostly from the South and South-Western parts of the Yamuna and Ganga Rivers banks, requiring immediate salinity and NO3− contamination control measures.

## 07 Three decades of depth-dependent groundwater response to climate variability and human regime in the transboundary Indus-Ganges-Brahmaputra-Meghna mega river basin aquifers

*Advances in Water Resources Volume 149, March 2021, 103856*

***Pragnaditya Malakar, Abhijit Mukherjee, Soumendra N.Bhanja, Auroop R.Ganguly, Ranjan Kumar Ray, AnwarZahid, SudeshnaSarkar, DipankarSaha, Siddhartha Chattopadhyay***

**Abstract:** Groundwater plays a major role in human adaptation and ecological sustainability against climate variability by providing global water and food security. In the Indus-Ganges-Brahmaputra-Meghna aquifers (IGBM), groundwater abstraction has been reported to be one of the primary contributors to groundwater storage variability. However, there is still a lack of understanding on the relative influence of climate and abstraction on groundwater. Data-guided statistical studies are reported to be crucial in understanding the human-natural complex system. Here, we attributed the long-term (1985–2015) impact of local-precipitation, global-climate cycles, and human influence on multi-depth groundwater levels (n=6753) in the IGBM using lag correlation analysis, wavelet coherence analysis, and regression-based dominance analysis. Our findings highlight the variable patterns of phase lags observed between multi-depth groundwater levels and precipitation depending on the different nature of climatic and anthropogenic drivers in different parts of the basin. We observed intuitive responses, i.e., rapid response in shallow groundwater and relatively delayed responses to the global climate patterns with increasing depth. However, in the most exploited areas, the hydrological processes governing the groundwater recharge are overwhelmed by unsustainable groundwater abstraction, thus decoupling the hydro-climatic continuum. Our results also suggest groundwater abstraction to be the dominant influence in most of the basin, particularly at the greater depth of the aquifer, thus highlighting the importance of understanding multi-depth groundwater dynamics for future groundwater management and policy interventions.

## 08 Machine-learning-based regional-scale groundwater level prediction using GRACE

*Hydrogeology Journal volume 29, pages1027–1042 (2021)*

***Pragnaditya Malakar, Abhijit Mukherjee, Soumendra N. Bhanja, Ranjan Kumar Ray, Sudeshna Sarkar & Anwar Zahid***

**Abstract:** The rapid decline of groundwater levels (GWL) due to pervasive groundwater abstraction in the densely populated (~1 billion) Indus-Ganges-Brahmaputra-Meghna (IGBM) transboundary river basins of South Asia, necessitates a robust framework of prediction and understanding. While few localized studies exist, three-dimensional regional-scale characterization of GWL prediction is yet to be implemented. Here, 'support vector machine', a machine-learning-based method, is applied to data from the Gravity Recovery and Climate Experiment (GRACE) and data on land-surface-model-based groundwater storage and meteorological variables, to predict the GWL anomaly (GWLA) in the IGBM. The study has three main objectives, (1) to understand the spatial (observation well locations) and subsurface (shallow vs. deep observation wells) variability in prediction results for in-situ GWLA data for a large number of observation wells (n = 4,791); (2) to determine its relationship with groundwater abstraction, and; (3) to outline the advantages and limitations of using GRACE data for predicting GWLAs. The findings, based on individual observation well results, suggest significant prediction efficiency (median statistics: $r > 0.71$, $NSE > 0.70$; $p < 0.05$) in most of the IGBM; however, the study identifies hotspots, mostly in the agriculture-intensive regions, having relatively poor model performance. Further analysis of the subsurface depth-wise prediction statistics reveals that the significant dominance of pumping in the deeper depths of the aquifer is linked to the relatively poor model performance for the deep observation wells (screen depth > 35 m) compared with the shallow observation wells (screen depth < 35 m), thus, highlighting the limitation of GRACE in representing spatial and depth-dependent local-scale pumping.

## 09 Assessment of groundwater depletion–induced land subsidence and characterisation of damaging cracks on houses: a case study in Mohali-Chandigarh area, India

*Bulletin of Engineering Geology and the Environment volume 80, pages3217–3231 (2021)*

***Neha Kadiyan, R. S. Chatterjee, Pranshu Pranjal, Pankaj Agrawal, S. K. Jain, M. L. Angurala, A. K. Biyani, M. S. Sati, Dheeraj Kumar, Ashutosh Bhardwaj & P. K. Champati Ray***

**Abstract:** The present study identified groundwater depletion–induced land subsidence by spaceborne differential interferometric SAR (DInSAR) technique and assessed the damaging impacts of land subsidence by characterising the cracks on houses in Mohali-Chandigarh area of India. First, we identified groundwater depletion hot spots using pre-monsoon and post-monsoon groundwater-level (GWL) data of Central Ground Water Board (CGWB), India, for the period of 2005–2018. Both conventional and advanced DInSAR techniques were used to identify temporally consistent subsiding areas and measure precise rates of subsidence in and around groundwater depletion hot spots. We studied the damaging impacts of land surface deformation by characterising the damaging cracks on houses in affected areas. Groundwater depletion and resulting aquifer-system compaction increase effective stress on confining clay layer which leads to stress build-up at the soil-structure interface and causes damaging cracks on houses. A variety of damaging cracks on houses were observed at the affected areas such as Sohana, Landran, Kharar and Kurali localities. We attempted to characterise the damaging cracks on the basis of shape, size, orientation, surface morphology and texture of the cracks; sense of ground movement; and nature of stress build-up at the interface. We identified tensional cracks, compressional cracks and shear cracks with diverse orientations and separation widths. Finally, a comparative assessment of groundwater depletion, land subsidence and damaging impacts on houses has been made. Using DInSAR technique, we identified land subsidence in and around the groundwater depletion areas in Sohana and Landran (both in Mohali City area), Kharar and Kurali (in Mohali district outside Mohali City area) and Sectors 27–28 in Chandigarh with radar line-of-sight subsidence rates of ~6–7.5 cm/year, ~5.5–6.5 cm/year, and ~ 4 cm/year respectively. We observed that the houses in and around Landran appears to be worst affected followed by Kharar, Sohana and Kurali. From this study, it appears that the type of construction of the houses, e.g. prevalence of masonry and reinforced masonry structures, is primarily responsible for the worst damaging impacts of the houses in Landran and Kurali areas besides the magnitude of land subsidence.

## 10 Prediction of groundwater quality using efficient machine learning technique

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***Sudhakar Singha , Srinivas Pasupuleti , Soumya S Singha , Rambabu Singh , Suresh Kumar***

**Abstract:** To ensure safe drinking water sources in the future, it is imperative to understand the quality and pollution level of existing groundwater. The prediction of water quality with high accuracy is the key to control water pollution and the improvement of water management. In this study, a deep learning (DL) based model is proposed for predicting groundwater quality and compared with three other machine learning (ML) models, namely, random forest (RF), eXtreme gradient boosting (XGBoost), and artificial neural network (ANN). A total of 226 groundwater samples are collected from an agriculturally intensive area Arang of Raipur district, Chhattisgarh, India, and various physicochemical parameters are measured to compute entropy weight-based groundwater quality index (EWQI). Prediction performances of models are determined by introducing five error metrics. Results showed that DL model is the best prediction model with the highest accuracy in terms of R2, i.e., R2 = 0996 against the RF (R2 = 0.886), XGBoost (R2 = 0.0.927), and ANN (R2 = 0.917). The uncertainty of the DL model output is cross-verified by running the proposed algorithm with newly randomized dataset for ten times, where minor deviations in the mean value of performance metrics are observed. Moreover, input variable importance computed by prediction models highlights that DL model is the most realistic and accurate approach in the prediction of groundwater quality.

# COLLECTABLES


1 *Heliborne Survey in Ganga Yamuna Doab area at Fatehpur, Uttar Pradesh.*

2 *Soil Infiltration Test at Motaua Soraia village, Block Behta, Sitapur district, Uttar Pradesh*

3 *Special study at an acid mine drainage site at North Eastern Coal Field, Margherita, Tinsukia district , Assam.*

4 *Demonstration of Rain Water Harvesting Structures located in the premises of Bhujal Bhawan, Faridabad to Sh. Pankaj Kumar, IAS, Secretary, Dept of WR, RD & GR , MoJS*

5 *Interaction with beneficiaries under PMKSY scheme at Gonda district, Uttar Pradesh.*

6 *Swachhta Pakhwada, 2021 organised by CGWB, Jammu at Bajindi talab, Patiya Keran, Jammu, UT of J&K.*

7 *High Yielding exploratory well drilled down to a depth of 200.00 m bgl at Akurde village, Bhudargad taluka of Kolhapur district , Maharashtra*

# COLLECTABLES








1. *Sharing NAQUIM report of Dun Belt, Udhampur District to Sh. Rajeev Bhushan, Chief Planning Officer, Udhampur.*
2. *Soil infiltration study using Double Ring Infiltrometer at Naraluru Village, Anekal Taluk, Bangalore, Karnataka.*
3. *Drill Cuttings of Exploratory Drilling site at Gujwal, Samba District , Jammu & Kashmir*
4. *Regional Director, CGWB, SWR Bangalore inspecting the Drilling site and ongoing Pumping test at Gundulpet, Karnataka.*
5. *Verification and finalization of outsourcing Exploratory Well and Observation Well sites*
6. *Sharing the Report on National Aquifer Mapping and Management and its findings of Rajouri District to Deputy Commissioner of Rajouri, Sh. Mohd. Sheikh Nazir (KAS).*
7. *GW Exploration at Makkhanpur, Nawagarh Block, Bemetara District, Chhattisgarh.*