India's Water Magazine

WaterAge

April 2023 300 | US $ 15

Your knowledge and information partner

SEA WATER DESALINATION

Initiative of

SHUDH JAL FOUNDATION
JAL AAJ AUR KAL

Find us on:

www.waterage.in

AADYS
COMPONENTS PVT. LTD.

One-stop-shop for Components

Ensuring smooth running for your Water & Wastewater Plants

The components from Aadys Components are rapidly getting approvals in municipal water and wastewater treatment as well as in industrial process applications across all industries and strongly recommended by water treatment specialists. Aadys Components provides a wide of range of components for water & wastewater treatment plants which are offered either as individual item, equipment, skid mounted packages or fully integrated systems. All components are sourced from world class manufacturers and industry leaders in their respective fields. The company continually strives to improve its capabilities and performance in order to provide the highest quality and technologically advanced products available in the industry.

COMPONENTS

- FRP Vessels
- RO Membranes
- RO Membrane Housings
- Dosing Pumps
- Sludge Dewatering Screw Press
- Filter Media
- Resins
- On-line Monitoring System
- Instruments
- RO Anti0scalants
- Iron Removal Media
- Valves etc.

SEGMENTS SERVED

- OEMs
- Industries
- Hospitals/Hotels/Malls
- SEZs
- Defence
- Institutions
- Public Health Departments
- Public Sector Undertakings (PSUs) etc.

AADYS COMPONENTS PVT. LTD.

CORPORATE OFFICE:
605, Bhikaji Cama Bhawan,
New Delhi-110066.
Ph: +91 11 41551444

HEAD OFFICE:
SCO 146-147, IIIrd Floor, Sector-34A,
Chandigarh-160022.
Ph: +91 172-5275055, 4012755

E-mail: sales@aadys.co.in

www.aadys.co.in

INDUSTRY INSIGHT:

CASE STUDY

ADVERTORIAL

MANAGEMENT

FOUNDER : Sanjiv Chaudhary
GROUP EDITOR : Yogesh Tomar
EDITOR–IN–CHIEF : Renu Tomar
ASSISTANT EDITOR : Manisha Singh
DESIGN & GRAPHICS : Virender Kumar
MARKETING & OPERATION : Poonam Singh

PRINTER
Fine Art: D–7 /3, Okhla Industrial Area, Phase 2, New Delhi 110 020

PRINTED AT
Fine Art:
D–7 /3, Okhla Industrial Area, Phase 2, New Delhi 110 020

PUBLISHER
WaterAge
Initiative of SHUDH JAL FOUNDATION
605, Bhikaji Cama Bhawan, Bhikaji Cama Place, New Delhi – 110 066

EDITOR
Renu Tomar
#4048, B 5 & 6, Vasant Kunj, New Delhi – 110 070

For editorial contributions / press releases, write to: **editor@waterage.in**
For advertising enquiries, write to: **info@waterage.in**
For magazine & e–newsletter subscription, write to: **enquiry@waterage.in**
For support and feedback, write to: **enquiry@waterage.in**

Published by **WaterAge** (Initiative of SHUDH JAL FOUNDATION) :
605, Bhikaji Cama Bhawan, Bhikaji Cama Place, New Delhi – 110 066, **E–mail: enquiry@waterage.in**

RENU TOMAR
(Editor-in-Chief)

SEA WATER DESALINATION IS CRUCIAL FOR ADDRESSING WATER SCARCITY

Water shortage is a growing worldwide issue that is forcing communities all over the world to come up with creative solutions. Traditional freshwater supplies are becoming less and less suitable as populations rise and the effects of climate change become more obvious. Sea water desalination appears as a critical solution to close the growing gap between water demand and supply in this urgent situation. As the world's population grows, the amount of water needed for home, agricultural, and industrial uses will rise exponentially. As a result of excessive consumption and droughts brought on by the climate, conventional freshwater sources including rivers, lakes, and underground aquifers are being depleted. Seawater is a plentiful but underutilised resource with enormous promise in many places, especially dry coastal regions.

Desalination of seawater offers a workable remedy for the problem of water shortage. With this method, salt and other contaminants are taken out of salt water to create drinkable water. The cost and energy need of the desalination process have considerably decreased by to improvements in desalination techniques like reverse osmosis and multi-stage flash distillation, making it more affordable and sustainable. While seawater desalination offers a lifeline to areas with a shortage of water, it is crucial to address the process's environmental effects. Marine habitats may suffer if brine, a byproduct of desalination, is released into the water. These environmental worries may be reduced, though, with careful planning and the incorporation of the right technology, such as brine dilution and the utilisation of renewable energy sources.

Infrastructure for the desalination of seawater has significant economic advantages. It boosts local economies, generates employment possibilities, and lessens reliance on expensive water imports. Additionally, having access to safe and dependable water fosters sustainable development in water-stressed areas while enhancing agricultural output and public health. To further research and development in desalination technology, governments, private businesses, and academic institutions must work together. Desalination projects can become more sustainable and affordable by pursuing novel solutions, such as membrane advancements, energy-efficient desalination techniques, and the use of solar or wave energy.

Sea water desalination offers a practical and workable answer to the growing water shortage. There are obstacles to overcome, but technical improvements, environmental concerns, and teamwork can assure its successful implementation. To ensure a sustainable water future for future generations, governments, politicians, and communities must acknowledge the urgent need to prioritise and invest in desalination projects. The moment is here to take action.







Liquiclear TM
NATURALLY PURE
Refreshing Allure
Naturally Pure
Hydration Secure
Meet your
next-generation
LDI water purifier
Naturally Pure
Embrace the natural purity your body deserves
Refreshing Allure
Rejuvenate your body and mind with refreshing purity
Hydration Secure
Hydration that safeguards your health and well-being
LDI TM
Tunable TDS
Fully Automatic
Low Maintenance
24 Hour Operation
Energy Efficient
Saves about 80% more water
Retains Natural Minerals
*Terms & conditions apply
For more details, please contact +91 88009 42942
or visit www.liquiclear.in or write to us at info@liquiclear.in
CE
ISO
VOCAL for LOCAL
MAKE IN INDIA
Follow us :

Study Emphasizes Rejuvenation of Waterbodies as Key to Enhance Water Resilience

A recent study conducted by the Sundaram Climate Institute (SCI) highlights the significance of revitalizing waterbodies to improve water resilience and address critical issues such as groundwater recharge and flood mitigation. The study, titled "Making India Water Resilient – Lessons from Madurai," draws from five years of research encompassing over 2,118 households and approximately 100 waterbodies. The report's release took place at an event hosted by the Madras Management Association in the city.

According to the study, numerous reports, including one from the Union Ministry of Jal Shakti, reveal that nearly half of Tamil Nadu's 1,06,957 waterbodies remain unused. During her presentation, Mridula Ramesh, founder of SCI, emphasized the declining per capita availability of water in India, particularly exacerbated during El–Nino years. It is predicted that urban water demand could surge by 20–30% in the coming years.

The study proposes several solutions to bridge the widening gap between rising water demand and seasonal supply. These include enhancing storage capacity in waterbodies, implementing rainwater harvesting techniques, and promoting wastewater reuse. In Madurai, for instance, approximately 84% of sewage remains untreated, and reusing half of this wastewater could significantly bolster water resilience in the region.

However, the study also reveals that around 52% of households in Madurai possess dysfunctional rainwater harvesting (RWH) systems, with roughly half of the surveyed households depending on groundwater for their water needs. Additionally, nearly 43% of households incur a monthly expense of 400 on drinking water. The research underscores the lack of awareness regarding water consumption and sewage recycling among most households.

Furthermore, the study highlights the crucial role of waterbodies in groundwater recharge, with 50 waterbodies in Madurai significantly replenishing groundwater levels within a radius of 200 feet. To preserve waterbodies, the report recommends fostering community engagement and proposes initiatives like "tank tourism" to create employment opportunities, drawing inspiration from the successful model implemented at Kodaikanal lake.

Rajendra Singh, a renowned water conservationist and environmentalist, shared insights into the rejuvenation of rivers based on the work done by the Tarun Bharat Sangh in Rajasthan. Singh recounted how restoring waterbodies and recharging wells had led to approximately 1.7 million youths returning to villages.

The study emphasizes the importance of solutions rooted in indigenous wisdom, underscoring water as the true bank. It suggests community–driven decentralized water management and the alignment of agricultural practices with rainfall patterns as viable strategies to address water–related challenges and mitigate the impacts of climate change.

Amit Chandra, Chairman of Bain Capital, emphasized four fundamental pillars for water management: recycling, demand and supply management, innovation, and technology. Efficient water use through metering systems and wastewater utilization, similar to successful practices in Singapore and Namibia, can pave the way for water resilience.

During a panel discussion, Ravichandran Purushuthaman, President (India Region) of Danfoss Industries; J. Srinivasan, Distinguished Scientist at IISC Bangalore; Mridula Ramesh; and Muthiah Murugappan, CEO of EID Parry's India Ltd., shared their experiences and insights on water management. N.K. Ranganath, water ambassador at Grundfos Pumps India, facilitated the discussion.

As India's water demand is projected to face a potential shortfall in the coming decade, the study underscores the urgent need to address this impending crisis. By rejuvenating waterbodies, implementing sustainable water management practices, and embracing innovative approaches, the nation can enhance water resilience and ensure sustainability.

Amritsar Set to Benefit from 24x7 Potable Canal Water Supply, Eliminating Need for RO Systems

In a significant development for the city of Amritsar, the officials of Amritsar Urban Water and Wastewater Management Limited have announced the implementation of a groundbreaking project that will provide a 24x7 potable canal water supply. The project aims to address the depleting groundwater levels and the increasing contamination of

water with toxic elements, thereby mitigating the risk of chronic diseases caused by consuming such water.

Under the leadership of Sandeep Rishi, the Managing Director of Amritsar Urban Water and Wastewater Management Limited, who also serves as the Municipal Commissioner, this ambitious initiative aims to revolutionize the water supply system in the city. Rishi highlighted that currently, a large portion of the population relies on groundwater accessed through motors and submersible pumps installed in their households. However, the groundwater is often contaminated and necessitates the use of water filters and reverse osmosis (RO) systems to make it safe for consumption. This has imposed financial burdens on the residents, who not only bear the cost of purchasing and maintaining these systems but also pay for the associated electricity bills.

With the forthcoming implementation of the canal water project, the need for filters and RO systems at home will become obsolete. The project promises to solve the pervasive problem of water contamination, consequently providing a boon for the residents of Amritsar. Rishi emphasized that the city's dwellers will no longer have to invest in filtration equipment or bear the expenses of RO system installation and repair. Moreover, the detrimental health effects resulting from consuming toxic water will be effectively eliminated, enhancing the overall well–being of the citizens.

This canal water project is a visionary undertaking initiated by the Punjab Government, which aims to provide canal water to every city and town across the state. The water will undergo comprehensive treatment in specially established plants before distribution. The project has garnered substantial financial backing, with the World Bank sanctioning crores of funds to support its execution.

The advent of a 24x7 potable canal water supply in Amritsar marks a significant step forward in the city's journey toward becoming a smart city. With the elimination of the need for RO systems, residents can look forward to enhanced convenience, reduced financial burden, and improved access to safe drinking water. This transformative endeavor is set to have a far–reaching positive impact on the lives of Amritsar's residents, ensuring a sustainable and healthy future for generations to come.

Gurugram's 'WeForWater' Takes Action to Prevent Impending Water Crisis by Recharging Groundwater

Gurugram, a city located in a semi–arid region, is facing the looming threat of a severe water crisis, driven by rapid urbanization and industrialization. As per the report by the International Resource Panel, if current trends persist, there will be a projected 40 percent gap between water supply and demand by 2030, with nearly half of the global population residing in water–stressed areas by 2025. Several Indian cities, including Mumbai, Jaipur, Bhatinda, Lucknow, Nagpur, and Chennai, are already grappling with acute water shortages. In response to this alarming situation, the Abhipsa Foundation has launched the 'WeForWater' movement, aimed

at mitigating the water crisis and making India water positive by 2040.

'WeForWater' is driven by the conviction that addressing water scarcity requires the participation of every individual. The movement focuses on collaboration, innovation, and community engagement to build and support water initiatives across the nation. The organization has outlined four key pillars—initiate, sustain, maintain, and measure—to achieve water resilience and combat the impending crisis effectively.

The primary objective of 'WeForWater' is to conserve and revitalize existing water-positive infrastructures, communities, landscapes, and technological interventions. To achieve this, the movement emphasizes the creation of community forests and biodiversity committees, the revival of fresh and wastewater ponds, and the maintenance of biodiversity parks. Additionally, the organization promotes effective management of wastewater, stormwater, and rainwater, along with the facilitation of water-sensitive infrastructure and water auditing.

One of the primary issues contributing to Gurugram's water scarcity is the depletion of groundwater resources resulting from overexploitation. The city heavily relies on rainfall to replenish groundwater, but due to extensive urbanization and industrial activities, rainwater runoff often ends up in sewers or stormwater drains. As a consequence, the groundwater reserves are severely affected, leading to land subsidence—an alarming phenomenon where the Earth's surface gradually sinks or suddenly settles.

The 'WeForWater' movement recognizes the urgent need to address these challenges and protect the city's water resources. By implementing sustainable practices and involving the local communities, 'WeForWater' aims to avert the 'Day Zero' scenario—an alarming situation where water taps run dry. The organization's ambitious vision to make India water positive by 2040 aligns with the larger goal of ensuring a sustainable and secure future for the country.

With its comprehensive approach and focus on collaboration, innovation, and community participation, 'WeForWater' offers a beacon of hope for Gurugram and other water-stressed regions in India. By adopting the

principles and initiatives put forth by the movement, there is a tangible opportunity to address the impending water crisis and ensure a more resilient and water–positive future for all.

Delhi Aims to Achieve Full Sewage Treatment Compliance by December, Reducing Pollution Load on Yamuna River

In a significant step towards reducing pollution in the Yamuna River, Water Minister Saurabh Bharadwaj announced that Delhi will be able to treat all the sewage it generates as per prescribed standards by December. This development will help alleviate the pollution load on the river and improve its water quality.

Currently, Delhi generates 768 million gallons per day (MGD) of sewage, out of which only 530 MGD undergoes treatment. The 35 sewage treatment plants (STPs) in the city, with a cumulative capacity of 632 MGD, are operating at only 69% of their installed capacity. This situation calls for urgent measures to enhance sewage treatment capabilities.

By June, Delhi's sewage treatment capacity is expected to increase to 727 MGD, and further rise to 814 MGD by December of this year. Additionally, plans are underway to expand the capacity to 965 MGD by June of the following year, ensuring the accommodation of future sewage generation.

The treatment standards for sewage require the biological oxygen demand (BOD) and total soluble solids (TSS) in treated wastewater to be below 10 milligrams per liter. At present, only 160.5 MGD of the treated wastewater meets these standards. An optimal BOD level of less than 3 milligrams per liter is considered ideal for assessing water quality.

To address the issue comprehensively, the Delhi government has extended the sewer network to 839 of the 1,799 unauthorised colonies in the city. These efforts aim to curb the discharge of untreated wastewater from such areas into the Yamuna River.

It is noteworthy that the stretch of the Yamuna River between Wazirabad and Okhla, comprising less than 2% of its total length, accounts for approximately 80% of the river's pollution load. The pollution is primarily caused by the release of untreated wastewater from unauthorised colonies and slum clusters, as well as the poor quality of treated wastewater discharged from sewage treatment plants and common effluent treatment plants (CETPs).

With a commitment to clean the Yamuna River to bathing standards by February 2025, the Delhi government is taking vital steps toward restoring the river's health. For the river to be considered suitable for bathing, the BOD level should be less than 3 milligrams per liter, and the dissolved oxygen should exceed 5 milligrams per liter.

By achieving full compliance with sewage treatment standards, Delhi aims to significantly reduce the pollution load on the Yamuna River, safeguarding the environment and promoting better water quality for the region.

Gurugram to Install 100 New Sewage Treatment Plants to Prevent Water Pollution

Gurugram, a city in Haryana, is embarking on a significant civic initiative to tackle water pollution by introducing 100 new sewage treatment plants (STPs). The Gurugram Metropolitan Development Authority (GMDA) aims to achieve 100 percent purification and utilization of wastewater by the end of this year.

Currently, Gurugram produces a staggering 412 million litres per day (MLD) of sewage water, with 388 MLD undergoing treatment. Unfortunately, the remaining 24 MLD, combined with illegally discharged sewage, amounts to a concerning 75 MLD of untreated waste, which eventually finds its way into the Yamuna River.

To address this environmental challenge, the GMDA plans to establish 100 new STPs throughout the city. The construction of these treatment plants will play a crucial role in preventing the discharge of sewage water into drains and ensuring proper purification of wastewater.

According to official data, Gurugram already utilizes 125 MLD of treated water for various purposes, including horticulture, within the city. An additional 75 MLD is sent to neighboring villages in Jhajjar for irrigation. These numbers reflect the positive impact of the existing STPs in the region, with two major plants currently operating in Dhanwapur and Behrampur.

The urgency to address the issue of polluted wastewater became evident when the National Green Tribunal (NGT) took note of the discharge of polluted water into the Najafgarh drain in December 2022. The NGT directed the Haryana State Pollution Control Board (HSPCB) and civic agencies in Gurugram to establish an independent monitoring mechanism to assess the pollution levels in the Najafgarh drain promptly.

The Najafgarh drain, once a part of the Sahibi river basin originating in Jaipur district of Rajasthan, now flows through Haryana before entering Delhi near Dhansa. It runs for approximately 57 kilometers through Delhi before ultimately emptying into the Yamuna River at Wazirabad. The NGT's intervention underscores the need to take immediate action to prevent further pollution of this vital waterway.

The introduction of 100 new STPs in Gurugram showcases the city's commitment to sustainable development and environmental conservation. By ensuring that all wastewater is treated and recycled, the initiative aims to safeguard the local ecosystem and protect the Yamuna River from contamination.

Through this ambitious project, Gurugram aims to set an example for other cities in India facing similar challenges related to water pollution. The installation of these treatment plants will contribute significantly to improving the overall water quality and promoting responsible water resource management in the region.

As the project progresses, it is expected to garner the support and cooperation of the local community, environmental organizations, and government bodies. With concerted efforts, Gurugram is taking a significant step towards a cleaner and more sustainable future, where wastewater is treated, reused, and the ecological balance is preserved.

Japanese Model Wastewater Treatment Plants Considered for Implementation in Kerala City

In a bid to enhance wastewater treatment capabilities, the city corporation and the Kerala Water Authority (KWA) are actively exploring the possibility of installing Japanese decentralized wastewater treatment plants, known as 'Johkasou,' in the city. The implementation of these innovative plants aims to address the growing concerns surrounding wastewater management and contribute to the effective reuse of treated wastewater.

During a recent meeting of the river rejuvenation committee (RRC) in April, the Managing Director of the KWA shared that the authority is collaborating with the city corporation to establish Johkasou facilities at the KWA office located in Vellayambalam. The decision came in response to the directives given by the chief secretary in a previous RRC meeting held in February, which emphasized the exploration of Japanese underground models of Sewage Treatment Plants (STPs). The Secretary of the water resources department also expressed his intention to visit Johkasou plants that have been successfully implemented in Delhi.

The Indian government has already shown support for the collaboration with Japan in the area of decentralized domestic wastewater management. In April 2022, the Union cabinet granted ex–post facto approval for a memorandum of cooperation signed between India and Japan, specifically in the field of decentralized domestic wastewater management. The joint efforts between the two nations aim to leverage the advanced Johkasou technology for the effective treatment and reuse of wastewater.

The implementation of the Johkasou system holds immense potential for managing both greywater (domestic wastewater) and blackwater (wastewater from toilets) in settlements covered under the Jal Jeevan Mission. Furthermore, it will significantly contribute to the sustainability of freshwater sources, aligning with the goals of the mission. The adoption of this innovative technology will enable urban local bodies to develop comprehensive plans for tackling the complex issue of wastewater treatment.

Johkasou, as described in a case study by the Asian Development Bank Institute, is a decentralized wastewater treatment system designed to treat human waste from flush toilets and domestic wastewater. Its introduction in the Kerala city will not only enhance wastewater management practices but also support the broader objectives of the Jal Jeevan Mission.

The move to consider Japanese wastewater treatment models highlights the commitment of the city corporation and the KWA to implement advanced technologies and strategies in addressing environmental challenges. By exploring the potential of the Johkasou system, the authorities aim to establish a sustainable and efficient wastewater management framework that aligns with international best practices.

As the discussions progress, further assessments and feasibility studies will be conducted to determine the optimal locations for implementing the Johkasou facilities within the city. The initiative showcases a progressive approach towards wastewater treatment, ensuring a cleaner and healthier environment for the residents of Kerala.

A NEW PARADIGM FOR TRANSFORMING INDIAN AGRICULTURE TO CLIMATE–RESILIENT AND SUSTAINABLE AGRICULTURE THROUGH INTEGRATED WATER RESOURCES MANAGEMENT

Suhas P. Wani
Former Director,
Research Program Asia and ICRISAT Development Centre

Suhas P. Wani is a Former Director, Research Program Asia and ICRISAT Development Centre (IDC), International Crops Research Institute for the Semi–Arid Tropics (ICRISAT), Patancheru Po. 502 324, Currently Intl. Consultant for Asian Development Bank (ADB), International Fund for Development (IFAD), and FAO, Bangkok, Thailand.

Indian agriculture is the backbone of India's food, nutrition, and income security as well as sustainable growth. Indian agriculture is unique with 20 agro–eco regions, and 80 agro–eco sub–regions growing more than 100 crops in 1000,000 villages by 145 million farm–holders. India moved from ship to mouth situation in the late 1960s to food self–sufficiency and has become Atmanirbhar and an exporter of food by producing 316.06 million tonnes in 2020–2021. However, rural India needs urgent attention as there is a great divide between the urban and rural family incomes, and the primary sector's contribution to national GDP is hovering around 17–18% although the Indian economy is largely agrarian with 950 million rural population driving the economy. However, there is a large untapped potential in Indian agriculture to become the growth engine for the sustainable development of India as large yield gaps are existing. However, the challenges of growing water scarcity, increasing land degradation, growing population, urbanization, and most importantly impacts of climate change. Due to climate change with increasing temperatures, aridity is increasing in the country, and rainfall variability with a reduced number of rainy days and increasing intensity in different parts is a major concern. There is an urgent need to develop and adopt large–scale climate resilient management practices at a local level through empowering the small farm–holders with strengthened science of delivery using new science tools such as remote sensing (RS), global information system (GIS), internet of things (IoT), information technology (IT), artificial intelligence (AI), machine learning (ML), etc. Business as usual will not work and a new paradigm through building partnerships, enhancing collective action, market–led agro–eco region–based diversification and scaling–up through the empowerment of small farm–holders using new science tools is proposed. Integrated watershed management is a well–proven approach for managing limited water resources in the country to overcome water scarcity and ensure food, income, and livelihood security for the ever–growing population in the country. The government of India's action plan with 11 national missions is in place and all stakeholders need to contribute by enabling policies and sincere implementation for building resilience against the impacts of climate change.

Current status of Indian Agriculture India has moved from "Ship to mouth" to surplus production of cereals

India has moved from the "ship to mouth "situation in the late 1960s to food self–sufficiency and has become Atmanirbhar and exporter of food, largely because of integrated efforts of our Annadatas (food Producers–Farmers), agricultural scientists, and policymakers. Food secure India with surplus food production produced 291.95 million tonnes of food grain production in 2019–20 and 316.06 million tonnes in 2020–2021 which is higher by 4.82 million tonnes (Ministry of Agriculture, Co–operation and Farmer Welfare, 2022). Even, during the COVID–19 pandemic, the agriculture sector showed resilience and our Annadatas enabled the country to see the first green shoots of the economy in the agriculture sector. Agriculture is on the right path, however, our Annadatas financial miserable situation is causing migration from rural areas to urban areas. In addition, the challenges to our food, nutrition, and income security are due to the growing population, growing water scarcity, and climate change impacts.

Rural India needs urgent attention for transforming the agrarian economy

Rural India comprises of a number of villages anywhere between 649481 according to Census, 2011 to 1000000 (MGNREGA) varying from 608,662 as per the Integrated Information Management System (IIMS) of the Ministry of drinking water and sanitation. The Swach Bharat Abhiyan (Gramin) report by the same ministry indicates 605,805 villages according to various government department databases as well as the definition (Rajeshvari Ganeshan, 2017). In rural India, agriculture is a primary sector providing a livelihood for 58% population of India, although, it contributes 17–18% to the national GDP. Although the Indian economy is largely agrarian as 950 million rural population (70% of the total population) drives the economy, the rural–urban divide is so prominent that the average rural income per capita per year (Rs 40,925) is less than half of the urban counterpart (Rs 98,435) in terms of net value added (NVA) as per the Ministry of Statistics and Project implementation (GoI, 2013, NSSO, 2013). Farmers in India are in distress as farming is not profitable and 55% of agriculture is rain–fed largely that depends on the vagaries of the monsoon and the uncertainties are further increased with climate variability and climate change impacts (Wani and Rockstrom, 2011). Thousands of farmers in different states committed suicides due to financial losses/crop failures, (11,772 in 2013, 12,360 in 2014, 12,602 in 2015, and 11,370 in 2016) (Das, 2011).

India is blessed with the largest arable agricultural land in the world followed by the USA and China enabling food security for 1.4 billion people with 314.51 million tonnes which is higher by 4.82 million tonnes in 2020–2021 (Department of Agriculture, Cooperation and Farmers Welfare, 2022) from 126 million ha under food grain cultivation. In spite of India's unique achievement in food production, India's food security position globally was 72nd as compared to the 3rd position for the United States of America, and the 35th position for China (Global Food Security Index, 2020). India has achieved self–sufficiency in cereals, pulses, milk but still imports edible oils. With increasing incomes food choices are changing and greater demand for fruits and vegetables is observed.

Challenges for sustainable agriculture and achieving food security

India has achieved food self–sufficiency for its growing population which is 1.4 billion at present (Wikipedia 2022a). However, the United Nations has projected that India may surpass China as the world's most populous country by 2023 instead of by 2027 as previously estimated as per the 2022 edition of the World Population Prospects (WPP). India's current population of 1.4 billion (UN–DESA, 2019) is projected to peak at 1.65 billion by 2060 (CBTE Database, 2021). With no room for agricultural extensification, the number of landholdings has surged to 146 M in 2015 from a modest 71 M in 1970 (Agriculture Census, 2019). In fact, 69% of the current landholdings are marginal farms (< 1 ha area) compared to 51% in 1970 suggesting that land fragmentation has continued possibly because of the prevailing socio–economic structure. With a strong linear correlation between population growth and the number of landholdings, smallholder farms remain the stark reality of Indian production systems (Das et al.2022). Such rapid strides in population in India have serious implications on water availability and particularly for food production as 80% of water withdrawals in India are for agriculture.

With the stagnant growth rate of 3.1 percent, achieving food, nutrition, and income security for the ever–growing population of India (1.46 billion by 2025 and 1.7 billion by 2050) remains a challenge (Government of India, 2017) as 55 percent of our agriculture is rain–fed. In brief, the challenges for India for sustainable development and food security in the 21st century are (Wani et al. 2018):

- Climate variability and impacts of climate change
- Growing population, urbanization, and increasing incomes
- Large yield gaps with low crop yields
- Water scarcity
- Minimizing land degradation
- Poverty elimination

Climate variability and Impacts of climate change on Agriculture

The constant increase in greenhouse gases concentrations, since preindustrial times, has led to positive radiative forcing of the climate, tending to warm the surface. Evidence over the past few decades has shown that significant changes in climate are taking place all over the world as a result of enhanced human activities in deforestation, emission of various greenhouse gases, and indiscriminate use of fossil fuels. For example, rise in atmospheric temperature by 0.740 C over the last 100 years due to global warming and projected a temperature increase of 1.8 to 40 C by 2100, global latitudes, especially in seasonally dry and tropical regions of the world as per the IPCC (Intergovernmental Panel on Climate Change) report (IPCC, 2007, 2018). The results of climate change research indicate that climate variability and change may lead to more frequent weather–related disasters in the form of floods, droughts, landslides, and sea level rise. Increased dryness and wetness in different parts of the country in the place of moderate climates existing earlier are observed in these regions. Climate change–induced changes in the cryosphere are also widespread, leading to a global reduction in snow and ice cover (Huss et al. 2017). Snow cover, glaciers, and permafrost are projected with high confidence to continue declining in almost all regions throughout the 21st century (IPCC, 2019). The accelerated melting of glaciers is expected to have a negative effect on the water resources of mountain regions and their adjacent lowlands, with tropical mountain regions being among the most vulnerable (Buytaert et al. 2017). Although the accelerated melting of glaciers may locally and temporarily increase streamflow, the reduction of glacier cover tends to lead to more variable river flows and reductions in base flow, while reductions in base flow in glacier–fed rivers are becoming evident in the Andes and the Himalayas (Walter et al. 2010). Such changes are likely to exacerbate water stress, which is among the main problems to be faced by many societies and

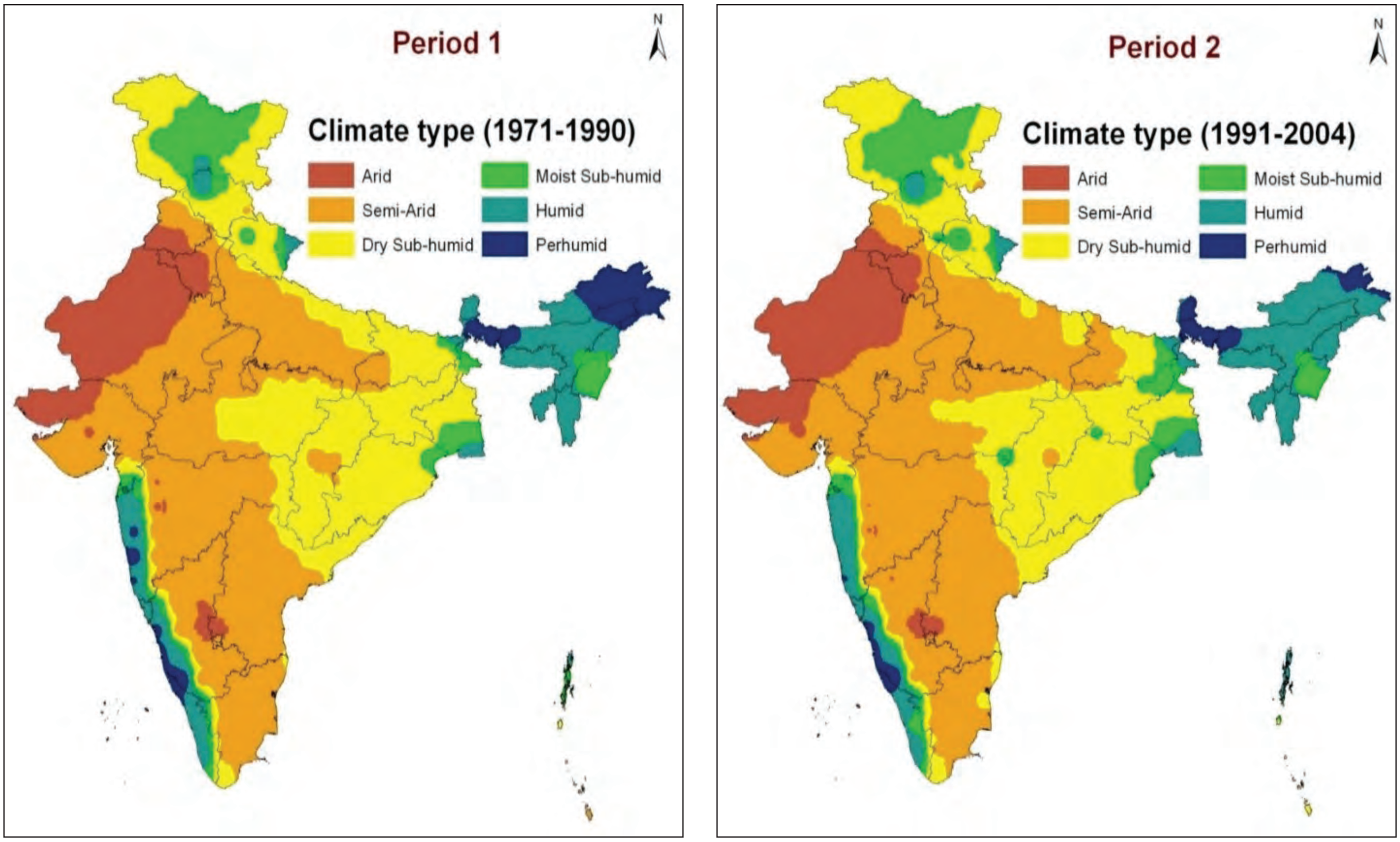


Figure 1. Changes in agro–climatic regions in India due to climate change during 1971–1990 and 1991–2004). Source: Rao et al. 2013.

the World in the 21st century. Future yields of rice, wheat, maize, and soybean will likely decrease significantly, by at least 25% in tropical and temperate regions as per the 5th Assessment Report of the IPCC (Porter et al. 2014). Global temperature increases of approximately 40C or more above late 20th century levels, combined with increasing food demand, could pose large risks to food security, both regionally and globally (John et al. 2020). At the international level climate change impacts are well established, however, there is an urgent need to assess the impacts of climate change at local (district and watershed) levels and develop suitable adaptation strategies for sustainable development.

In India, the number of rainy days during the season has decreased and rainfall intensities increased resulting in the frequent occurrence of dry spells during the crop growth period (Rao, et al. 2013, Figure 1). In north India, irrigated wheat yields decreased as the temperatures increase and a 20 C increase resulted in a 17% decrease in grain yield, and with the further increase in temperature, the decrease in yield was very high (Aggarwal, 2008). So, the effect of climate change scenarios of different periods can be positive or negative for a given region depending upon the magnitude of change in atmospheric CO2 and temperature. The highest decrease in chickpea grain yield per degree rise in seasonal rabi temperature was observed in Haryana (3.01 q ha–1), followed by Punjab (1.81 q ha–1), Rajasthan (1.27 q ha–1), and Uttar Pradesh (0.53 q ha–1) (Kalra et al. 2008). It was further indicated that due to climate change, there is a reduction in crop yield of 10 to 40% at the present yield level by the turn of the century. Changes in patterns and magnitudes of precipitation are also likely to affect rain–fed crop productivity and influence the availability of water resources for irrigation. Climate change is expected to exacerbate both the degree and incidence of high temperatures, thus negatively affecting major crops (John et al. 2020). Using an emissions scenario (Avnery et al. 2011) estimated that ozone–induced global yield reductions would be 10.6% for wheat, 4.3% for maize, and 12.1% for soybean by the year 2030.

Climate change is real and already at our doorstep, its implications are going to be borne by the poorest of the poor. Climate change will have a large effect on water globally which will vary regionally. This is due to spatially variable changes in precipitation, increased rate of glacier melt and retreat affecting river water flows, greater evaporation due to an increase in temperature, and higher water demand. These changes are likely to affect all aspects of agricultural water management including irrigation availability, soil moisture, evapotranspiration, and run–off (Boomiraj et al. 2010) as well as rainwater harvesting. Rain–fed agriculture economies are largely based on weather–sensitive agricultural production systems and are particularly vulnerable to climate change. This vulnerability has been demonstrated by the devastating effects of recent flooding and the various prolonged droughts during the twentieth century. Thus for many poor countries that are highly vulnerable to the effects of climate change, understanding farmers' responses to climatic variation are crucial in designing appropriate coping strategies for climate change (Wani et al. 2010, Wani 2020). Increased semi–arid areas by 8.45 M ha in Madhya Pradesh, Bihar, Uttar Pradesh, Karnataka, and Punjab resulting in an overall 3.45 m ha addition to SAT (Rao et al. 2013 Figure 1) is a concern as the areas affected are granaries of India. Dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions. If the climatic change is accompanied by an increase in climate variability, many agricultural producers will experience definite hardships and increased risk due to reduced water availability and increased demand for irrigation.

For example, in a state like Karnataka in South India, which has a spectrum of climates ranging from per–humid type in the coastal and Malnad region to arid type in the Ballari–Vijayapura (Bellary–Bijapur) region, it was observed by Rao et al. 2016 that the south–west monsoon rainfall is likely to be more uncertain, with both increasing and decreasing trends in different parts of the state. Surface air temperature and diurnal temperature ranges are likely to increase along the high ranges of the Western Ghats and under such conditions there is a threat to thermo–sensitive crops such as black pepper (Piper nigrum), cardamom (Elettaria cardamomum), tea (Camellia sinensis), coffee (Coffea spp.), cashew (Anacardium occidentale) and other plantation crops. There are shifts in areas under different climates in the state. A study indicated shifts in rainfall peaks by 2–3 weeks in some parts of Karnataka influencing the time of sowing and subsequent crop growth, necessitating shifts in crops and cropping patterns to match the modified rainfall regime (Rao et al.2016). Several studies have clearly indicated that there is an urgent need to understand the impacts of climate change at the local level to benefit the farmers.

Growing population, urbanization, and increasing incomes

With the increasing migration of rural people to urban areas, the reduced contribution of agriculture and allied sectors to national GDP, the large income gap between urban and rural population, changing food habits due to increased incomes, and inefficient management of water resources are putting tremendous pressure on water demand in India. The World Economic Forum estimated that in India by 2030, 51% of the population adding 350 million individuals will be in the upper middle high–income and high–consuming category as compared to 24% in 2020 (World Economic Forum 2019). Increasing urbanization, shrinking farm size, development in education, and migration to cities in search of better livelihoods is increasing food demand. For example, in India with the growing population as well as increasing incomes more people are taking animal–based food and a shrinking number of vegetarian diet people (Table 1).

Table 1. Increasing population, water footprint and freshwater demand: Indian scenario.

Parameters	**2010**	**2022**	**2050**
Population in India (Million)	1150	1400	1660
Vegetarian percentage population	60 %	50 %	40 %
Vegetarian Population (Million)	690	700	664
Non–Vegetarian Population (Million)	460	700	996
Daily water footprint for Vegetarian diet, Liter/day	4500		
Daily water footprint on–Vegetarian diet, Liter/day	15000		
Annual Water requirement for Vegetarian diet (BCM)	1133	1149	1090
Annual Water requirement for Non–Vegetarian diet			
(BCM)	2519	3832	5453
Total water requirement (BCM)	3652	4971	6543

Source: Derived from Water Demand in India in 2010–2050 by Sector–Statista 2021.
***Population used for 2022 is the actual population and for 2050 it is estimated by the UN.**

Large yield gaps with low crop yields (Untapped potential)

Currently, farmers' crop yields are low, particularly in developing countries in Asia, Africa, WANA, and Latin America with large yield gaps (0.5 to 5 t ha–1) based on the agro–eco region and the technologies used by the farmers (Rockström and Falkanmark, 2000, Wani et al. 2003a, & 2011, Bhatia et al., 2006 Rockström et al. 2010, FAO and DWFI, 2015, Anderson et al. 2016). Large yield gaps for rice (5.47 q ha–1), maize (12.77 q ha–1), oil seeds, and field peas were reported in India (Beigh et al. 2015). Current rainwater use efficiency in dryland agriculture varies between 35% and 45% and the vast potential of rain–fed agriculture could be unlocked by using available scientific technologies, including improved cultivars. The vast opportunities existing in dryland areas can be harnessed for improving rural livelihoods (Wani et al., 2018).

Growing water scarcity

Water is one of the five eternal elements (namely, earth, water, fire, air, and ether) which are also known in ancient Indian literature "Pancha maha bhuta" is an elixir of life. Water is an essential part of the world's ecosystem and without water, life would be impossible. Historically, many of the early great civilizations, the so–called cradle of civilization like Mesopotamia situated between the major rivers Tigris and Euphrates; the ancient society of Egyptians depended entirely on the Nile; the Indus Valley civilization in India flourished along the once famous Sarasvati river. Water has always had a pervasive influence on the cultural and religious life of Indian people. The great bath of Mohenjo–Daro is a great testimony to this fact. The bath is considered by scholars as the "earliest public water tank of the ancient world" (Singh et.al 2020).

Meeting food demand for the growing population in tropical India with limited arable land and water resources is a challenge during the 21st century. During the 2011 census, India entered the league of water–deficient nations (below 1700 cubic meters per person) per year and India is amongst the most water–stressed countries. Per capita, water availability in 1951 was 5177 m3 per year which has fallen to 977 cubic meters in 2010 and is expected to reach 802 cubic meters in 2022 and 677 in 2050 due to population growth (Table 2).

Table 2. Water resources availability and demand in India.

Water Resources availability	2010	2022	2050
Estimated annual precipitation (including snowfall) (km3)	4000		
Average annual potential in rivers (km3)	1869		
Estimated utilizable water (km3)	1123		
Surface water (km3)	690		
Groundwater (km3)	433		
Existing surface storage (km3)	214	412	412
Population (Million)	1150	1400*	1660*
Per Capita water availability (m3)	977	802	677

Water demand in different sectors (BCM)

Domestic	56	73	102
Irrigation	688 (84%)	910 (83%)	1072 (74%)
Industry	12	23	63
Energy	5	15	130
Others	52	72	80
Total	813	1093	1447

Source: Derived from Water Demand in India in 2010–2050 by Sector–Statista 2021.
***Population used for 2022 is the actual population and for 2050 it is estimated by the UN.**

Water scarcity varies in different regions which could be physical scarcity, economic scarcity, or institutional scarcity. Physical water scarcity occurs when the demand of the population exceeds the available water resources of a region meaning when water is not abundant enough to meet all demands of the population. Physical water scarcity is often a seasonal phenomenon, rather than a chronic one and climate change is likely to cause shifts in seasonal water availability throughout the year in several places (IPCC, 2014). Globally about four billion people live under conditions of severe physical water scarcity for at least one month per year (Mekonnen and Hoekstra, 2016). Economic water scarcity occurs when water is adequate, but is unavailable due to a lack of significant investment in water infrastructure. Around 1.6 billion people, or almost a quarter of the world's population, face economic water scarcity, which means they lack the necessary infrastructure to access water (UN–Water, 2014).

India receives half of its annual rainfall in just 15 days making floods and drought a fact of life in the country. With an annual average rainfall of 1180 mm, India does not face a water crisis but it's the management of water resources calling attention urgently and particularly so in agriculture. Water stress is primarily a blue water issue, and large opportunities are still possible in the management of rain–fed areas, i.e., the green water resources in the landscape as per the Comprehensive Assessment of green and blue water (Rockstrom et al. 2009). Compared to the 6.5 billion global population facing blue water stress by 2050, only 0.27 billion will have water scarcity if both green and blue water are considered

Increasing land degradation

Diminished ability of the land to support soil functions or services required for sustainable intensification results in large yield gaps between potential yield and actual yield in farmers' fields (Wani, 2021). The land is the base for all primary production systems and is a non–renewable resource. Of late, domestic and industrial sectors are competing with agriculture for good quality land and water resources. The demand for food is increasing with the increasing population, urbanization, increasing incomes shrinking farm size, development in education, and migration to cities in search of better livelihoods. More people in India are taking animal–based food while the population on vegetarian diets (which needs almost 1/3rd of water for producing the same calories in food) is shrinking. Increased food production has to come from the available, finite, and limited water and land resources that are declining in quality and quantity (Wani et al., 2011a, 2011b).

Land degradation which is in existence in the past also, has become a serious problem worldwide as the pace of natural resource degradation has greatly increased in recent times due to the burgeoning population and the increased exploitation of natural resources. Global food systems are responsible for 80% of the world's deforestation, 70% of freshwater use, and contribute to 40% of the planet's degraded land, according to the latest report by the U.N.'s Convention to Combat Desertification (UNCCD). The cost to restore one billion degraded hectares (2.47 billion acres) of land by 2030 is estimated to be $300 billion annually. Investing in restoration creates benefits that exceed the costs, says the report, as every dollar invested in restoration activities provides a $7–30 return in economic benefits (Global land outlook, 2022). The global experiences relating to land degradation highlighted the important degradation processes (loss of soil organic matter, soil physical degradation, nutrient depletion, chemical degradation, soil erosion and sedimentation, and degradation of landscape functions) that are closely linked to water use and management (Bossio et al. 2010). Some 97.85 million hectares — nearly 30 percent of India's land — underwent land degradation during 2018–19, according to Desertification and Land Degradation Atlas of India, released by the Space Applications Centre of the Indian Space Research Organisation. Land degradation has increased with irrigation availability resulting in erosion, salinity building, overuse of irrigation as well as run–off causing nutrient loss resulting in severe land degradation affecting productivity. Also inappropriate use of chemical fertilisers such as overuse of nitrogen, also use of di–ammonium phosphate in place of single super phosphate resulting in sulphur deficiency starting with soybean growing areas in Madhya Pradesh caused land degradation through nutrient depletion. Also, the emergence of secondary and micro–

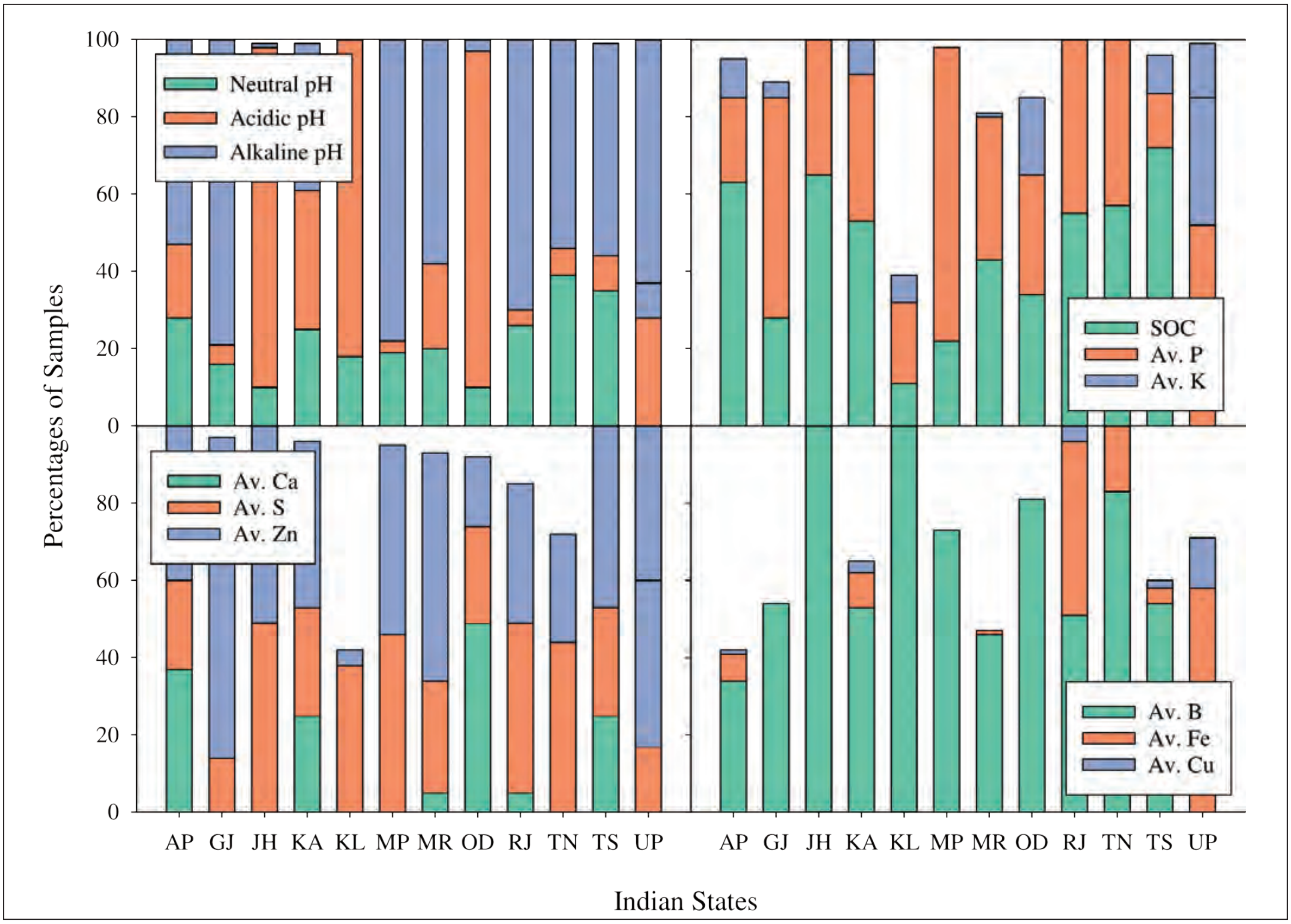


Figure 2. Percentages of soil samples showing different ranges of soil pH and deficiencies in soil organic carbon (SOC) and different nutrient contents in farmers' fields samples collected from selected states of India. (AP: Andhra Pradesh, GJ: Gujrat, JH: Jharkhand, KA: Karnataka, KL: Kerala, MP: Madhya Pradesh, MR: Maharashtra, OD: Odisha, RJ: Rajasthan, TN: Tamil Nadu, TS: Telangana, and UP: Uttar Pradesh). Source: Das et al.2022

nutrients deficiency in rain–fed areas have caused and continues to cause land degradation in India. Soil health is severely affected due to land degradation and is in need of urgent attention. Often, soil fertility is the limiting factor to increased yields in rain–fed agriculture (Rego et al.2005). Soil degradation, through nutrient depletion and loss of organic matter, causes serious yield decline closely related to water determinants, as it affects water availability for crops, due to poor rainfall infiltration, and plant water uptake, due to weak roots. Nutrient mining is a serious problem in smallholder rain–fed agriculture. On–farm diagnostic work of the International Crops Research Institute for the Semi–Arid Tropics (ICRISAT) in different community watersheds in different states of India as well as in Southern China, North Vietnam, and Northeast Thailand showed severe mining of soils for essential plant nutrients including secondary and micronutrients along with macronutrients (Sahrawat et al. 2007, Fig.2). Land degradation reduces WUE at field and landscape scales and affects water availability, quality, and storage. Because of this strong link between land and water productivity, improving water management in agriculture requires that land degradation be mitigated or prevented.

Business as usual (BAU) will not work

An innovative, implementable, and scalable strategy for sustainable and climate–resilient agriculture which is a primary sector is urgently needed in India. Business as usual (BAU) will not work and Innovative policies and strategies for climate–resilient agriculture for Atmanirbhar Bharat must be developed and implemented earnestly to address the challenge of climate change impacts, growing water scarcity, increasing land degradation, and large yield gaps. Unfortunately, agriculture in India is an untransformed sector, plagued with compartmentalization, poor extension reach to small farm–holders, poor infrastructure for storage and transportation resulting in huge post–harvest losses and a large number of middlemen (long value chains) along with a lack of water use (rainwater, surface water as well as groundwater) policies resulting in a lot of wastage, inefficient use, and overexploitation of the finite resource. The COVID lockdown has aggravated the woes of our "Annadatas" further in addition to climate change (Singh and Wani, 2020). Current strategies for food production will not meet our demand considering the impacts of climate change, growing population, decreasing per capita water

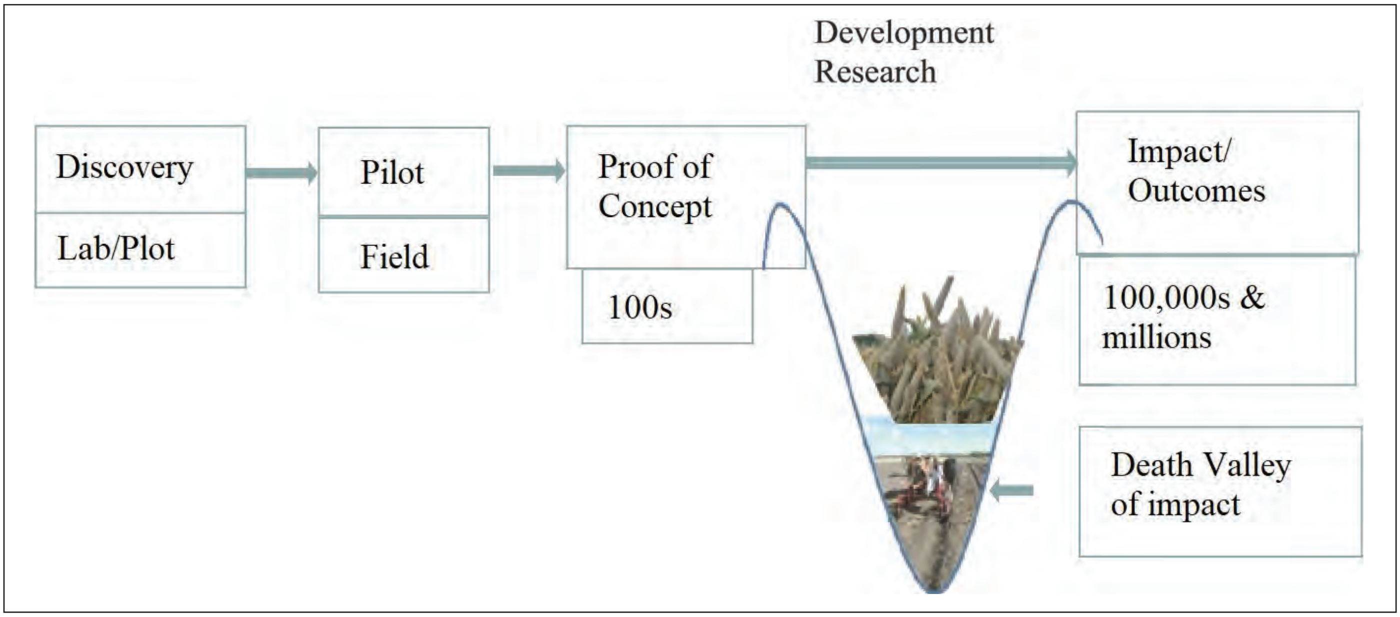


Figure 3. Death Valley of impacts: Pictorial representation of the life cycle of technology/product. (Source: Wani and Raju 2016, 2020; Wani 2021)

availability, and growing demand for water for food production due to increasing incomes, changing food habits and growing food demand (Table 1 & 2).

Urgent need to surpass "Death Valley of Impacts´

Large yield gaps for all the crops are observed in India inspite of the largest research network in the country and the availability of game–changing technologies with the researchers for increasing agricultural productivity, due to the existence of the Death Valley of impacts (Wani and Raju, 2018, 2020). do not penetrate smallholder farms. A recent assessment of more than 100,000 articles by the CERES 2030 Team (Nature, 2020) suggests that it is smallholder farms are generally neglected while developing agricultural technology. The lack of a holistic approach to target system–level productivity, value–chains, and market linkages along with the impacts of climate change continue to affect small farm–holders (Wani and Raju, 2018; Wani et al., 2018; Wani, 2021). Significant impacts of innovative technologies are not being realized possibly because of the so–called "Death Valley of impact" (Fig. 3), which results from the lack of synergy amongst different actors, a compartmental approach adopted by researchers, supply–driven technologies (rather than being demand–driven), and poor community participation (Wani and Raju, 2016, 2020; Wani, 2021).

The weak science of delivery in India is the main constraint to benefitting small farm holders from new technologies/products in the country. The existing extension system is not up to the mark as fifty–nine percent of farmers in India do not get any knowledge support (extension support) and current government machinery is supporting only 11 percent of farmers while the remaining 30 percent of the farmers get support from peers, media and private agencies (NSSO, 2013, GoI, 2013). Reddy (2018), Hans India (2018), and Sumanth, et al.2020) highlighted the limited reach of the public extension, in addition, the extension system is burdened with non–extension responsibilities such as the distribution of subsidies and inputs, with little time left to attend to core extension activities like advising farmers to enhance adoption of new practices and techniques. The majority of farmers in India do not have access to any source of information; this lack of access severely limited their ability to increase productivity and income and reduce vulnerability (Glendenning et al. 2010). Lack of technical advice, inputs, and ideas, collectively known as extension services for the small farm–holders was identified by the Ceres 2030 researchers globally based on a meta–analysis of >1000 research papers and reports as the main constraint for the adoption of new approaches/technologies/products. Small farm–holders are more likely to adopt new approaches — specifically, planting climate–resilient crops — when they are supported by technical advice, input, and ideas (Nature Food, 2020). Science needs to change its focus for crossing the Death Valley of impacts to achieve impacts (Nature Food, 2020) and scientists as well as research managers, extension staff, policymakers, donor agencies, publishers of the research journals, and farmers must change their mind–set (Wani and Raju, 2018, 2020). Awareness building and community participation which are driven by the tangible benefits for society through their demand–based solutions rather than supply–driven solutions can change the mind–set of people. Agriculture and staying in rural areas are considered no–choice options which need to be changed through the development of rural areas with the provision of urban facilities in rural areas (PURA) like initiatives. Change of mind–sets and seeking their participation is a challenge that has to be pursued vigorously and rigorously.

A new paradigm is a must for addressing the climate change

As reported earlier BAU model won't work and there is an urgent need to transform Indian agriculture to become climate–resilient agriculture. We need to use new science tools like remote sensing, drones, artificial intelligence (AI), machine learning (ML), cloud computing, simulation modelling, global information system (GIS), and information and communication tools(ICT) tools like mobile, social media, etc. to reach millions of small far–holders (Wani and Raju, 2018, 2020, Wani et.al 2018, Dalwai, 2020, GoI, 2021, Wani, 2021). There is an urgent need to overcome the complexities of Indian agriculture. While providing solutions to the farmers the silos which are created with watertight boundaries need to be blasted through urgent reforms to enable the country to harness the power of the IT revolution. India is moving in the right direction for transforming agriculture in the country as evident from the number of initiatives and concept paper like IDEA (Indian Digital Ecosystem for Agriculture) by the government departments for transforming agriculture and new Farm Laws. Several states have digitized 90% of land records. Fortunately, India is in forefront of the IT revolution and the country must encash this opportunity by overcoming compartmentalization and holding of data which is the government's proprietary right. The Ministry of Statistics and Project Implementation need to be strengthened and work along with IT Ministry to collect, sanitize, organize, and develop protocols for data security, sharing, and use. Government reforms are in this direction, for example, the Ministry of Agriculture is named DOAC&FW, Ministry of Jal Shakti is newly formed by converging water–related activities of different ministries.

Agriculture in India is full of complexities with 20 agro–eco regions (AERs), 80 agro–eco sub–regions, growing 100 crops during three to four seasons in 29 states and 9 union territories. Further agriculture is a state subject and any advancement in agriculture becomes a challenging task for the central government. There is an urgent need for innovative and scalable policies across the country with the proper and honest implementation for sustainable climate–resilient agriculture. A holistic and integrated consortium approach for developing rain–fed areas sustainably for watershed development is recommended (Singh et al. 1998, Samra and Eshwaran 2000, Kerr 2001, Wani et al. 2003, 2011, Molden et al. 2007; Rockström et al. 2007, 2010, Dalwai 2020) and same can be employed for climate resilient agriculture in the country. The new paradigm for climate–resilient agriculture must be science–based using new science tools for providing integrated and holistic solutions to millions of small farm–holders. This calls for building partnerships with researchers, development agencies, private entrepreneurs, extension departments, and civil society organizations (CSOs) adopting a consortium approach.

In brief, the empowerment of small farm–holders is critical and to achieve this change of mind–set of all the actors is a must to ensure that small farm–holders become partners through community participation for adopting an integrated holistic value chain approach using new science tools (Wani et al.2018, Wani, 2021). Further, farmers need to adopt the" Fork to farm" approach based on the market demand instead of the minimum support price based ´Farm to fork" approach.

This has been understood by the central government and putting policies for green development across the country. However, much need to be done urgently, and state governments also must pursue a similar approach to sustainable development and for overcoming the challenges of climate change, water scarcity, income, and food security.

Efficient use of resources such as water, nutrients, sunlight, etc. is critical for harnessing the benefits through science–based interventions using new science tools. For example, in India, water and nutrient use efficiencies are currently hovering around 35–50% resulting in low crop yields. The government of India has taken up several steps towards misuse of resources (nutrients and water) through schemes like the Integrated Watershed Development Program (IWMP), Pradhan Mantri Kisan Sinchai Yojana, Soil health card mission, mandatory coating of all agricultural urea with an extract from neem cakes produced from neem trees (Azadirachta indica) to stop divergence of urea for industrial use (Wikipedia, 2022b) as well as enhances the NUE by 5 to 7% (Mangat and Narang (2004) through inhibiting denitrification and reducing the size of urea bag by 5 kg has gone a long way in enhancing NUE, reducing chemical use and increasing profits for the farmers. According to industry estimates, there could be savings of about ` 10,000 crores on account of lower use. Further, the use of Nanotechnologies for the controlled release of fertilizers can go a long way in doubling NUE. In India, already, Nanomaterials are being tested on a field scale for minimizing losses as well as for enhancing NUE. Nano–fertiliser uptake is more as fertilizers are loaded on nano–particles which enter the plant cells and work at the cellular level. Nano fertilizers can be applied either by spraying or soil application and compared to chemical fertilizers requirement and cost, nano–fertilizers are economically cheaper and are required in a lesser amount. India which is the largest importer of urea and DAP is eying self–sufficiency in urea through the production of a locally developed version of nano–urea in six plants by 2024–25 overcoming the import of 20 million tons of urea saving 40,000 crores INR annually (Hindustan Times, 2022) using the technology developed by Indian Farmers and Fertilisers Cooperative (IFFCO).

Enabling Innovative, Implementable, and Scalable Policies for Sustainable Climate Resilient Agriculture

For the success of any initiative/program enabling policies at a macro–and micro–level as well as enabling institutions and proper implementation, monitoring, and learning are very much needed. Policy–makers around the world face common challenges: improving coherence between sectoral policies, balancing economic growth with social, environmental, and climate action, and using resources more efficiently and effectively. A common ground for compromise needs to be found to effectively address trade–offs between development and environmental protection, and also between the diverging interests of the various economic sectors. At the same time, applying a nexus approach can bring mutual benefits between, among others, energy, agriculture, ecosystems, and water efficiency (IRENA, 2015). The best example of Watershed management in India clearly demonstrated that the watersheds which started as a drought–prone area program (DPAP) by the central government in close integration with the state governments evolved through common guidelines by the government of India. Through evolving watershed guidelines this program transformed from soil conservation, and rainwater harvesting to water harvesting, efficient water use, and soil conservation to livelihood improvement through a number of revisions in watershed guidelines (Wani et al.2008a).

Similar was the case for many successful scaling–up programs such as Bhoochetana and Bhoo Samrudhi in Karnataka, Rythu Kosam in Andhra Pradesh, and several corporate social responsibility (CSR) projects (Wani, 2021). The government of India is actively pursuing the transformation of agriculture and a basket of new reforms to promote value–chain development as well as marketing at national and international levels. New reforms such as the creation of Gramin Agricultural Markets (GrAMs) as aggregation platforms, opening up of three market channels viz.

APMCs, intra and interstate direct trade under The Farmers Produce' Trade and commerce (Promotion and Facilitation) ordinance, 2020, Agricultural Export Promotion Policy 2018 focussing on volumes, standards & quality and cluster approach to production, liberalization of control orders under The Essential Commodities Act,1955, contracts in respect of farming and services through Farmers (Empowerment and Protection) Agreement on Price Assurance, Kisan rail and air flights, Farm Services Ordinance, 2020, and Promotion of 10,000 FPOs. Under Atmanirbhar Bharat which targets an investment of 1.65 lakh crore in the farm sector, Agri. logistics will get a boost across all sectors (Bhosale,).

For rural transformation, proper implementation is very critical and a must. Awareness building amongst the public and making it a public movement through active participation, DBT, implementation through an online process, and removing intermediaries who generate corruption. As indicated earlier, there are no policies for sustainable water use in agriculture, AESR– market–based agriculture (fork to farm) instead of MSP–based agriculture (farm to fork), and shifting agriculture to a business model rather than subsistence agriculture in India. Such enabling policies and associated institutions would help the scaling–up of integrated holistic solutions for the farmers and transform the rural sector through a new paradigm.

Strategies for climate change in India

India is committed to the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, which represent the international consensus on the way to deal with climate change. It has a very comprehensive framework of legal and institutional mechanisms in the region to respond to the tremendous challenges to the environment it is facing, owing to population growth, poverty, and illiteracy augmented by urbanization and industrial development and has initiated several climate–friendly measures, particularly in the area of renewable energy. India adopted the National Environment Policy 2006 and has also taken many other measures and policy initiatives (Vipin Chandra and Sandhya, 2016).

India has, for many years, large nationally funded programs for reducing the adverse impacts due to natural climate variability. These programs need to be extended and enhanced to cover the additional risks of climate change, through the provision of financial resources and relevant technologies. Currently, several social sectors and development schemes that emphasize livelihood security, the welfare of the weaker sections, and rural infrastructure are under implementation. The Government of India also set up an expert committee to study the impact of climate change on various sectors on May 7, 2007. The committee has studied the impact of anthropogenic climate change on India and has come out with its first set of findings and the research agenda that the ministries need to follow and implement in order to address India's vulnerability to anthropogenic climate change impacts (Vipin Chandra and Sandhya, 2016).

Both mitigation and adaptation are needed to significantly reduce the risks and increase the resilience of the world's most vulnerable citizens. Adaptation and mitigation should not be considered as either/or strategies, but rather as complementary ones that should be pursued together. Several GoI policies and schemes significantly address adaptation objectives.

The government of India has set up an 'Expert Committee on the Impacts of Climate Change to identify the measures that India may have to take in the future in relation to addressing vulnerability to anthropogenic climate change impacts. The National Action Plan on Climate change, prepared under the guidance and direction of the Prime Minister's Council on Climate Change, reflects the importance the Government attaches to mobilizing our national energies to meet the challenge of climate change. The National Action Plan focuses attention on 8 priority National Missions (Vipin Chandra and Sandhya, 2016). Seeking to expand its activities in different sectors to achieve the country's updated climate action targets, the government has decided to add three new 'missions' — on coastal ecosystem, human health and sustainable transport in addition to the eight missions (Jawaharlal Nehru National Solar Mission (JNNSM), Energy conservation and efficiency, National Mission on strategic knowledge for climate change (NMSKCC), National mission for sustaining Himalayan ecosystem, National Water Mission, Green India Mission, National mission on sustainable habitat (NMSH), National Mission for sustainable agriculture) to implement its existing National Action Plan on Climate Change (NAPCC), taking the total number of such dedicated missions to 11 (Visva Mohan, 2022).

Renewable energy solutions– including clean energy for homes, communities, solar and wind water pumps and clean and efficient household solutions for cooking and heating The following is the installed capacity for Renewables: Wind power: 41.2 GW, Solar Power, 59.34 GW, biomass/Co–generation: 10.2 GW, Small Hydro Power: 4.88 GW, Waste to Energy: 0.47 GW, Large Hydro: 46.85 GW. India has set a target to reduce the carbon intensity of the nation's economy by less than 45% by the end of the decade, achieve 50% cumulative electric power installed by 2030, and achieve net–zero carbon emissions by 2070. India has been ranked among the top 5 countries in the world, and the best among the G 20 countries, based on its Climate Change performance. India jumps 2 spots higher, and is now ranked 8th as per Climate Change Performance Index (CCPI, 2023) (Arora,2022).

For agriculture, we need to adopt sustainable land, water, and crop management practices to ensure the efficient use of resources for enhancing productivity. Integrated watershed management is a well–proven approach for adaptation as well as mitigating the effects of climate change while ensuring food, income, and livelihood security (Wani and Rockstrom, 2011, Wani and Raju, 2021).. We must consider green and grey water management for enhancing efficiency in agriculture along with blue water. We have always overlooked green water as a source for addressing water scarcity in agriculture and we need to build awareness about the huge potential of green water in India which is blessed with an average rainfall of 1180 mm per annum.

There is an urgent need for minimizing land degradation, we need to adopt strategies for carbon sequestration through different cropping systems including legumes, the addition of organic manures, green manuring, mulching, suitable land, and water management practices, and measures to enhance green water use efficiency in agriculture (Wani, 2020,2021, Wani and Raju,2018, 2020). For reducing poverty in rural areas we need to strengthen collective action through strengthening farmer–producer organizations (FPOs) as promoted by the GoI. There is an urgent need to strengthen market–led agro–eco region–based diversification by adopting the “fork to farm” approach instead of the “farm to fork” approach currently adopted by the farmers since the green revolution days. Now our country has moved from “Ship to mouth” situation to a surplus food producer and exporter (Wani, 2020, 2021, Wani and Singh, 2021).

Conclusions

Indian agriculture is unique with the largest arable land in the world cultivated by 145 million farmers in 20 agro–eco regions and 80 agro–eco sub–regions growing >100 crops during three–four seasons. However, there is a wide gap in family incomes between rural and urban families. Further, growing population, water and land scarcity exacerbated with impacts of climate change which is already at the doorstep are the challenges for food security, nutrition security, and sustainable livelihoods. To address the challenges of climate change we need to understand the effects of climate change at a local level and adopt resilient technologies through the empowerment of the small farm–holders. Along with sustainable agriculture through an integrated, holistic, and partnership–based approach using new science tools for empowering the farmers, there is an urgent need to ensure the provisioning of urban facilities like medical, education, power, sanitation, etc. in rural areas through (PURA) to check migration to urban areas. Adaptation and mitigation measures for climate change are essential and GoI’s 11 missions need to be strengthened through enabling policies and sincere implementation to harness the potential of Indian agriculture to become the growth engine for sustainable development. Business as usual will not work and farmers need to adopt a “fork to farm” approach in place of the existing ′farm to fork” approach along with market–led agro–eco region–based diversification and value chain approach through collectivization for saving water, energy, and land for sustainable development by harnessing the power of new science tools.

Dr. Mayur J. Kapadia
former Additional General Manager & Head, Quality Control Division, GNFC Ltd., Bharuch, Gujarat

Mayur Kapadia is a former Add General Manager & Laboratory Head of GNFC Ltd, Bharuch, Gujarat, India. He possesses industrial experience of 40 years in the fields of Quality Control, Lab Set up, Cooling Water Management, ISI certification, and many other areas. He has to his credit technical suggestion awards, more than 20 publications, and more than 15 presentations. He has been conducting training programs on Quality Control, NABL, ISI certification, Cooling Water Management, etc. He is an active member of the committee of the Bureau of Indian Standards, which has also conferred upon him an Appreciation award for his immense contributions.

WATER:

A DRIVER FOR THE COUNTRY'S DEVELOPMENT

Water is a unique, non–substitutable resource of limited quantity and also a foundation of life, societies, and economies. Water holds the position at the core of sustainable development. But unlike most other valuable resources, its **'true value'** is often not realized. Water is also critical for socio–economic development, energy, food production, healthy ecosystems, climate change, and human survival itself. Water is not only a basic **'human need'** but also a **'human right'**.

Water has its interconnections with health, energy, climate, biodiversity, infrastructure, urban planning, digitalisation, food, landscape management, tourism, industries, transport, and trade. Hence, a resilient approach to water management has the full potential to transform the global economy. By understanding the true value of water and by investing in water management, a country can build better and accelerate its progress towards a sustainable and inclusive economy that leaves no one behind.

In view of the foregoing facts and significance, Water is aptly covered in the United Nations' Sustainable Development Goal (SDG) at number 6, which is "Ensure Availability and Sustainable Management of Water and Sanitation for All". The achievements of both the water cycle and sanitation systems are designed to contribute

Poor education is a burden on the society and nation. Improved health status of children increases school attendance, thereby acquisition of virtues and talents in them

to the progress towards other SDGs, most notably on health (SDG 3), education (SDG 4), economics (SDG 8), environment (SDG 13) and aquatic life (SDG 14).

Water is a potential source for national development as well as the upliftment of poor people. The greatest economic benefit could be felt in countries which have the greatest water challenge. Focus on Water Management could become a building block for the economic and social development of a country through its impact on several sectors.

Health, Hygiene & Education

A large population worldwide do not have access to basic sanitation facilities such as toilets or latrines. Contaminated water and a lack of basic sanitation cause community diseases leading to increased health costs for the country. Clean and potable water is vital for reducing the global burden of disease and improving health. Many people in poor countries still have to consume water that is not protected against contamination from faeces. Communities must have enough water resources for their needs, in particular, women and girls must have access to clean, private sanitation facilities to manage menstruation and maternity with dignity and safety. Improvement in water management and sanitation can lead to less illness and closer access to better facilities, which finally translate into higher productivity for the country.

Improved hygiene can greatly improve health outcomes in many cases with little need for additional expensive infrastructure. Inadequate access to hand hygiene facilities can cause an increased risk for the spread of many bacterial, viral and other infectious diseases. Diseases like diarrhoea cause children mortality to a great extent. Proper water management can aid to reduced medical costs for the country. It can also prevent the loss of value that is lost through human life. Access to clean water

Water is essential for inclusive growth, so diminishing water supplies translates into slower growth.

and safe sanitation services contributes to the social development of a country by providing a life of dignity and equality for the population.

Poor education is a burden on the society and nation. Improved health status of children increases school attendance, thereby acquisition of virtues and talents in them. Developed personality and human resource is a strength for the economic development of the country.

Food, Agriculture & Ecosystem

Agriculture uses the major share of global freshwater resources. Food security has long been a challenge for human societies. The food security value of water is high but rarely quantified. In many regions of the world, water for food production has been a contributing factor to the depletion of aquifers, reduction of river flows, degradation of wildlife habitats, and pollution, thus causing environmental degradation. By understanding the intrinsic value of water for food production and undertaking proper water management, countries can harness many benefits like achieving food security, accommodating shifts in consumption patterns, providing livelihood resilience for small farmers, improving nutrition, alleviating poverty, revitalizing rural economies, supporting climate change mitigation and adaptation. Improvement in water resource management makes the country more resilient to rainfall variability and maintains the eco–system.

Industry, Energy & Business

Industry and energy combined withdraw 19% of the world's freshwater. Unfortunately, these sectors are highly focused on monetization, hence they are not inclined to certain aspects of the value of water. For them, the most straightforward monetary valuation of water is understood as the price of raw water plus treatment cost plus disposal cost.

However, it is important for industry and business sectors to recognize the overall economic productivity of water. Water management in these areas leads to various economic benefits, such as job creation, higher product value per unit of water, higher production and productivity, etc. Therefore, they should aim to curtail inefficient water use, high discharges of pollutants, and degradation of marine and freshwater systems. Water is required to be viewed as a part of a circular economy so that each liter is reused again and again.

Conclusion

Water is essential for inclusive growth, so diminishing water supplies translates into slower growth. Further, economic growth is a "thirsty business", so it is pertinent that water should become a part of the nation's infrastructure rather than a consumable resource. Good water management should be an absolute priority for every generation, and for every government throughout the world for global development.

The world needs a paradigm shift in how it understands, values, and manages water:

- **Understanding Water** means making evidence–based decisions about water.
- **Valuing Water** means recognizing the values that societies, governments, and businesses accord to water and its uses. Valuing should also include decisions about appropriately pricing water and sanitation services.
- **Managing Water** means pursuing integrated approaches to water resource management across local, national, regional, and global levels.


DROPX®
DUVERA®
BUILDING TRUST
Filter Bags
Cartridge Filters
Filter Housings
Filter Bag Housings
Norit Carbon,
Granular, Coconut, Powder Carbon
Mno2,
Filter Media
Anion and Cation
Ion Exchange Resin
FRP/SS/MS Vessles
Distribution Systems
Multiport Valves
Dosing Pumps
RO//NF Membranes /MBR
FRP/SS Membrane Housings
Ultra Filtration Membranes
MBR Membranes / EDI
High Pressure / Fire
Transfer Borewell Pumps
UPVC/SS
Mult-Cartridge Housings
Flow Meters
TDS, ORP, PH Metres
Pressure Gauge, Switches
Victaulic Coupling & Gasket
DropX® Chemicals
for ETP, STP, BOILER & RO
UV& Systems
& Control Panels
ETP / STP
Components
Blowers
Filter Press
QUA® PURE TECHNOLOGY
SHAKTI® PUMPING LIFE
omikon BLOWERS & SYSTEMS PVT. LTD.
Alfa ≈ Aerosol® PRESSURE VESSELS
DIGITAL INSTRUMENTS CORPORATION
ALFA® THE UV EXPERT
PENTAIR
HYDRANAUTICS www.membranes.com
DUPONT™
MILTON ROY
Danfoss
GUDDI PLASTCON PVT. LTD.
ION EXCHANGE
256/10 Church Road, Near Shiv Mandir, Jashola Vihar, New Delhi - 10025
Email : sales@duverawater.com | Call : 87440 40406, 85951 49016, 82872 03644 | Website : www.duverawater.com

ANALYSIS OF THE ROCK MECHANICS BEHIND RAVELING FORMATION OF 91M X 70M X 45M CAVITY THROUGH CROWN OF DOWNSTREAM SURGE GALLERY CAVERN OF PUNATSANGCHHU – II HYDROELECRIC PROJECT, BHUTAN

Yoginder Kumar Sharma
Consultant & Faculty,
Civil Design & Underground Construction

Yoginder Kumar Sharma is a Former Member Central Water Commission and Ex–officio Additional Secretary to Government of India has done his Masters in Structural Civil Engineering from PEC, Chandigarh. He has an illustrious career of 36 years in Government. He has a rich experience of 15 years in design of hydroelectric projects, backed up with experience as Director (Technical) in implementing and managing construction the two mega hydroelectric projects in Bhutan, respectively that of 5 years in Punatsangchhu–I a 1200MW H E project and of 7 years in Punatsangchhu – II a 1020MW H E Project.

In the case of underground caverns of large height, the structural geology of the rock mass, at large, surrounding the cavern, becomes critical for stability of the underground excavation. Therefore, evaluation of the impact of the latest encountered geological features, on the stability of the excavation, a proper scientific analysis and review of the support design of underground structures, are essential to be performed iteratively incorporating modified geological parameters and instrumentation feedback gathered.

This article presents analysis of rock mechanics behind the raveling formation of the huge cavity of a size of a football field and of 1/3rd height of the Eiffel Tower, through the crown of the 314m long, 58m high & 19m wide Downstream Surge Gallery (DSG) in Punatsangchhu–II HE Project, Bhutan, which happened in 2016, a 3 years after the crown had been excavated and supported. Depicting from the 3D Numerical Analysis done two years after the failure, in 2018, by an independent agency of repute, this article establishes that, a raveling failure of rock mass happened in the hanging wall, formed from intersection of the rock mass by a steeply dipping major Shear Zone and comprising of multiple inclined discontinuities in a highly jointed and fractured rock mass (Class V & IV) having joint sets infilled with clay and crushed mass, due to the confining stresses present around the crown got transformed into tensile nature.

The raveling failure of this rock mass thus having rendered to state of mere assemblage of loosely packed rock mass in the crown got triggered, when the excavation in the cavern reached larger depths, and the crown arch was confronted with withdrawal of bearing support resulted from large displacements and dislodging of the key stones at their Springing level in the widely yielded rock pillars which slid along the cracked cross–section formed all along the traverse of the Shear Zone, under the heavy load subjected from the assembly of loosely packed rock mass in the crown as it had lost the stabilizing arch action due to absence of any confining pressure.

Introduction

The Punatsangchhu–II Hydroelectric Project (1020 MW) is a run–of–the–river scheme (Fig.1) and it is spread over a distance of about 15 km along Wangdue – Tsirang National Highway in Wangduephodrang Dzongkhag of Bhutan. Originally in the DPR, the Power House Complex was contemplated to be a Surface Power House, to be located on the right bank at a site 3km downstream from the present location of the Underground PH Complex.

The location of the PH Complex was changed to the underground site selected by the Consultants WAPCOS, just before the start of construction in 2010. The underground Power House Complex (Fig.2) comprises 3 huge caverns in close proximity that of Power House (PH) Cavern 240.7m (L) x

Figure 1: Project Layout showing change of PH Location

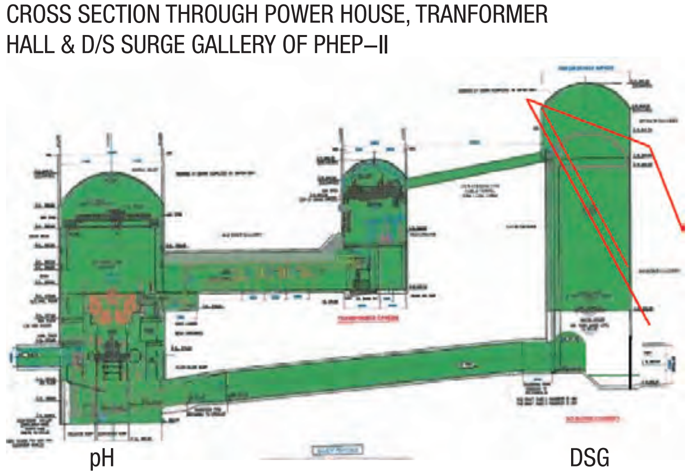


Figure 2: Excavation in PH Complex on 02.03.2016

23.9m (W) x 52m (H) , Transformer Hall (TH) Cavern 216.1m (L) x 14.7m (W) x 26.5m (H) and the Downstream Surge Gallery (DSG) 314m (L)x 18.8m (W) x 58.7m (H) besides a network of Tunnels, Pressure Shafts, Bus Duct Tunnels and Draft Tubes opening in to these caverns.

The Huge Rock Fall

A huge cavity of the size of a football field and of height of one third the height of Eiffel Tower formed in year 2016 on 3rd January, through the crown of the underground cavern of the Downstream Surge Gallery (DSG) of the Project, at the time when the cavern was under excavation for 3 years and had been yet excavated to a depth of 35m to 40m. The failed reach in the DSG starting at RD ±140m (Photo–1) was estimated to continue till RD ±210m.

Geology – Perceived v/s Actual

The DSG having been investigated apparently through one borehole DSC1 only (Fig.3) by the WAPCOS, the significant observation by Geological Survey of India, the Geology Consultant, was that, "Rock mass conditions of only limited reach in the DSG have been explored"1

and evaluated the rock mass classification in the three caverns as "Good to Fair". However, during the excavations the rock mass in the

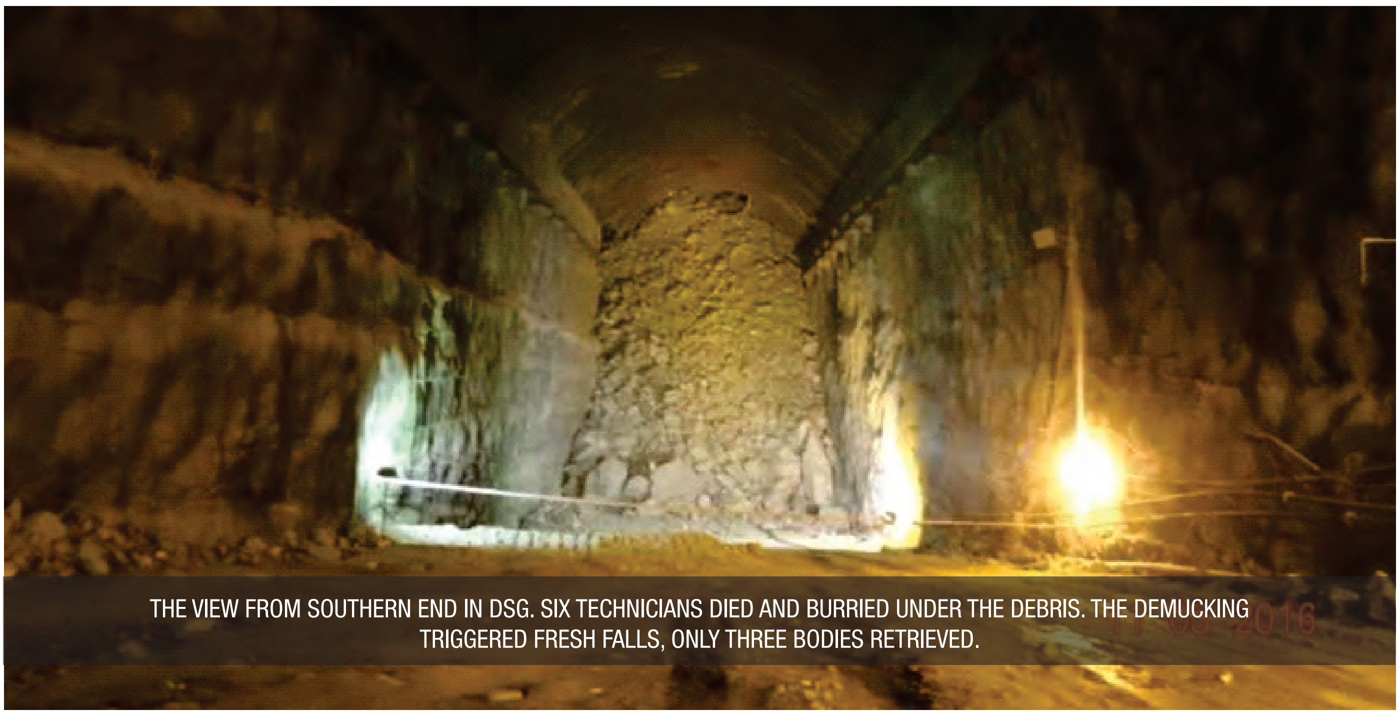
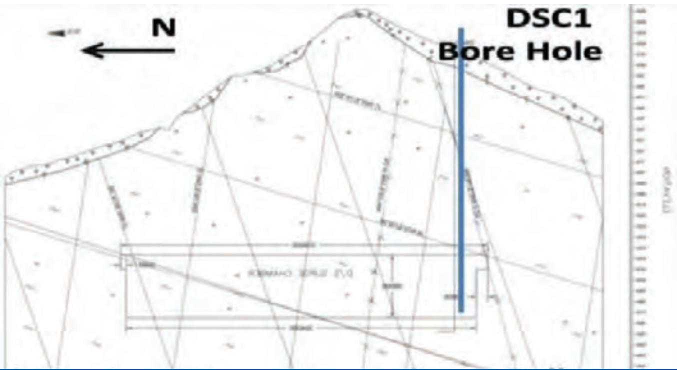


Image1: DSG Cavern view from southern end, blocked with fallen debris at RD ±140m



314m Long Downstream Surge Gallery (DSG) site was investigated by the consultants WAPCOS, who decided the changed location based on their only one borehole DSC1. The other borehole DSC3, was driven by consultants at a different & far away location to that suggested by their own Geology Consultants GSI.

Figure 3: The only available Bore Hole DSC1 in DSG

Rock Mass Category Actually Encountered in three Caverns

CAVERN	FAIR TO GOOD	POOR TO FAIR	POOR	VERY POOR
pH				
CAVERN	NIL	44.8%	54.07%	1.12%
TH				
CAVERN	NIL	35.65%	56.94%	7.4%
DSG				
CAVERN	NIL	40.0%	50.95%	9.05%

Table–1 Actual Rock Mass encountered

three caverns was found to be only "Poor to Very Poor" (Table–1). The Norwegian Geotechnical Institute (NGI) has also reported10 that the rock mass in the DSG comprised "Poor to Very Poor" classification.

The DSG aligned at N10E direction comprise quartzo–feldspathic gneiss, biotite micaceous quartzite with leucogranite and pegmatite patches and veins. At places leucogranite / pegmatite is crushed / sheared and fractured due to deformation/folded rock strata. In general foliation has gentle dips 10–25 / N205–240 direction and has seven prominent open to tight joint sets, filled with clay and rock flour.

Intersection of DSG By Major Shear Zone

A Major Shear Zone (45–60/N030) was met in the DSG crown during excavation of Central Gullet between RD ±121 to RD ±129m, which resulted in formation of 8m high cavity. The same shear zone was met earlier in the Construction Adits of PH and DSG caverns in 2012 (Fig.4). Many other geotechnical problems viz. low dipping foliation joints posing slabbing conditions in the crown portion, erratically occurrence of intrusive bodies of variable dimensions, minor shearing along foliation joints and other joints at few locations were encountered 2, besides presence of water (seepage/dripping) along shear zone.

The Project Authority suggested to change the layout design of the three caverns to save their intersection by the DSG. Only the layout of PH & TH caverns was shifted by the Designers, the Central Water Commission, by 36m and 18m respectively towards South to keep these two caverns stay clear of the effect of the Shear Zone (Fig.5). Whereas the DSG remained unaltered and intersected in its mid–length throughout its full depth of 58.5m by the steep Shear Zone (Fig.5).

Hanging Wall Formed by the Major Shear Zone in the DSG

The failed reach of the DSG, comprising of highly jointed and fractured rock–mass of class IV & class–V 210 with open joints, actually formed a Hanging Wall, which lied over the traverse of the major shear zone dipping steeply at 55 which intersected the DSG throughout its depth in a reach between RD ±130m to RD ±180m. The Shear Zone only marginally

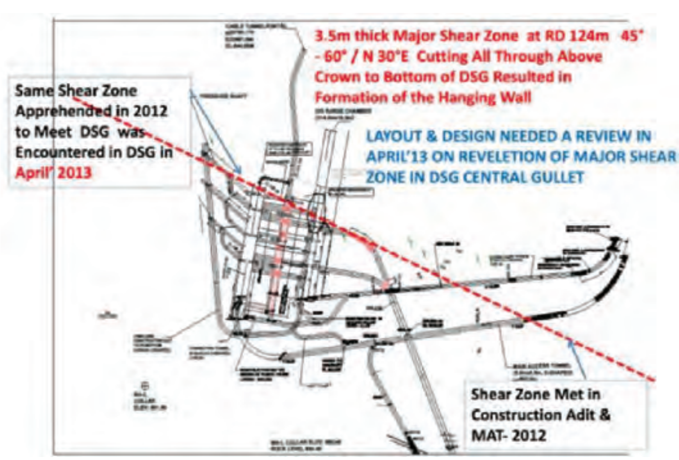


Figure 4: The Shear Zone cutting Access Tunnels & Caverns

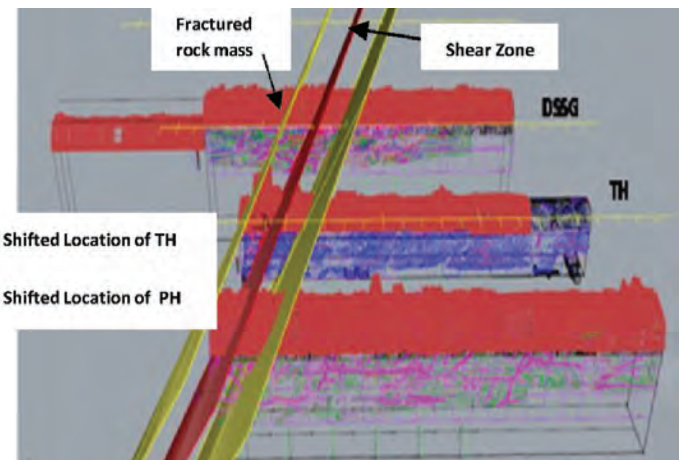


Figure 5: Precarious conditions present only in DSG

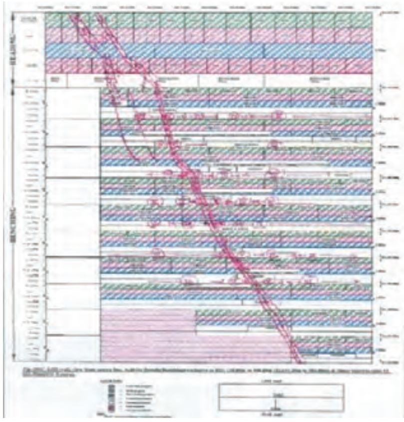


Figure 6: Shear Zone intercept in U/S Wall & Crown

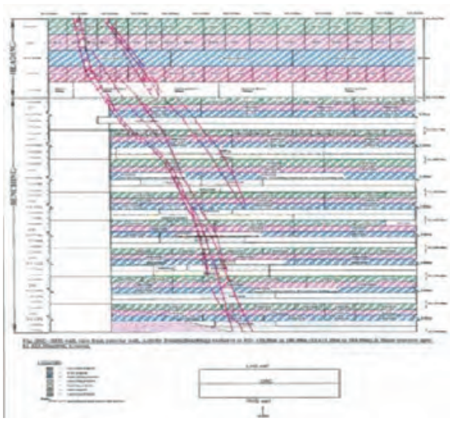


Figure 7: Shear Zone intercept in D/S Wall & Crown

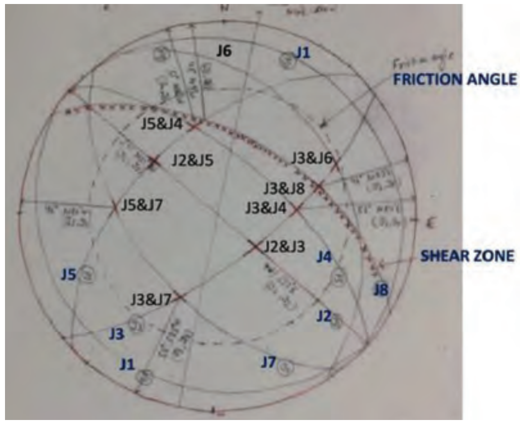


Figure 8: Presence of 8 nos. of Wedge Sets steeper than Friction Angle in DSG Crown

intersected the two adjacent caverns of the PH and TH, that too near their respective Gable Ends, and thus Hanging Wall phenomenon is not present in PH & TH caverns.

Layout of PH Complex and Rock Support Designs originally Finalized With Mis–Conceived Geology apparently Lacked input of actual number of joints In comparison to the 4 joint sets considered in the Investigation1 and thus also in carrying out the Designs, the Joint Sets actually present 4 in the DSG as encountered during the excavation comprise: J1 23°/S 40° W & J1 23°/N 40° E ; J2 Vertical N 40° E; J3 70°/S40° E; J4 65°/ N 40° E; J5 65°/ N 40° W; J6 50°/ N 55° E; J7 40°/ S 65° W and the J8 Shear 55°/ N 30°E.

The Major Geological Structural Features affecting stability of the DSG cavern of huge height of 58.5m were the presence of the major Shear Zone and 7 nos. of joint sets with dip steeper than the Angle of the Internal Friction of the Rock Mass along with the foliation dip as flat as 15°. The

Figure 9: Yielding in rock pillar between DSG & TH cavern with excavation would reach 38m in DSG

Figure 10: Yielding in rock pillar between DSG & TH cavern with excavation to full height in DSG

8 nos. of typical potential wedge system 4 formed by joint sets J3&J7; J5&J7; J2&J5; J5&J4; J3&J6; J3&J8; J3&J4 and J2&J3 were all lying within the Friction Circle, as depicted in the Sterionet (Fig. 8).

These wedges having Dip Steeper than Friction Angle & Crushed Rock & Clay filled Joints, were highly unstable and prone to fall out under gravity if were subjected to unconfined conditions.

The Numerical Analysis Apprised to the Designer Consultants in 2014, before start of excavation in benching

The analysis had established that with the Designed supports provided Massive Yielding of rock mass would be occurring in the intermediate Rock Pillar with progress of excavation, when DSG is excavated to 38m (Fig.9) and excavation of DSG's Full Height of 58.5m(Fig.10).

However, the Designers did not take the above–mentioned analysis in to any consideration and junked it. But it is Ironical that, the excavated depth in DSG was indeed of around 38m on 3rd March 2016, when the massive rock fall happened in the DSG Cavern.

Instrumentation Readings Warned of Hanging Wall Sliding on the Shear Zone

The readings of the Instrumentation of over a period (Table–2) at RD 135m and at RD 180m in both walls of the DSG show that as the excavation in benching in the DSG was nearing 38m, the Hanging Wall reach of the Down Stream Gallery lying in North of the Shear Zone, separated from the South side along the traverse of the Shear Zone, was bodily sliding vertically and drifting towards North. By 02.03.2016, the Hanging Wall, sliding on the Shear Zone Plane have had at the SPL , a Vertical Settlement of 96mm and displacements in X– direction of 27mm and in Z– direction (towards North) of 16mm.

The Massive Raveling Cavity Formed Through Crown of The DSG

Scientific Analysis & Design to Cater to the Actual Structural Geology was Apparently Absent

Displacements Observed at RD 135m in D/S Wall of DSG at El. 620m	Depth in Rock	25.09.14	26.11.14	09.01.15	20.03.15	20.04.15	27.05.15	31.07.15	16.10.15	02.03.16
Benching Reached at	El. 608.5m 25.08.14	El. 608.5m 25.08.14	El. 605.0m 21.12.14	El. 605.0m 12.02.15	El. 599m 06.04.15	El. 596m 26.04.15	El. 596m 26.05.15	El. 593m 17.07.15	El. 590m 09.10.15	El. 590m 09.10.15
Bodily Movement (mm) increased with progress of excavation in Benching in DSG as seen from Surface Target Readings;	Surface Movement (mm)	X=2, Y=–2, Z=0	X=7, Y=–48, Z=11	X=–15, Y=–40, Z=5	X=–4, Y=–53, Z=1	X=–15, Y=–42, Z=7	X=–27, Y=–50, Z=4	X=–28, Y=–53, Z=4	X=–28, Y=–47, Z=4	X=–27, Y=–96, Z=16
	Load Cell	0.0 KN	1.4 KN	1.3 KN	1.3 KN	N.A.	N.A.	N.A.	2 KN	3.5 KN
	MPBX@5m	–1.0	–2.1	–1.5	–1.5	–1.5	N.A.	–1.8	–1.8	–4.7
	MPBX@10m	–1.9	–1.9	–1.4	–1.4	–1.7	N.A.	–0.3	–2.1	–4.4
While distress with in the rock mass, as seen from MPBX readings, is not alarming.	MPBX@15m	–1.9	–2.4	–2.3	–2.3	–2.3	N.A.	–0.7	–2.8	–9.6
	MPBX@20m	–1.0	–2.7	–2.6	–2.6	–2.8	N.A.	–0.8	–3.6	–8.7
	MPBX@25m	–0.9	–2.5	–2.5	–2.5	–2.5	N.A.	–0.2	–3.8	–11.6

Table – 2 SurfaceTarget readings showed bodily movement

A Numerical Analysis with actual Geological Conditions if was done at right time, it would have established the instability of the underground structure of DSG. However, the Rock Support Design in the Crown remained unchanged except of addition of steel rib supports and few spot rock bolts at few locations as per redesign.

The 3D Numerical Analysis8 Done in 2018 by NIRM8

However, the 3D Numerical Analysis, though incorporating only 4 Joint Sets & Shear Zone J1,J3,J4,J5 & J8 as considered by the Designers and yet not incorporating 3 more actually present joint sets i.e. J2, J6 & J7 defined above, was performed two years after the Crown Failure, only in 2018 by the National Institute of Rock Mechanics8, at the request of the Project Authority to evaluate independently the state of stability of the three caverns of the PH Complex.

The Uniaxial Compressive Strength of the Intact Rock in the DSG is of the

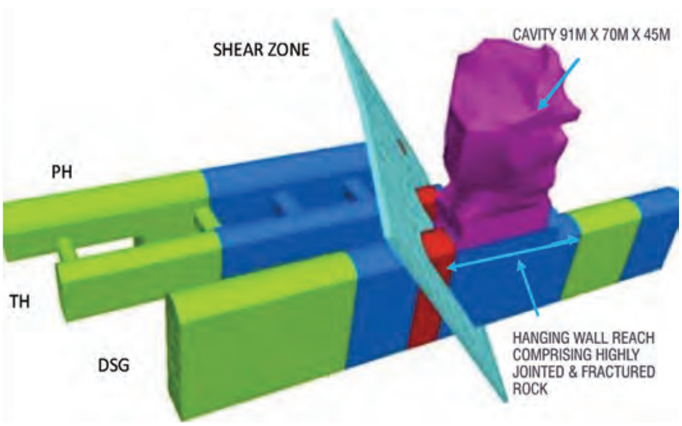


Figure 11 Cavity of size 91m x 70m x 45m formed in DSG crown from RD ±140m to RD ± 210m

order of 55 MPa and that of 3.5m thick Shear Zone is 3 MPa. Whereas, the Uniaxial Compressive Strength of the Rock Mass in this 'later failed' reach in the Hanging Wall is of the order of 1.08 to 2.84 MPa.

This reduced UCS of Rock Mass in the hanging wall reach to about 2MPa while the UCS of its parent constituent Rock being 55 MPa, is resulted due to presence of Crushed & Fractured Infilling Material in the excessive number of the Joints. This matrix of jointed rock mass and the fractured rock and clay fillings thus have large variability of strength across the rock mass and makes the resulting conglomerate of rock mass Brittle.

State of In–situ Stresses Before Excavation of the DSG

In the Hanging Wall portion in the Crown of DSG, the in–situ stresses stood higher than the existing poor strength of the rock mass. The In–Situ Maximum Vertical Stresses in Un– excavated DSG Cavern between RD 136 m to RD 195m are of the order of 5 MPa, which is higher than the UCS of the Rock Mass of 1 to 2.8 MPa.

Prior to the excavation, the rock mass in the Hanging Wall had different sizes of fractured blocks of parent rock having crushed material and clay fillings in their multiple

joints, was present as an "assemblage of blocks of rock" existing in a tightly packed state due to presence of the confining stresses around the rock mass.

Importance of state of stresses for the stability in excavated underground openings

Moderate stresses around an excavated section are usually favorable for stability.
Low stresses around the excavated section are often unfavorable for the stability.

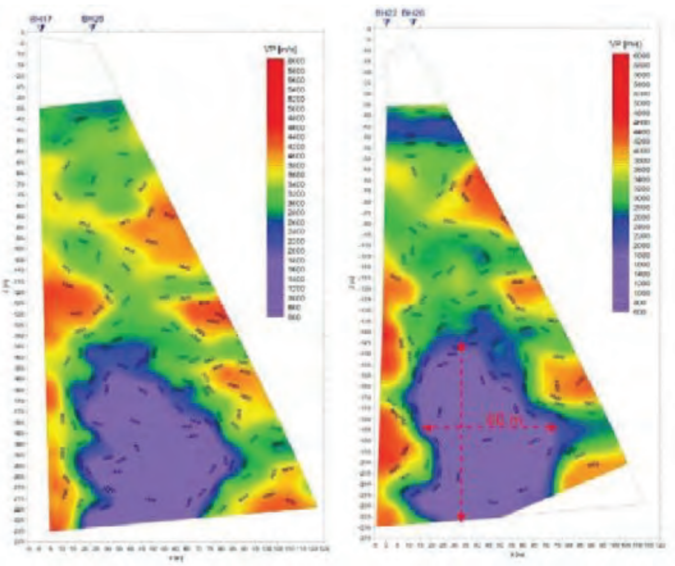


Figure 12 X–Hole Tomography results of cavity

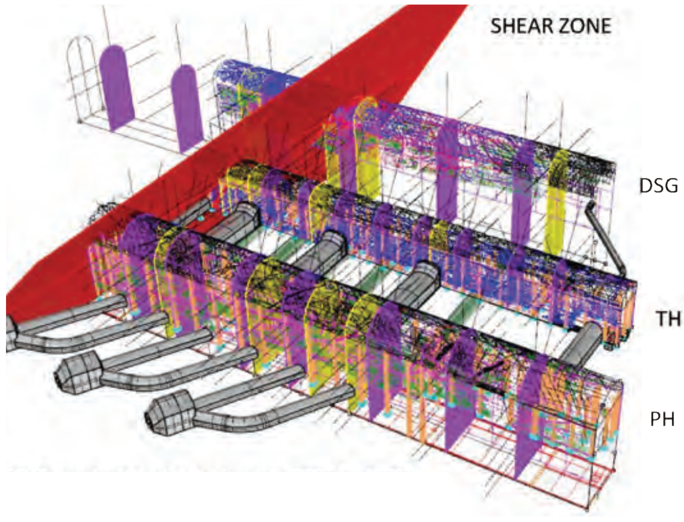


Figure 14 The 3D Numerical Model Analyzed in 2018 by NIRM

State of Major Principal Stresses in the DSG at the Verge of Failure 8

The Major Principal Stresses in the DSG cavern are oriented along the direction of Longitudinal Axis of the DSG Cavern but does not provide confinement at interface with Shear Zone in the Hanging Wall. In Situ Stresses being more than the Rock Mass Strength, it resulted the fractured and crushed rock mass present in joints to be in yielded state thus making rock blocks present in the Hanging Wall prone to displacements.

The 3D Analysis8 establishes that Major Principal Stresses from their In–Situ value of 5MPa, had marginalized after excavation, to 2 MPa i.e. equal to the UCS of the Rock Mass and the this Relaxed Zone is particularly concentrated extending up to about 100m, in a shape similar to the later on formed Cavity (Fig. 15 & Fig. 16). However, within the arc shaped reach immediately above the crown of DSG, where Rock Bolts had pre stressed the rock mass / Back Filled Concrete thus making an arch action prevailing, the Major Principal Stresses are developed of the order of 7 MPa. This proves that the intended arch action prevailed until the sudden rock fall on 3rd March 2016.

The phenomenon of the marginalization of the Major Principal Stress from In–Situ value of 5MPa to 2MPa prevailed up to a height of about 100m above the crown in DSG in a length of about 50m from RD 140m to RD 190m at the verge of the massive failure (Fig. 15 & Fig. 16).

The shape and size of the zone of the marginalized Major Principal Stress (Fig. 15 & Fig. 16) significantly matches with the shape and size of the huge cavity formed in the massive rockfall.

State of Minor Principal Stresses in the DSG at the Verge of Failure 8

The Minor Principal Stresses in the DSG cavern are oriented in transverse direction, that is along the perpendicular direction to the Longitudinal Axis of the DSG Cavern.

Because of their orientation, the Minor Principal Stresses would have provided the confining pressure on the rock mass in the crown of the DSG cavern and retained together its constituent rock blocks and would have made it act as one mass, which is so required, so as to produce arch action in the crown of DSG cavern.

The analysis8 establishes that at the verge of the massive rock mass failure, the minor principal stress, which are aligned transversally in the DSG cavern, had become tensile or of a very small insignificant value, in the DSG walls at crown's spring level & below. Absence of the confining pressure could not hold the constituent rock blocks together as one mass against gravitational force.

There were wide spread Tensile Transverse Stresses developed in DSG Walls at Springing Level of the Crown and below, when the benching had progressed to a depth of 35 to 40m in the DSG.

3D numerical Analysis Corroborates that Rock Pillars of the DSG were Inherently Weak Due to Presence of the shear zone. It shows wide spread yielding of rock along the traverse of the Traverse of The Shear Zone in the Associated Hanging Wall Reach

Principal Stresses	
Vertical Stess (σ_v) in MPa i) Measured Vertical Stress ii) Estimated Vertical Stress	**4.14 MPa** **5.17 MPa**
Maximum Horizontal principal Stress (σ_H) in MPa	4.02 MPa
Minimum Horizontal principal Stress (σ_h) in MPa	2.99 MPa
Maximum Horizontal principal Stress direction	N 17º
Ratio of σ_H/σ_v (measured)	0.97
Ratio of σ_h/σ_v (measured)	0.72
Ratio of σ_H/σ_v (measured)	0.78
Ratio of σ_h/σ_v (measured)	0.58
Longitudinal AXIS of Downstream Surge Gallery	**N 10º E**

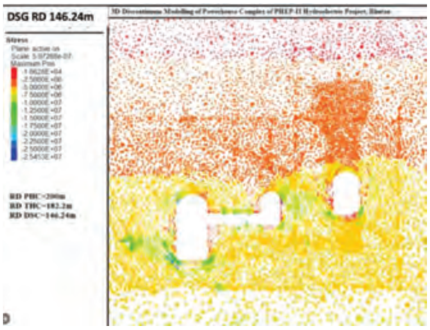


Figure 15: Marginalized Major Ppal Stresses above DSG

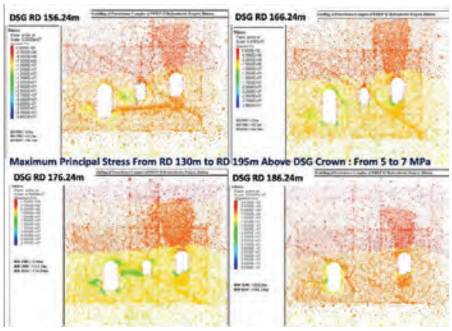


Figure 16: Marginalized Major Ppal Stresses above DSG in extended reaches

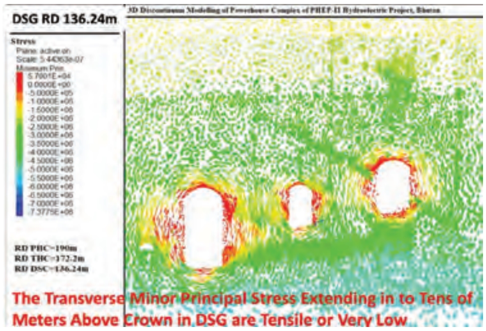


Figure 17: Presence of Tensile Minor Ppal Stresses above DSG

Learnings from the similarity in the Case of the Ravelling in Hanging Wall of a Stope in Canada

Ref. International Journal of rock mechanics & mining sciences available at @Sciencedirect.com– 30 June 2003,

Paper Titled: "STRESS, INSTABILITY AND DESIGN OF UNDERGROUND EXCAVATIONS" by C.D. Martina ,*, P.K. Kaiserb, R. ChristianssonC.

The phenomenon, mode and nature of the raveling failure discussed in the paper are exactly found replicated in the present case of DSG in its failed reach. The following are quoted from the Article9 mentioned above which discusses a case study of the "Ravelling Failure" which happened in the Hanging Wall of the Stope No. 3300 in a Canadian mine. The following is quoted from the Paper.

Figure 22: shows Plan view of open Stopes and stoping sequence (circled numbers). The Stope 3300 was stable until mining of Stope 3400 commenced. The transverse stopes averaged 35m in width, 45m in length and over 180 m in height. Experience at the mine indicated stopes of these dimensions were stable. However no. 3300 Stope, which had similar good quality. Rock mass conditions, experienced significant hanging wall problems.

The overall massive Sulphide ore Zone at the depth, was 300m long along the strike and 45m in width from Foot Wall to Hanging Wall and dipped between 65 to 85 (Fig. 23).

The Hanging Wall rock mass consisted of blocky norites with one subvertical joint set at approximately 1 m spacing and a second set of horizontal continuous joints also at approximately 1 m spacing.

These fracture sets formed potential wedges in the hanging wall and backs of stopes. However, simple wedges do not usually lead to progressive ravelling, particularly when the Geological

Strength Index ranges from 60 to 85 (Compressive Strength 25 to 100 Mpa, Tensile Strength –0.4 to –2.65 MPa. & Em 27 to 80 Gpa.)

Mining of Stopes 2900 and 3300 were carried out without any incident. The Stope 3300 remained open and stable for approximately one year.

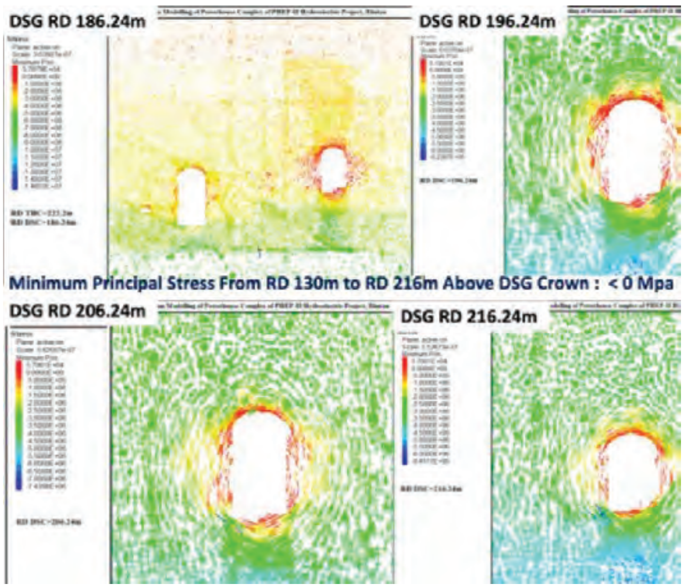


Figure 18 Tensile Minor Ppal Stresses

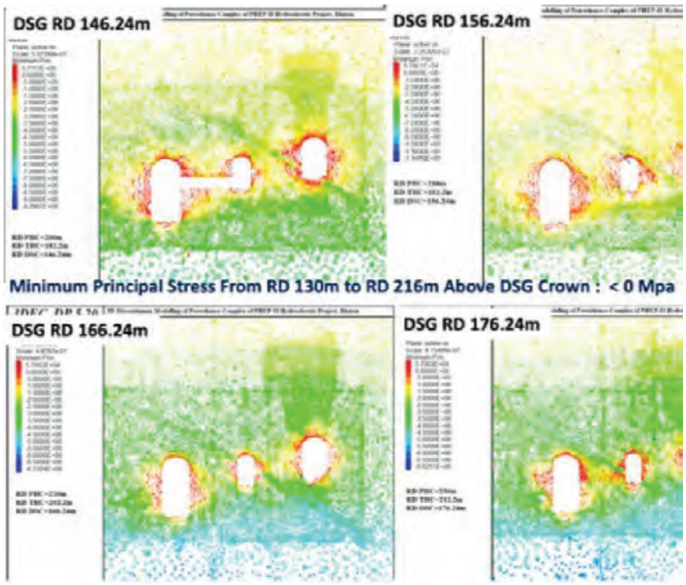


Figure 19 Tensile Minor Ppal Stresses

Figure 20: Shows Sectional Plan of Minor Principal Stresses at SPL El. 620m There were wide spread Tensile Transverse Stresses developed in DSG Walls at Springing Level of the Crown and below, when the benching had progressed to a depth of 35 to 40m in the DSG.

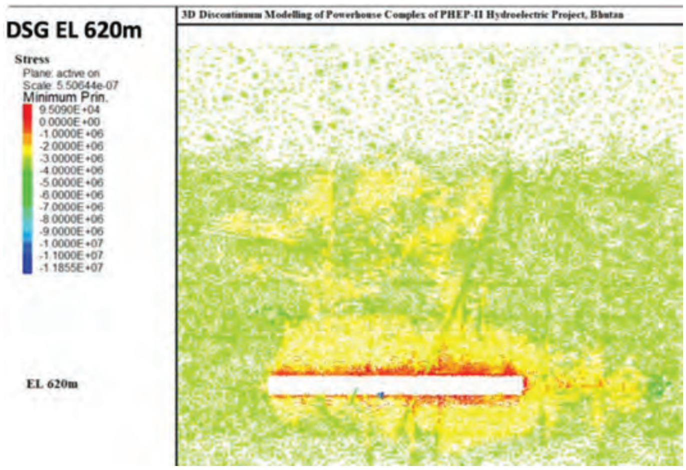


Figure 20 Tensile Minor Ppal Stresses in Sectional Plan of DSG

The mining of Stope 3400 was coincident with ravelling of the Stope 3300 Hanging Wall.

Figure 24 shows that because of the Stope geometry, a zone of relaxation, extends several tens of meters into the Hanging Wall of the Stope 3300, after Stope 3400 was excavated.

The shaded portion in Hanging Wall marks the Region of Loss of Confinement / Zone of Relaxation in the Hanging Wall of the Stope 3300.

Sigma 3 is ranging from –1 to 0 In the Zone of Relaxation.

- The fracture sets formed potential wedges in the Hanging Wall and backs of stopes.
- The Ravelling occurs where Confining Stresses are less than Zero.
- A Zone of Relaxation extends several tens of meters into the Hanging Wall because of Geometry of the stope/ Hanging Wall.
- There is loss of ductile behaviour due to occurrence of loss of confinement pressure. The higher the confining pressure, the greater is ductility observed and vice–a–versa. Increasing the strain rate, makes rock appear more brittle.
- It is the variability in rock strength rather than stress, that is responsible for the frequently observed variability in depth of failure and failure mode

Striking Similarities Between Case of Ravelling in DSG to the Case of Canadian Mine

There are striking similarities found in the following conditions present in the DSG in its failed reach to the conditions discussed in the above cited article on ravelling in the Canadian mine.

- There existed a significant Problematic Hanging Wall2 10
  in the DSG cavern from about RD 140m onwards to RD 210m.

DSG RD 146m

Strength to Stress ratio is Zero in the U/S Wall of DSG in section at RD 145m up to about 15m in to the wall, which means Yielding of rock. The rock classification in the reach is Class–V

Figure 21a

DSG RD 156m

Strength to Stress ratio is Zero in the U/S Wall of DSG in section at RD 155m up to about 10m in to the wall, which mean Yielding of rock. The rock classification in the reach is Class–IV

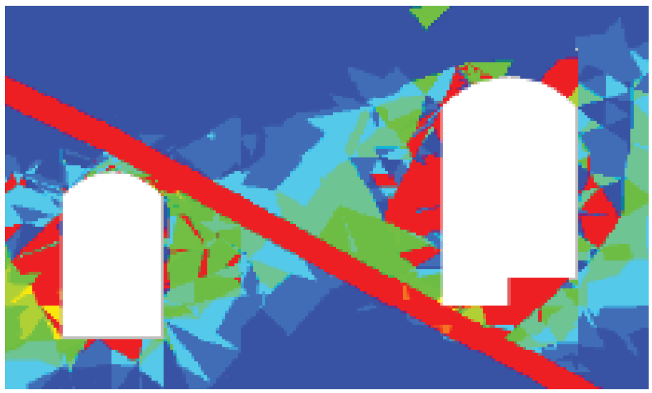


Figure 21b

- The rock mass is the reach in the Hanging Wall is blocky comprising numerous joint sets. These fracture sets form potential wedges3.
- The Confining Stresses in the Hanging Wall above the crown in DSG in the reach from about RD 140m to about R 210m, along the traverse of the Shear

Zone are Less than Zero8. The rock mass thus showed distinct brittle behaviour resulting in an instantaneous rock fall.

- There is a great variability in the parent rock blocks and the rock mass which decides the depth of failure and Mode of Failure.
- The geometry of the inclined discontinuities present in the rock mass extends the relaxation zone to several of meters above the crown8 and thus guide the Gravity Induced & Structurally Controlled

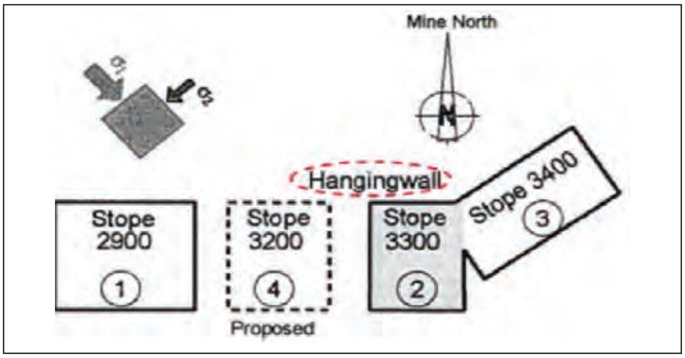


Figure. 22 Plan View of Open Stopes

Fall of the Blocks of the rocks in the Hanging Wall.

As is seen in the 3D Analysis8 of the DSG done in 2018 mentioned earlier above, having all the above conditions mentioned in the above quoted Article9 on, actually present in the Hanging Wall in DSG from about RD140m up to about RD 210m, formation of the huge cavity got inevitable.

Similar to the ravelling in the Hanging Wall in the Canadian Mine quoted in the earlier above–mentioned article, the raveling failure happened three years after in Hanging Wall reach extending from RD 140m to RD 210m in the DSG crown forming the Cavity of size 91m height x 70m length x 45m width (Fig. 25)

Correct Design for The Large Cavern in Highly Fractured Rock Mass Missing

The Rock Pillar between the DSG and TH caverns consisted of only 40m thickness which stood intersected by the 3.5m thick Shear Zone diagonally through its length between RD 130m to RD 180m at a steep inclination of 55. The 3D Analysis has established that rock pillar in this Hanging Wall without the provision of Wall Beam and Cable Anchors became extensively yielded up to 15m of its thickness of 40m. The provided design of 8m/10m long Rockbolts at 1.5m x 1.5m spacing in the walls proved insufficient to prevent the large scale yielding in the Hanging Wall of the DSG.

The correct design for improving the stability of the crown and walls of the DSG would be as shown in Fig. 26 below.

Displacement of Key Stones at Springing Level 8 of DSG Crown

The 3D Analysis8 establishes that displacement of 65mm to 100mm occurred in the DSG Walls below Springing Level of the Crown (Fig. 27). Instrumentation Observations too indicate that Distress in the Wall supporting the Crown, in the reach of the traverse of Shear Zone in DSG i.e. RD 135m to RD 195m increased as excavation in Benching progressed. The Settlement in Wall Support increased to 96mm on 02.03.2016 when Benching had reached El. 590m (excavated depth about 35m).

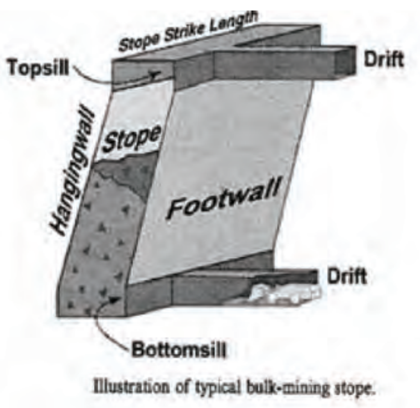
Findings of The Norwegian Geotechnical Institute 10

The Norwegian Geotechnical Institute has mentioned in its findings after study of the DSG Failure Site done in 2016–17 that:

- The steel ribs do not and will not provide any acceptable rock support. (The ribs formed only a passive support. The active support was successfully provided by Rock Bolt System for 3 years)
- The ribs do not show any sign of deformation and the ribs failed at the joints. The steel ribs do not show any sign of bearing the load from rock mass, where as the rock pillars are more loaded.
- The rock mass in the footwall of the shear zone first started to move down because of the insufficient support and stress relaxation.
- Later on, as the key block in the footwall moved, the rock blocks at the hanging wall moved downward flowingly
- The orientation of the maximum horizontal stress is parallel with axis of the DSG which does not help to prevent the rock fall through confining on the rock blocks at the roof.
- The shape of the cavity is controlled by the discontinuities
- It is clear that the major mechanism of the rock fall was **structurally controlled block fall.**

Conclusion

A wide spread yielding and increased settlement & displacement 8 in



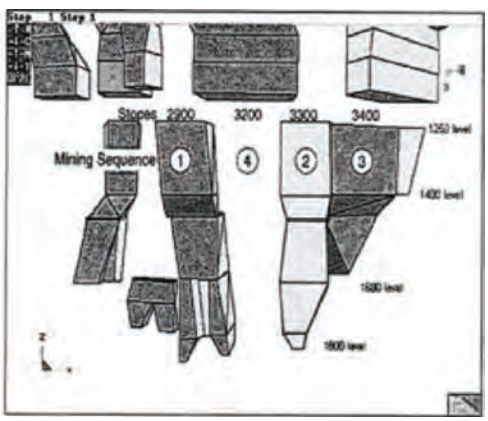


Figure 23: The presence of
Hanging Wall dipping 65 to 85 in Stope 3300

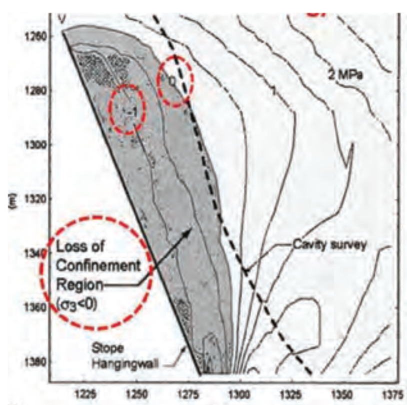


Fig. 24 24 Loss of Confinement extending in Hanging Wall

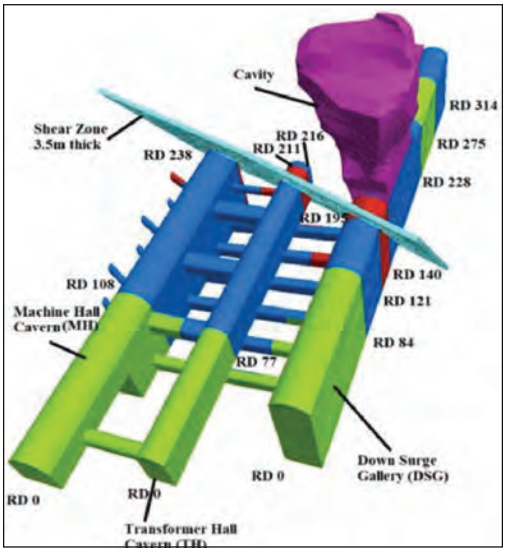
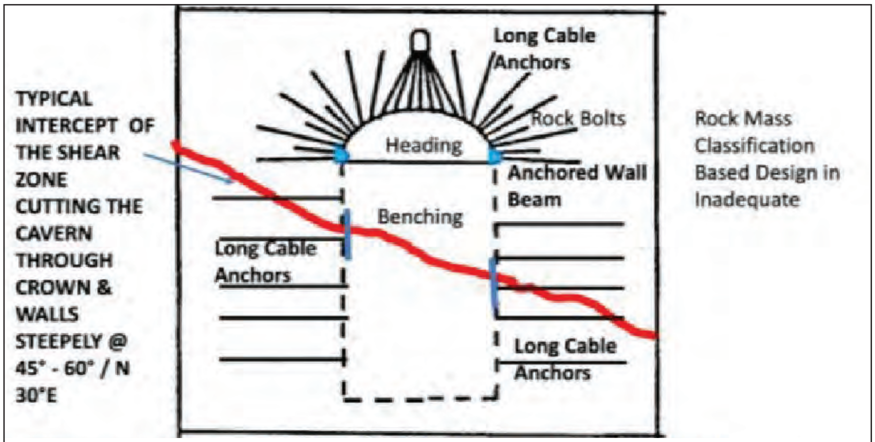


Fig. 25 The 91m x 70m x 45m Cavity above DSG crown formed through fractured rock mass



Designers did not design cable Anchors and Wall Beams, to strengthen the crown at heading stage before benching down, nor after knowing that rock pillers are sheared & pre–cracked.

Fig. 26 The methodology needed providing Long Cable Anchors & Wall Beams

the footwall at SPL in the overloaded rock pillars would have finally resulted in failure of wall support to the crown in bearing10. The rock mass in the Crown having already transformed to a state of assemblage of loosely packed blocks in tensile state with no confining pressures around, imploded ravelling9 suddenly along structural discontinuities, with brittleness resulting from increase in rate of yielding associated to lack of confining pressure on blocks of rock mass in the Hanging Wall.

References :

- Geological Investigation Report of Punatsangchhu–II H.E. Project submitted by the Geology Consultant, Geological Survey of India.
- Construction Stage Geological Notes made by the PHEP–II Resident Geologist and submitted to the Designers/ Consultants during different stages of excavation in the Project.
- Construction Drawings prepared and submitted to the Project Authority for carrying out construction by the Designers, Central Water Commission.
- Construction Stage Geological Notes made by the Resident Geologist of the Civil Contractor of PHEP–II, the "Jaiprakash Associate Limited" and submitted to the Project Authority during different stages of excavation of the DSG in the Project.
- Conference Paper by Barton, Nick. (2015), titled : "Forty years with the Q–system – Lessons and Developments" https://www.researchgate.net/publication/322317410_Forty_years_with_the_Q–system_–_Lessons_and_Developments
- Numerical Analysis carried out in 2014 by the Civil Contractor of PHEP–II, the "Jaiprakash Associate Limited" and submitted to the Designers CWC by the Project Authority, before start of the Benching Stage of excavation of DSG in the Project.
- Paper by Cheng Y and Liu , Taiwan, – 6th Cong. ISRM, titled : "Montreal Design of large underground caverns – a case history based on the Mingtan Pumped Storage Project in Taiwan" https://static.rocscience.cloud/assets/resources/learning/hoek/Practical–Rock–Engineering–Chapter–13–Design–of–Large–Underground–Caverns–Remediated.pdf
- 3D Discontinuum Modelling of Powerhouse Complex of Punatsangchhu–II Hydroelectric Project, Bhutan (Case–I & Case–II) by National Institute of Rock Mechanics.
- Paper by C.D. Martina ,*, P.K. Kaiserb, R. ChristianssonC in International Journal of Rock Mechanics & Mining Sciences titled : "Stress, instability and design of underground excavations" . Available online at www.sciencedirect.com https://era.library.ualberta.ca/items/5a0aad85–bffa–4686–bae3– d589a64361dc/view/6b99475a–7814–4079–93b0–a22b373f79d2/Stress,–20instability–20and–20design–20of–20underground–20excavations.pdf
- Report by Norwegian Geotechnical Institute on their findings on the occurrence of the huge rock mass fall in the DSG cavern of PHEP–II

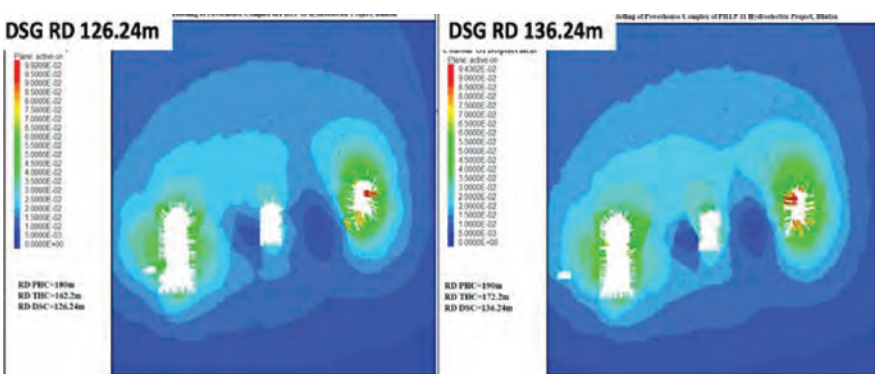


Fig. 27 The 3D Numerical Analysis showing excessive movement of Key stones in walls of the DSG

INNOVATING WATER DESIGN IN LUXURY VILLAS – BALANCING CONVENIENCE AND CONSERVATION

Nandita Kanwar
Director Business Strategy & Growth, Hydromo

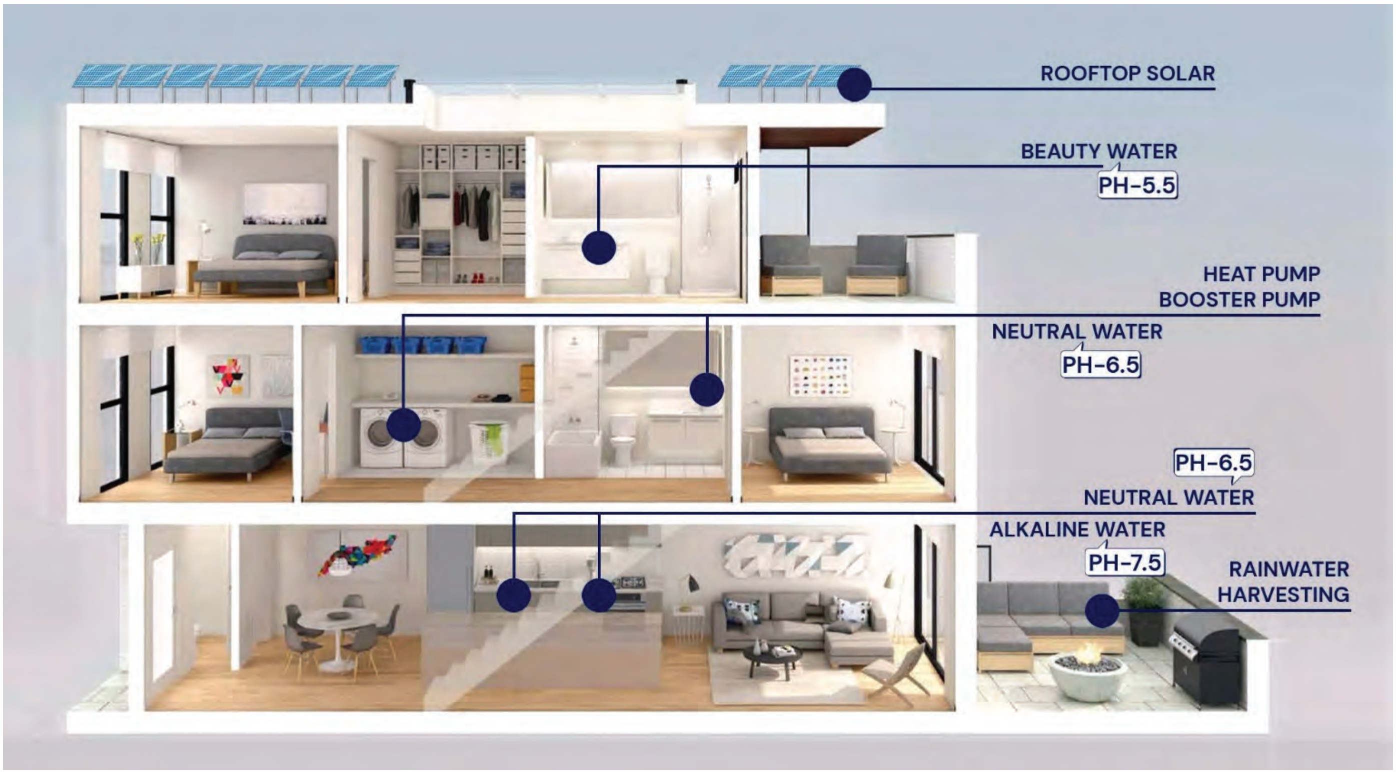
***Nandita** has over 20+ years' global experience in areas of market research, marketing & digital marketing and is passionate about driving*

result, sales-oriented marketing strategies including digital marketing execution for B2B and B2C for global and domestic brands. At Hydromo, she leads the growth & Strategy. She is also responsible for understanding market gaps and implementing new product lines that add value & revenue streams to the chain.

In the realm of luxury villa design, the incorporation of advanced water systems is becoming increasingly essential. In the wake of the COVID–19 pandemic, people have embraced the concept of staying indoors and creating comfortable sanctuaries within their homes. With sustainability gaining momentum, it is essential to highlight the significance of water management design in luxury villas.

Water, an invaluable resource, is becoming scarcer each day. On average, a typical household uses approximately 300 gallons (1,136 liters) of water per day. India is the largest user of groundwater in the world using an estimated 230 cubic kilometers of groundwater per year – over a quarter of the global total.

At Villas, we observe water being consumed for drinking, utilities, pools, gardening & car washing &



aesthetics – like fountains, landscaping and further there is waste water generated equally. Not letting this water go to waste and putting even the waste water to use by recycling and reusing is what water design in villas is all about.

The Importance of Designing Water Infrastructure at Luxury Villas with sophisticated technologies, AI and human expertise.

When it comes to luxury villas, designing efficient water infrastructure is paramount. Incorporating sustainable practices from the inception of a villa's construction can yield substantial long–term benefits. Integrating intelligent plumbing systems, automations, rainwater harvesting, and greywater recycling along with sophisticated AI technologies can help maximize water significantly. Predictability modeling and alerts will aid at various interventions.

An instance could be, Whether turning pumps on or off, determining chemical dosages, or deciding when to maintain assets, AI enables intelligent recommendations driven by ML and hence cuts manual intervention and enhances quality.

Furthermore, landscape design, including drought–resistant plants and efficient irrigation systems, can minimize outdoor water usage.

However, the usage of untreated hard water, which contains high level ppm could harm your sophisticated fittings like ultra modern shower panels, heat pumps, washing machines, dishwashers, glassware and even plumbing which affects their functioning and also durability.

TDS Level (PPM)	Water Use
Below 300	Drinking water
300–600	Drinking and cooking water, aquariums, hydroponics
600–900	Drinking, cooking, and irrigation for sensitive plants
900–1,200	Irrigation for most plants, industrial uses (cooling, boilers)
1,200–2,000	Irrigation for salt–tolerant crops, non–potable uses
Above 2,000	Non–potable uses, industrial processes, specialized applications

Water touch points

Treated water plays a crucial role in luxury villas, particularly at all water touch points, as it ensures the provision of clean and safe water for drinking , maintenance & aesthetics.

Treated water of pH:

Water touch points, such as indoor and outdoor swimming pools, require treated water to maintain proper hygiene and prevent the growth of harmful bacteria. Treated water also contributes to a pleasant bathing experience in indoor and outdoor pools, where water quality and clarity are crucial for comfort and enjoyment.

pH Level	Water Use
0–2	Highly acidic; not suitable for most uses
2–4	Strongly acidic; not suitable for most uses
4–6	Moderately acidic; not suitable for drinking, but can be used for irrigation and industrial purposes
6–7	Slightly acidic to neutral; suitable for drinking, cooking, and most common uses
7–8	Neutral to slightly alkaline; suitable for drinking, cooking, and common uses
8–10	Moderately alkaline; not suitable for drinking, but can be used for irrigation and some industrial processes
10–12	Strongly alkaline; not suitable for most uses
Above 12	Highly alkaline; not suitable for most uses

Controlling Water Wastage

In Filtration:

To address water wastage in filtration systems, implementing reverse osmosis systems with 70% recovery rates can reduce wastewater generation significantly. One of the prominent areas where water wastage occurs is through filtration systems. Although necessary for ensuring clean water, these systems can inadvertently contribute to significant water loss. To address this issue, designers and homeowners must prioritize innovative solutions that balance conservation, convenience, and effective management.

Maximizing Efficiency

Luxury villas often feature ornamental water features like fountains, waterfalls, and decorative pools. Using recycled water in these features helps prevent excess water wastage. Maximizing the efficiency of water touch points in luxury villas involves adopting advanced water management technologies and sustainable practices.

Installing smart sensors and automated controls can help optimize water usage at various touch points. These technologies can monitor water levels, detect leaks or abnormalities, and automatically adjust water flow or shut off when not in use. This ensures efficient water consumption by reducing wastage and preventing unnecessary water usage.

Implementing water recycling systems allows for the treatment and reuse of water from certain touch points. For example, wastewater from dishwashers, washing machines, or showers can be treated and reused for irrigation purposes or for non–potable water needs, such as toilet flushing. This approach helps conserve water resources and reduces the overall demand for treated water.

IGBC Rating

The Indian Green Building Council (IGBC) rates buildings for their water management through a certification system known as the "IGBC Green Homes" rating. This rating system evaluates various aspects of water conservation and management practices in buildings to promote sustainable water usage.

The IGBC assesses the building's efforts to reduce water consumption. This includes the installation of water–efficient fixtures. Buildings that implement systems for treating and reusing graywater (e.g., from sinks, showers, and laundry) or blackwater (e.g., from toilets) are rated positively. Additionally, rainwater harvesting systems that collect and store rainwater for non–potable uses, such as flushing toilets or irrigation, contribute to higher ratings.

The IGBC also considers water quality aspects. The rating system encourages buildings to maintain appropriate water quality through the implementation of filtration and purification systems to ensure the provision of safe and clean water.

As the world adapts to a post–COVID era, the importance of sustainable living and water conservation has come to the forefront. Luxury villas, known for their opulence and comfort, must also embrace responsible water management design. By implementing innovative solutions that control water wastage in filtration systems, prioritizing efficient water infrastructure, and utilizing advanced technologies, luxury villas can lead the way in conserving water resources. Let us remember that water is a finite resource, and every drop saved contributes to a greener and more sustainable future.

About Contacts Pricing Partners

INDIA'S WATER MAGAZINE

Your knowledge and information partner

ABOUT US

WaterAge monthly magazine provide an established audience of corporate deal makers with the most up-to-date information on technologies, trends, and the updates of water & wastewater industry.

Try it now

BANNER ADS ON

WEBSITE

Be seen where it really matter!!
Create the buzz in water market.

Advertise with us on our website:

www.waterage.in

and reach out to 1500 quality readers daily!

Find us on:

SHUDH JAL FOUNDATION
JAL AAJ AUR KAL

605, Bhikaji Cama Bhawan, Bhikaji Cama Place, New Delhi – 110 066
M.: +91 98759 06502, E-mail: enquiry@waterage.in, Web.: www.waterage.in

CYANIDE, THIOCYANATE, AND PHENOL REMOVAL FROM WASTEWATER IN STEEL PLANT **BY BACTASERVE BACTERIAL CULTURE**

Ashutosh Vadanagekar
Director, Amalgam Biotech

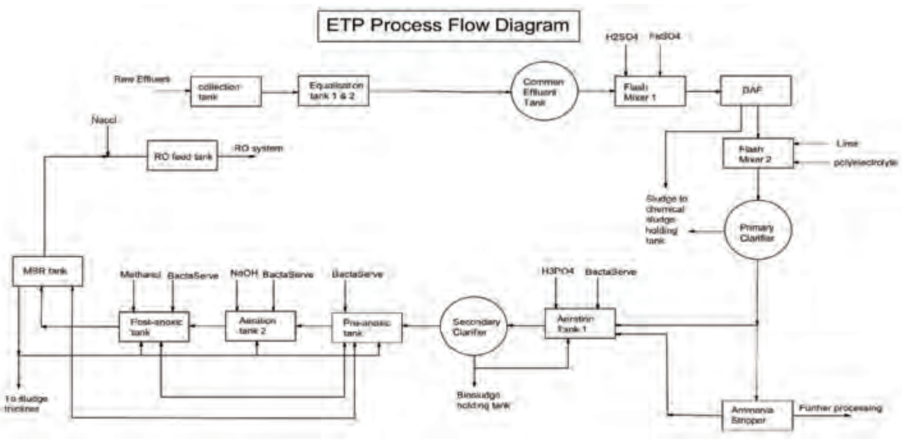
Background

In the steel industry, toxic materials like Cyanide, Thiocyanate, and Phenol are produced in industrial processes during the production of coke. This steel plant is located in the eastern part of India. It is one of the largest manufacturers of Plate Mill plates, HR plates and coils, ERW pipes, SW pipes, CR sheets, and coils, Galvanised sheets (GP & GC), and silicon steel sheets.

Plant Specifications

The capacity of this ETP is 3600 m3/day, having two aeration tanks in series along with pre–anoxic and post–anoxic tanks followed by a membrane bioreactor. ETP–treated effluent is then fed to RO for effluent recycling.

Process Flow Diagram



Challenges

The coke manufacturing process generates cyanide and thiocyanate which comes in the effluent. Cyanide at 6.5 ppm is a toxic molecule that requires adequate safety measures for 100% degradation. Thiocyanate at 350 ppm is relatively more stable than cyanide, requiring a higher degree of biodegradation efficiency. Phenol at 250 ppm also is a big challenge. NH3–N at 300 ppm further increases to 400 ppm after bacterial action on the thiocyanate molecule. Stage–2 NH3–N and subsequent denitrification require 2 stages of bacterial anoxic denitrification.

Ashutosh Vadanagekar is the Technical Director of Amalgam Biotech, which manufactures “Bacta Serve Bio–culture” used to generate MLSS (Bacteria) in Waste Water Treatment Plants. He has 12 years of professional experience & 13 years of running his own business. An Environmental Engineer & MBA with specialization in Marketing & International Business. He has 20 years of hands–on experience in Process Design in the field of Water, Wastewater, ZLD & Evaporation Technologies.

Suraj Kale is a service engineer at Amalgam Biotech, Pune. He has field 1 year of experience in ETP/STP commissioning and troubleshooting and 2 years of experience in ETP operation and maintenance. He has completed B.Tech in chemical engineering from MITAOE, Pune.

Table 1: Inlet parameters– Routine

Sr No.	Parameter	Values (mg/Lit.)
1	pH	9 – 9.5
2	Colour (Hazen)	< 20
3	Temperature (ºC)	35 – 38
4	Total suspended solids (TSS)	20 – 30
5	Total dissolved solids (TDS)	4200 – 4500
6	Conductivity (uS/cm)	6700
7	Oil & Grease	< 5
8	Iron	3 – 5
9	Total chromium	< 0.05
10	Silica	13.6 – 14.14
11	Fluorides	< 8

Table 2: Inlet parameters– Critical

Sr No.	Parameter	Values (mg/Lit.)
1	Chemical oxygen demand (COD)	1300 – 1800
2	Biological oxygen demand (BOD)	500 – 800
3	Ammoniacal nitrogen (NH3–N)	250 – 300
4	Nitrate (NO3)	25 – 30
5	Total Kjeldahl nitrogen (TKN) (As provided)	150 – 200
6	Cyanide (CN)	2.5 – 6.5
7	Thiocyanate (SCN)	300 – 350
8	Phenol (C6H5OH)	150 – 250

Special Technical Solution

As a solution, we dosed BactaServe Aerobic along with special strains of paracoccus and pseudomonas species for the removal of cyanide and thiocyanate. Pseudomonas species worked exceptionally well for phenol reduction from 250 ppm to 2.5 ppm.

Table 3: Bacterial cultures required over 45 days period

Sr No	Types of bacterial culture required	Where to add	Targeted pollutants	Strains added
1	BactaServe– Aerobic	Aeration tank 1	Thiocyanate	Paracoccus species & other mixed culture consortia.
			Phenols	Pseudomonas species.
			COD, BOD	Bacillus species like megatherium, amyloliquefican s & others.
2	BactaServe– Aerobic	Aeration tank 2	NH_3–N, Nitrification, Nitrate N_2	Nitrobacter & Nitrosomonas species.
3	BactaServe– Nutrient Removal	Anoxic Tank	Denitrification	Thiobacillus Species.

For the degradation to occur, we have provided them with a Bioculture dosing protocol as below:

Table 4: Dosing protocol

Dosage BactaServe – Aerobic & nutrient removal						
Sr No.	Days		A.T –1 (kg/ Day)	A.T –2 (kg/ Day)		Anoxic Tank (kg/Day)
1	Day 1 – Day 5	BactaServe – Aerobic.	10	5	BactaServe – Nutrient Removal	7
2	Day 6 – Day 10		8	3		6
3	Day 11 – Day 20		5	2.5		5
4	Day 21 – Day 30		4	1.5		3.5
5	Day 31 – Day 45		2	1		2

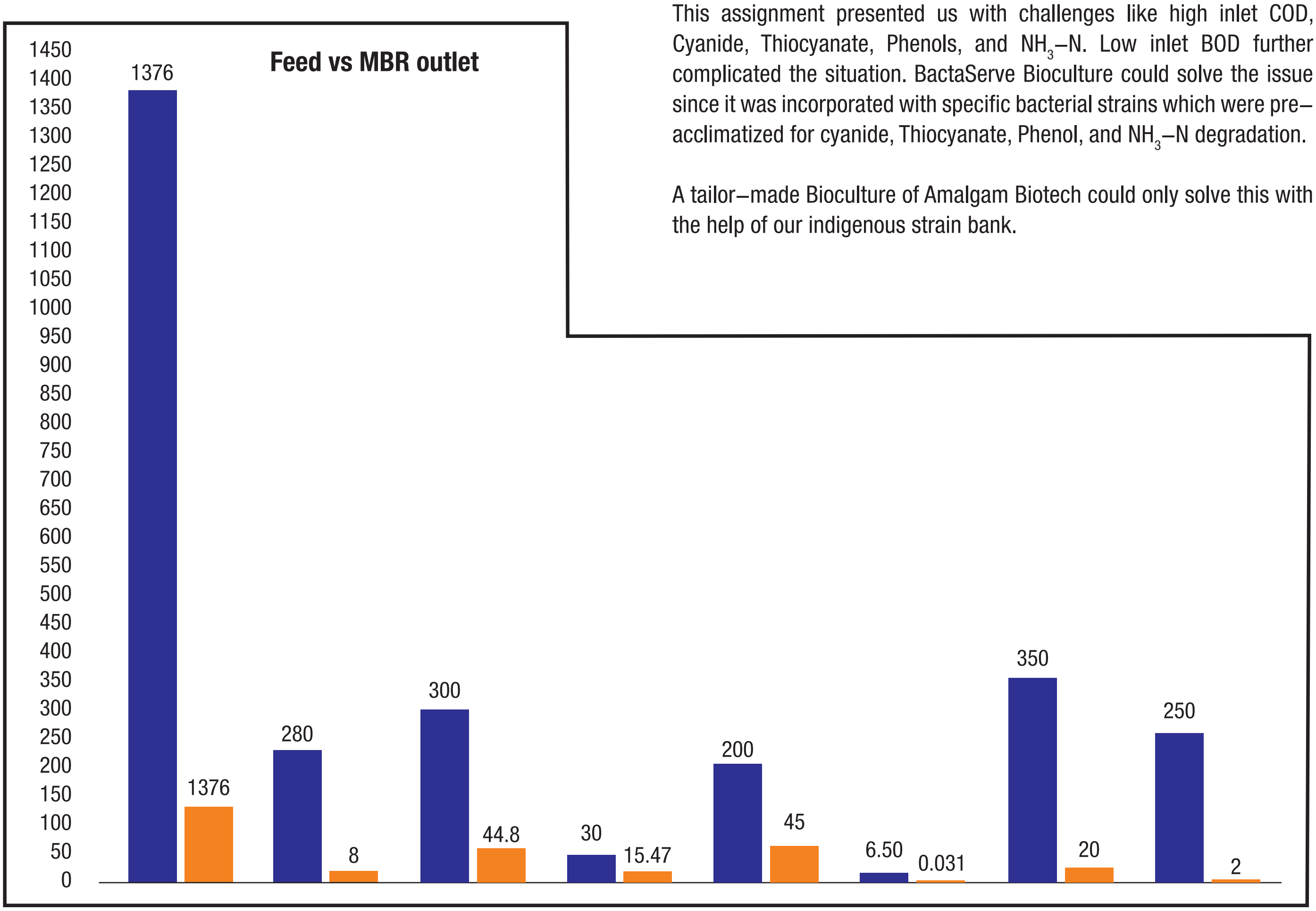
BactaServe nutrient removal containing nitrifiers ensures the conversion of 400 ppm NH_3– N to nitrates. The De–nitrifiers in an anoxic tank convert the NO_3–N to N_2 gas.

Photographic presentation of site performance

Table 5: Results

Sr No.	Parameter	Inlet Values (mg/Lit.)	MBR Outlet (mg/Lit.)
1	Chemical oxygen demand (COD)	1376	104
2	Biological oxygen demand (BOD)	280	8
3	Ammoniacal nitrogen (NH_3–N)	300	44.8
4	Nitrate (NO_3)	30	15.47
5	Total Kjeldahl nitrogen (TKN)	200	60
6	Cyanide (CN)	6.5	0.031
7	Thiocyanate (SCN)	350	20
8	Phenol (C_6H_5OH)	250	2

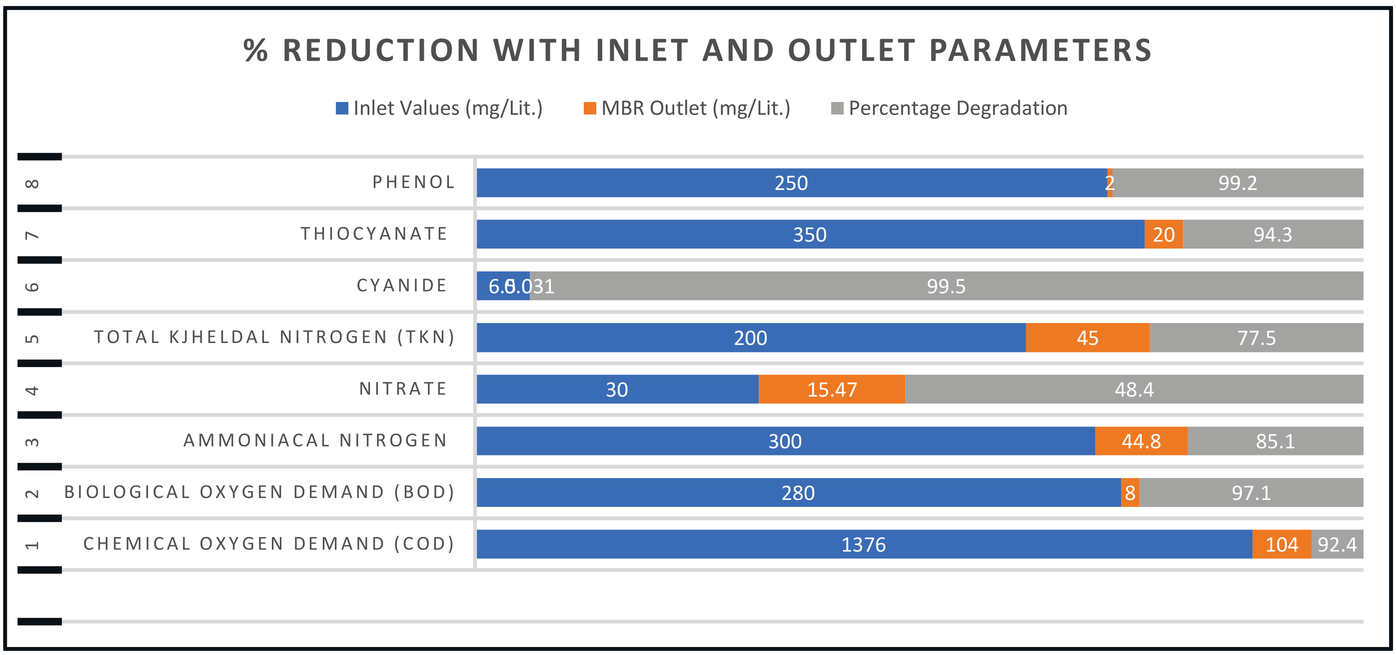
Graphical Presentation of Parameters



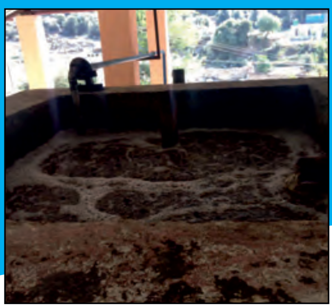
Executive Summary

This assignment presented us with challenges like high inlet COD, Cyanide, Thiocyanate, Phenols, and NH_3–N. Low inlet BOD further complicated the situation. BactaServe Bioculture could solve the issue since it was incorporated with specific bacterial strains which were pre–acclimatized for cyanide, Thiocyanate, Phenol, and NH_3–N degradation.

A tailor–made Bioculture of Amalgam Biotech could only solve this with the help of our indigenous strain bank.



JAI MAA ASSOCIATES
ENGINEERS & CONTRACTORS



JAI MAA ASSOCIATES Engineers & Contractors providing services to Military Engineering Services for last two decades

Pre-Engineered Building & Infrastructure	Electro-mechanical utility services
Water & Wastewater Treatment Projects	Low Tension Electric Works
Sewage Disposal and Water Distribution Network	Incinerators

JAI MAA ASSOCIATES
ENGINEERS & CONTRACTORS

JAI MAA ASSOCIATES

Shop No. 33 Gopinath Bazar, Delhi Cantt - 110 010
M.: +91 98111 88819, Fax: +91 11 2568 2346, E.: jaimaaassociatesdelhi@gmail.com, jaimaa98@gmail.com, info@jaimaaassociates.in

LEACHATE TREATMENT – AN IMPORTANT ASPECT MISSED OUT OR LESS ATTENDED FOR LEGACY WASTE, FRESH WASTE TREATMENT PLANTS & BIO REMEDIATION DUMPS IN VARIOUS CITIES ACROSS INDIA

Vinayak Kadam, General Manager – Operations, HWT

In today's world when wastewater is mainly sewage and effluent treatment is prioritized as a reusable water source, we tend to overlook one of the most difficult to treat effluent. Having an impact on the groundwater/surface water contamination, when on the other hand treatment of leachate can provide us most valuable Green Energy as one of the byproducts, The quantum generated is not as much, as compared to other effluents like industrial or sewage wastewater.

Leachate is a highly concentrated solution hence very difficult to optimize the process, even though fully organic matter is very harmful to mother earth especially in countries like ours so it's necessary to attain it.

Usually, the generation of leachate is a slow process, it starts with a hydrolysis process in solid waste dumps or during solid waste processing if not treated it will be absorbed in the soil beneath in legacy dumps or waste storage areas after the strict guidelines issued by NGT there are efforts to collect It scientifically and treat the same to dispose of as per Pollution control norms in India.

There are organizations now working in scientific waste management mainly (waste to energy plants) for fresh waste and legacy waste in which leachate treatment plants are made mandatory.

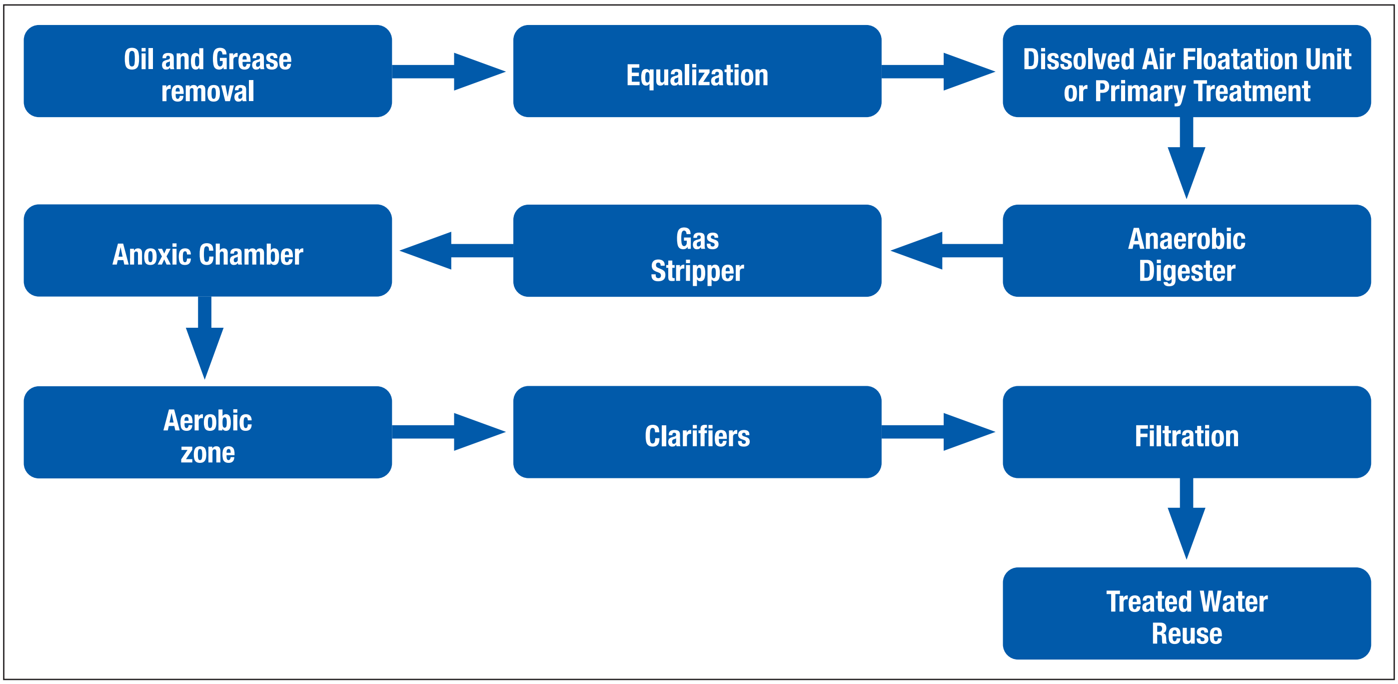
The best way to treat is by conventional biological treatment and if needed we can add physical membrane filtration.

Characteristics of leachate usually observed are mentioned below:

The below parameters change drastically based on: weather conditions, age of legacy dumps, and volume

1	TDS	PPM	50000–75000
2	COD	PPM	20000–70000
3	BOD	PPM	7500–25000
4	TSS	PPM	2000–3000
5	Oil and Grease	PPM	1500–5000
6	pH		4.5 – 7.5
7	TKN	PPM	400
8	Ammoniacal Nitrogen	PPM	1000–2000
9	Nitrogen	PPM	3000

Vinayak Kadam is an experienced General Manager of Projects and Operations with a demonstrated history of working in the municipal solid waste management Water and Wastewater, oil & energy industry.



The common and as–on–date successful treatment Process Flow Sheet

- The Products are : Bio Gas for use
- Treated Water : For Secondary use
- Compost : As an organic fertilizer

All this starts with a scientific collection system to be in place so that the leachate is collected in a collection pit and then further transferred to the treatment plant

Dissolved Air Flotation units or Primary Treatment

To Reduce the TSS and this process will bring down the COD Levels Of 20 to 25% reduction

Anaerobic Digester

- **The terminology used in Digester:**
  - **Chemical Oxygen Demand (COD)**
    Oxygen is required for the complete oxidation of biologically degradable and non–biodegradable organic matter. The organic matter in the reduced state such as Cl, CN, and NO also gets oxidized.
  - **Biological Oxygen Demand (BOD)**
    BOD is the oxygen quantity demanded by aerobic micro–organisms (bacteria) to stabilize the organic matter. Since BOD is directly proportional to the organic matter concentration.
  - **Total Solids**
    The amount and nature of dissolved and dissolved matter present in liquid very greatly. In potable waters, most of the matter is in dissolved form and consists mainly of inorganic salts and small amounts of organic matter. The amount of dissolved colloidal and suspended matter increases with pollution. Sludge represents extreme cases of pollution in which most of the solid matter is dissolved.
  - **Anaerobic Digester**
    Organic materials are decomposed biologically by various species of bacteria. Bacterial decomposition can occur without air in an anaerobic digester. These bacteria are Acetogenic bacteria and methanogen bacteria.
  - **Acetogenic Bacteria**
    Acetogenic bacteria are described as non–methanogenic or simply they are called 'acid formers'. Among the non–methanogenic bacteria that have been isolated from anaerobic digesters are Clostridium, lactobacillus, etc.
  - **Methanogenic Bacteria**
    Methanogenic bacteria are simply called methane formers. They are strictly called anaerobes. Methanogenic bacteria are H2–utilizing bacteria (methnospirillum hungates) and acid–utilizing bacteria.
  - **Biogas**
    Biogas produced from an Anaerobic digester consists of CO2 (38 to 48 %), CH4 (50 to 60 %), H2 S (1 to 2 %). The biogas has a high calorific value – 4500 Kcal / m. This can be used for various purposes it can be directly sent to the boiler as fuel for steam generation. Also, Biogas is used for gas engines

after removing H2S from biogas or else can be further used in vehicles after further purification.

- **Description Of Anaerobic Digester**

  Anaerobic Digester consists of a continuously stirred tank reactor where continuous mixing of effluent and biomass takes place with the help of agitators. The essential feature of that the washout of the active anaerobic bacterial biomass is recirculated.

  The basic idea underlying the anaerobic contact process is that;
  - Provide contact between the active biomass and feed.
  - Utilize the digester volume effectively.
  - Prevent stratification and temperature gradient
  - Minimize the formation of the scum layer and the deposition of sludge solids.

- **Basic Reactions in Digester System**

  Anaerobic digestion is performed by two groups of bacteria.
  - Acid–producing bacteria: –
    Acid–forming bacteria – butyric & propionic acid &
    Acidogenic bacteria – acetic acid & hydrogen
  - Methane–producing Bacteria: –
    Acetoacetic bacteria (Acidophilic) & Methane bacteria.

- **Basically, three stages are involved in the process of anaerobic digestion**
  - Hydrolysis:
    It is a process of suspended organics and soluble organics of higher molecular weight to a simple organic molecule
  - Acidogenesis:
    Degradation of small organic molecules to various volatile fatty acids ultimately to acetic acid. The process of conversion of a small organic molecule into acids is carried out by a group of anaerobic bacteria known as acid formers.
  - Methanogenesis:
    Production of methane, primarily from acetic acid produced at the end of the Acidogenesis process is converted into carbon dioxide and methane gases. The process of conversion of acid into carbon dioxide and methane gases is carried out by a group of anaerobic bacteria known as methane formers.

    Note: The Digestion process can reduce COD Levels up to 75 %

- **Aerobic Zone**

  This is basically aeration with a diffuser or aerator system to further reduce the COD Levels to acceptable limits

Conclusion

Leachate treatment nowadays is an need of an hour as the ground water contamination is maximum in this case if untreated it might get flown in near by waterbodies and can cause major damage to even surface water, we also need to note that as the concentration levels are very high without treatment it can't be disposed of off in the nature.

The conventional treatment with Digestors is an economical way to handle this affluent as other treatments are costly and involve much more tedious operation and more electrical power.

This treatment will also give us the much–needed green energy and organic fertilizer also treated water which can be used for gardening/ Toilet flushing or any other secondary operation.

Even though we develop a suitable system most of the success depends on the operation of the plant, operating the digesters, which is the heart of the system, and as it is the skilled process mentioned above the quality of leachate is not constant hence the feed to digesters is to be observed closely.

Feeding more than designed feed is not good also lesser than designed feed can also affect the health of the digester. There are some key parameters that give you the health of the digester to be monitored weekly. More important is that we are contributing to the environment by not disposing of untreated.

Subscribe

to our Magazine

WaterAge

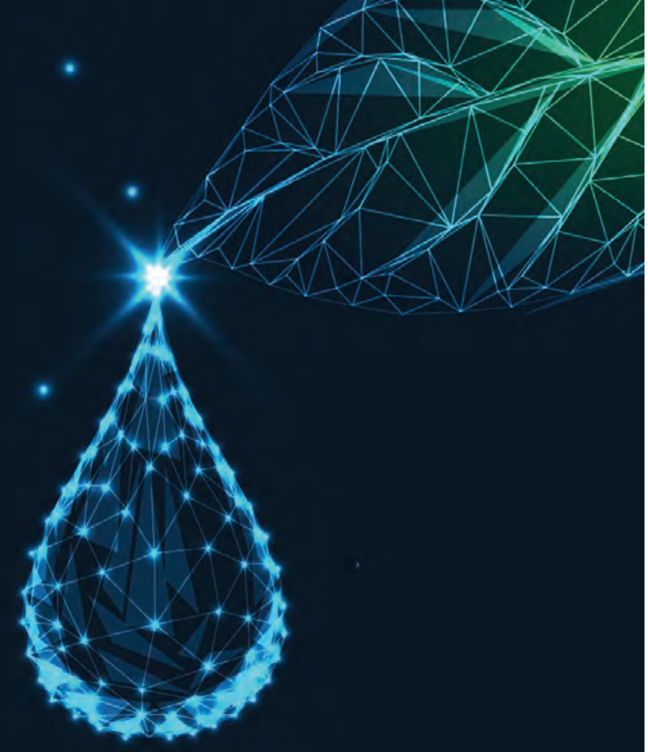
To get all updates about the happenings in the Water World, you can now subscrib our monthly magazine "WaterAge" which finds its readership among thousands of leading industries, government bodies, consultants and contractors based worldwide.

Find us on:

SHUDH JAL FOUNDATION
JAL AAJ AUR KAL

605, Bhikaji Cama Bhawan, Bhikaji Cama Place, New Delhi – 110 066
M.: +91 98759 06502, E-mail: enquiry@waterage.in, Web.: www.waterage.in

Revolutionizing **Water Solutions** to Address India's Water Challenges



Embracing Innovation for a Sustainable Water Future with **Liquiclear**

India, a land blessed with abundant natural resources, is grappling with severe water crises. A recent report by the Central Groundwater Board sheds light on the gravity of the situation, revealing that twelve Indian states are plagued by contaminated groundwater. The groundwater crisis in India is of paramount significance due to the indispensable role it plays as a decentralized source of drinking water for countless rural and urban families. Astonishingly, it fulfills nearly 80 percent of the domestic water needs in rural areas and 50 percent in urban regions, highlighting its critical importance.

Unlike surface water bodies, groundwater is generally less vulnerable to contamination and pollution, benefiting from the natural filtration process as rainwater percolates through soil layers, effectively removing impurities. However, in India, intensive use of groundwater for irrigation and industrial purposes has led to a troubling scenario. Various human activities related to land and water management have resulted in the pollution of this invaluable resource. It is imperative to address this crisis with urgency and employ innovative solutions that safeguard and restore the purity of our groundwater resources for the well-being of present and future generations.

The path forward lies in the pursuit of low-maintenance, innovative water purification and softening technologies that not only ensure safe water consumption but also preserve the natural minerals essential for our well-being. We must embark on this journey to replicate the purity of natural water and mitigate the hazards of contamination. Let us explore the realm of groundbreaking technology in-depth.

LDI Technology:

Redefining Water Transformation with Innovation

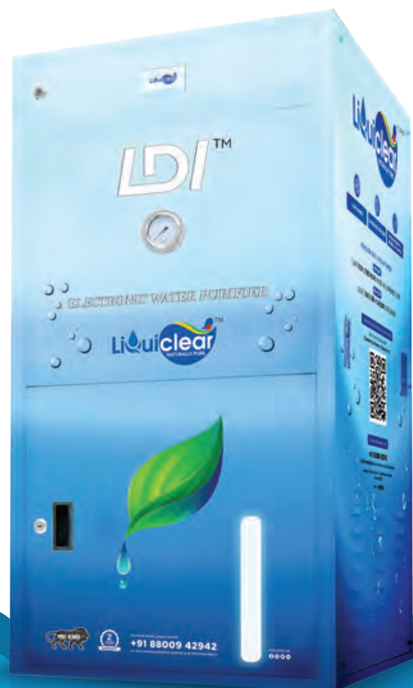
At the heart of Liquiclear's transformational water solutions lies Liqui De-ionization (LDI) technology. This cutting-edge and revolutionary approach to water purification and softening preserves the inherent goodness of water, ensuring that it remains mineral-rich and contaminant-free. Unlike traditional methods that strip water of its natural elements, LDI strikes a balance, delivering pure and refreshing water without compromising its essential minerals. On the other hand, its water-softening methods provide advanced and effective solutions to treat hard water by balancing its chemical composition naturally, without resin or salt.

By utilizing a pair of parallel carbon electrodes separated by a porous membrane, LDI creates an electric field that effectively attracts and captures ions present in the water. This process reduces ion concentration, ultimately resulting in deionized water with exceptional purity.

LDI Water Purifier:

An Unprecedented Revolution in Water Purification

Within the realm of water purification, LDI Water Purifiers emerge as game changers in sustainable water management. These innovative machines not only provide safe and clean drinking water but also play a significant role in preserving natural minerals in our water and reducing water wastage. By harnessing the power of an electric field, LDI water purifiers eliminate impurities, ensuring a rejuvenating drinking experience enriched with essential minerals. Beyond their remarkable purification capabilities, LDI water purifiers offer numerous advantages that set them apart. Their low maintenance requirements and high energy efficiency make them an ideal choice for homes, offices, and various commercial settings. With LDI water purifiers, individuals and businesses can savour the benefits of pure and mineral-rich water while actively contributing to reducing the wastage of water. Each sip becomes an immersive experience, as we embrace the richness of water while participating in building a sustainable future.



LDISF Electronic Water Softener:

Redefining the Water Softening Process

In the realm of water softening, LDISF Electronic Water Softeners present an advanced and efficient solution to combat the detrimental effects of hard water. These innovative machines utilize Liqui Deionization (LDI) technology, eliminating hardness without the use of resin or salt.

The advantages of LDISF electronic water softeners surpass those of traditional salt/resin-based alternatives. They provide a low-maintenance, cost-effective, and environmentally friendly means to address the challenges posed by hard water in residential and commercial settings alike.

Embracing LDISF electronic water softeners not only helps reduce water wastage but also mitigates the harmful consequences of hard water. This heralds a new era of sustainable water management, where the balance between environmental responsibility and water quality is achieved.

As India grapples with its grave water concerns, Liquiclear stands as a catalyst for change, driving sustainable water management forward. Our revolutionary technology offers a path to reducing water wastage and providing safe, mineral-rich drinking and soft water. Together, let us unite in combating the water crisis and building a more sustainable future for India.

NSF GUIDELINE 533 EXPANDS CERTIFICATION OFFERING TO INCLUDE INGREDIENTS USED IN DRINKING WATER PRODUCTS

NSF, the leading testing and certification organization in the water industry, is proud to announce the NSF Guideline 533 – Ingredients Used in Drinking Water Products certification program. A listing to NSF Guideline 533 means that a manufacturer's ingredients have been evaluated for health effects and are safe for use in drinking water products.

NSF has been listing PVC ingredients since the 1980s for PVC pressure pipes but has not expanded to other ingredients than PVC until now. Expanding its PVC ingredient listings will now include ingredients used in other material types, such as CPVC, PE, Nylon, etc., for health effects evaluation only.

"It can be challenging for ingredient suppliers to connect with product manufacturers, especially in foreign markets," said Nasrin Kashefi, Senior Manager of Residential Water at NSF. " An NSF listing for manufacturer's ingredients on NSF's public website exposes suppliers to hundreds of drinking water product manufacturers worldwide. Additionally, the NSF Guideline 533 certification program provides a listing that allows ingredient manufacturers to market their ingredients as NSF certified, which can help facilitate the listing of their customer's products under NSF/ANSI 14, NSF/ANSI/CAN 61."

NSF Guideline 533 expands NSF's certification offerings to include ingredients used in drinking water products, further strengthening its commitment to ensuring the safety and quality of drinking water products. Certified ingredient manufacturers can use the dedicated NSF mark to prove that their product is safe as reviewed by a third party.

"Manufacturers' customers can also enjoy simpler NSF approvals for products made with their ingredients," added Nasrin. "In most cases, no further testing or evaluation is required, which simplifies the process and reduces the cost. For product manufacturers, using NSF–listed ingredients enables quick sourcing of alternative ingredients and increases formulation flexibility." For more information on obtaining NSF Guideline 533 certification for your ingredients, please visit the NSF website.

13th IWA International Conference on Water Reclamation & Reuse
15–19 January, 2023
Venue:
ITC Grand Chola, Chennai, India
www.iwa–network.org/events

Renewable Energy Expo 2023
20–22 January, 2023
Venue:
Chennai Trade Centre, Nandambakkam, Chennai, India
www.renewableenergyexpo.biz

Water & Solid Waste Expo 2023
16–18 February, 2023
Venue:
Pragati Maidan, New Delhi
www.watersolidwaste.com

WAPTAG Water Expo 2023
23–25 March, 2023
Venue:
India Expo Center, Greater Noida, India
www.waptag.org

Smart Cities Expo 2023
27–29 March, 2023
Venue: Pragati Maidan, New Delhi
www.waterindia.com

Convergence India Expo 2023
27–29 March, 2023
Venue: Pragati Maidan, New Delhi, India
www.convergenceindia.org/

SRW India Water Expo
5–7 May, 2023
Venue: Chennai Trade Centre, CHENNAI TRADE CENTRE, Ramapuram, Tamil Nadu
www.waptag.org

Water & Plump Skills Expo 2023
18–19 May, 2023
Venue:
Pragati Maidan, New Delhi, India
www.plumbskillsexpo.com

Water Today's Water Expo 2023
23–25 September, 2023
Venue: Chennai Trade Centre, Chennai, India

IFAT 2023
17–19 October, 2023
Venue:
Bombay Exhibition Centre, Mumbai, India
www.ifat–india.com

Water India 2023
24–26 November, 2023
Venue: Kolkata, India
www.waterindia.net

Buyer/Seller:
Karnataka Co.Operative Milk Producers Federation Limited
Ref. Number: 58710838
Tender Number: KMF/ENGG/TUMUL–MEGA DAIRY/2022–23
Requirement: Design, Supply, Installation, Testing & Commissioning of Steam generation system, including steam header, steam piping, PRS insulation, structural Support & other utilities like Air compressor, water Treatment plant, suitable for 10LLPD expandable to 15LLPD capacity liquid milk processing plant along with 3LLPD capacity condensing plant, 1.5LLPD capacity curd plant on turn key basis for Tumkur Milk Union.
EMD: INR 2,200,000
Closing Date: 12/05/2023
Location: Tumkur – Karnataka – India

Buyer/Seller:
Bhiwandi Nizampur Municipal Corporation
Ref. Number: 58580291
Tender Number: 87/2022–2023
Requirement: Augmentation to bhiwandi nizampur water supply 100 MLD scheme for Construction of jack well, over head pump house, retaining wall, sub station, rcc bridge, raw water and pure water MS rising mains, conventional WTP
Closing Date: 09/05/2023
Location: Bhiwandi – Maharashtra – India

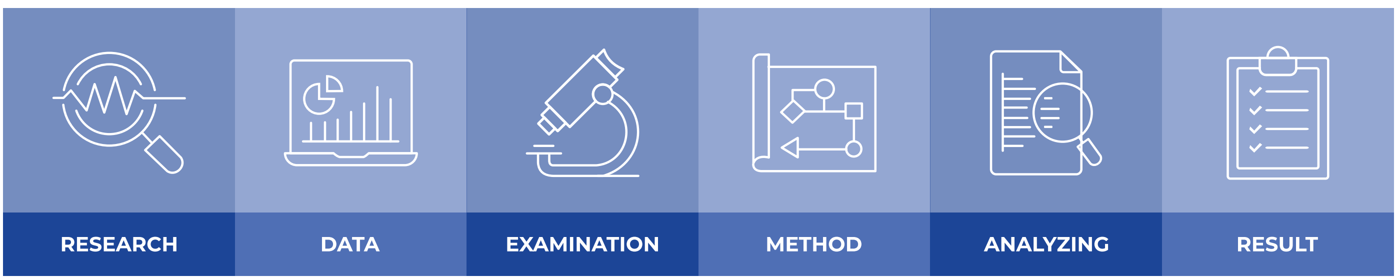
Buyer/Seller:
Haryana State Industrial And Infrastructure Development Corporation Limited
Ref. Number: 58392324
Requirement: Construction of 57 MLD WTP and all contingent works there to in all respect along with 120 months of operation and maintenance at IMT kharkhoda, district sonipat
Closing Date: 03/05/2023
Location: Sonipat – Haryana – India

Buyer/Seller:
Haryana State Industrial Development Corporation Limited
Ref. Number: 58151818
Tender Number : 2023_HBC_264464_1
Requirement: Construction of 57 mld wtp ... planning, design, engineering, procurement, construction, installation, testing, commissioning of 57 mld water treatment plant (wtp) alongwith oand m of 10 years at imt kharkhoda
Tender Detail: Construction of 57 Mld Wtp ... #*. Planning, Design, Engineering, Procurement, Construction, Installation, Testing, Commissioning of 57 Mld Water Treatment Plant (Wtp) Alongwith Oand M of 10 Years at Imt Kharkhoda
Document Fees: INR 50,000
EMD: INR 10,281,000
Closing Date: 03/05/2023
Location: Karnal – Haryana – India
Contact Details: Haryana Board Corporationllh siidcllkharkhodallindustrial Area kharkhoda

Buyer/Seller:
Madhya Pradesh Power Generation Company Limited
Ref. Number: 58772465
Tender Number: 2023_MPPGC_257602_1
Requirement: Work contract for routine maintenance of system and equipments of wt plant, pt plant and pump house, clarified water and filter water pump house, cw pump house, raw water pump house, dozing system (hp, lp dozing pumps) etc. of 210 mw atps
Document Fees: INR 1,000
EMD: INR 43,000
Tender Estimated Cost: INR 2,151,318
Closing Date: 01/05/2023
Location: Chachai, Madhya Pradesh, India
Contact Details: Madhya Pradesh Power Generating Company Limitedllchief Engineer(gen.)–amarkantak Thermal Power Station, Chachai, MPPGCL ATPS Chachai

Corrigendum – 1
Published On: 02/05/2023
Corrigendum Details: Deadline has been changes from May 1 2023 12:00AM to May 8 2023 12:00AM
Corrigendum Document: Available Corrigendum Document For Download
Buyer/Seller: Panchayat Raj Department
Ref. Number: 59437877
Tender Number: 2023_HRY_276380_1
Requirement: Village Jailaf,block– Narnaul, Laying of Rcc Waste Water Pipe Line
Tender Estimated Cost: 409,000
Closing Date: 08/05/2023
Location: Narnaul – Haryana – India
Contact Details: Haryana Governmentllpanchayati Raj Haryanallxen Panchayati Raj Narnaul jailaf

Corrigendum – 1
Published On: 02/05/2023
Corrigendum Details: Deadline has been changes from May 1 2023 12:00AM to May 8 2023 12:00AM
Corrigendum Document: Available Corrigendum Document For Download
Buyer/Seller: Panchayat Raj Department
Ref. Number: 59438550
Tender Number: 2023_HRY_276419_1
Requirement: Village Dohar Khurd, Block–Narnaul, Laying of Waste Water Pipe Line From H/o Lalchand S/o Ramchander to Pond
Tender Estimated Cost: 607,000
Closing Date: 08/05/2023
Location: Narnaul – Haryana – India
Contact Details: Haryana Governmentllpanchayati Raj Haryanallxen Panchayati Raj Narnaul Dohar Khurd



BOOK YOUR COPY NOW!

MAGAZINE SUBSCRIPTION FORM

Fill out the form below and subscribe to our magazine!

Name & Designation:

Company Name:

Address:

Pincode:

Mobile:

Email :

Website:

Magazine Subscriptions

Subscribers	Term	Issues	Price	% Savings	PAY
Domestic	5 Years	60	Rs. 24000	40%	Rs. 14400
International	5 Years	60	USD 3000	40%	USD 1800
Domestic	3 Years	36	Rs. 14400	25%	Rs. 10800
International	3 Years	36	USD 1800	30%	USD 1260
Domestic	2 Years	24	Rs. 9600	15%	Rs. 8160
International	2 Years	24	USD 1200	20%	USD 960
Domestic	1 Years	12	Rs. 4800	10%	Rs. 4320
International	1 Years	12	USD 600	Nil	USD 600

BHIM
BHARAT INTERFACE FOR MONEY

Scan for Pay UPI QR Code

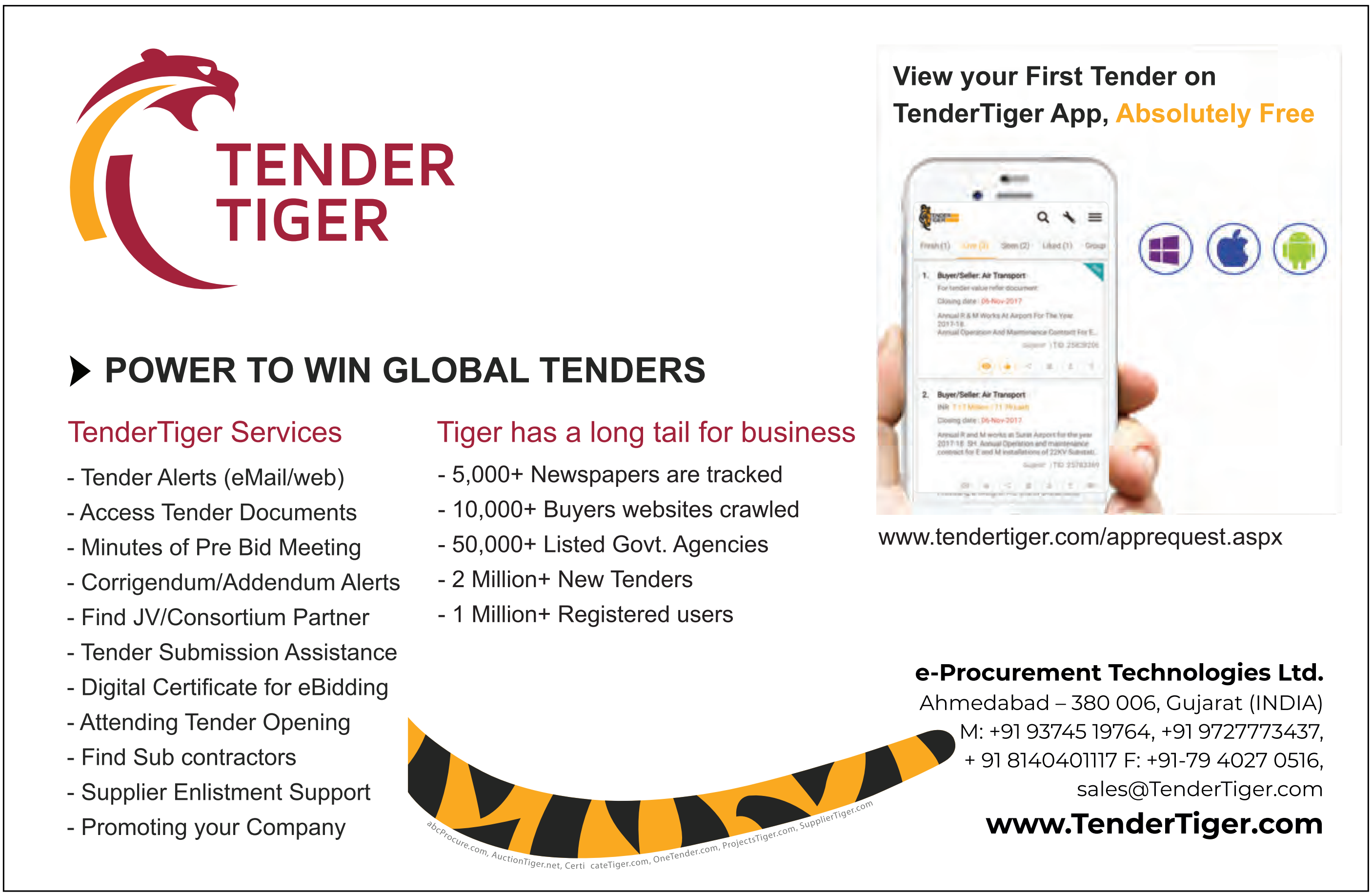
Merchant Name:
Shudhjal Foundation
Mobile: 70871 15455

Company	Page No.	Telephone	E–mail	Website
Aadys Components Pvt. Ltd.	1	+91 11 4155 1444	sales@aadys.co.in	www.aadys.co.in
Amikon Blowers & Systems Pvt. Ltd.	5	+91 11 41516313, +91 9311108295, +91 9311108296	amikonblowers@gmail.com, info@amikonblowers.com, sales@amikonblowers.com	
Aquadax South Asia Pvt. Ltd.	53	+91 9871866777	sales@aquadaxasia.com	www.aquadaxasia.com, www.aquadaxasia.in
Duvera	27	+91 8595 149016, +91 8744 040406	sales@duverawater.com	www.duverawater.com
E–Procurement Technologies Ltd.	44	+91 93745 19764	sales@TenderTiger.com	www.TenderTiger.com
IFAT	60	+91 99307 00292	bhola@ifat–india.com	www.ifat–india.com
Indus Waterways	Back Cover Inside	+91 172 5275055, +91 11 4552 4715	induswaterways@gmail.com	–
Jai Maa Associates	45	+91 98111 88819, +91 11 2568 2346	jaimaaassociatesdelhi@gmail.com, jaimaa98gmail.com, info@jaimaaassociates.in	–
Liquiclear	7	+91 88009 42942	info@liquiclear.in	www.liquiclear.in
Optimus Enviropro Pvt. Ltd.	Front Cover Inside	+91 11 4155 1444	sales@optimusenviro.pro	www.optimusenviro.pro
Rysa Infratech Pvt. Ltd.	Back Cover	+91 11 4552 4715	info@rysainfratech.com	www.rysainfratech.com
Triveni Constructions	6	+91 98143 21749, +91 98141 32026, +91 172 4039 981	trivani_anand@yahoo.com, triveniconstructions.mohali@gmail.com	–
Vrise	59	+91 8826527527, +91 9871195751	vriseengineers@gmail.com	
WaterAge Banner	41	+91 99589 60470	enquiry@waterage.in	www.waterage.in
WaterAge E–magazine	4	+91 99589 60470	enquiry@waterage.in	www.waterage.in
WaterAge Subscription	49	+91 99589 60470	enquiry@waterage.in	www.waterage.in

Thank You for Advertising with Us!

This Index is published as a service. Although every effort is taken to make it accurate, **WaterAge** assumes no responsibility for errors or ommissions.


V RISE
VRISE ENGINEERS LLP
AUTHORISED
REPRESENTATIVE
Wave Cyber
Wave Cyber
Wave Cyber
VRISE ENGINEERS LLP, B-14, Manavsthali Apartments, Vasundhara Enclave, New Delhi – 110096
Email: vriseengineers@gmail.com Mobile: +91 8826527527 / +91 9871195751


TENDER
TIGER
POWER TO WIN GLOBAL TENDERS
TenderTiger Services
- Tender Alerts (eMail/web)
- Access Tender Documents
- Minutes of Pre Bid Meeting
- Corrigendum/Addendum Alerts
- Find JV/Consortium Partner
- Tender Submission Assistance
- Digital Certificate for eBidding
- Attending Tender Opening
- Find Sub contractors
- Supplier Enlistment Support
- Promoting your Company
Tiger has a long tail for business
- 5,000+ Newspapers are tracked
- 10,000+ Buyers websites crawled
- 50,000+ Listed Govt. Agencies
- 2 Million+ New Tenders
- 1 Million+ Registered users
View your First Tender on
TenderTiger App, Absolutely Free
www.tendertiger.com/apprequest.aspx
abcProcure.com, AuctionTiger.net, CertificateTiger.com, OneTender.com, ProjectsTiger.com, SupplierTiger.com
e-Procurement Technologies Ltd.
Ahmedabad – 380 006, Gujarat (INDIA)
M: +91 93745 19764, +91 9727773437,
+ 91 8140401117 F: +91-79 4027 0516,
sales@TenderTiger.com
www.TenderTiger.com

Indus Waterways

Water & Wastewater Solutions

Indus Waterways providing consultancy for total water management and treatment solutions for Water and Wastewater Treatment, started business in 2009 and since then provided services to hundred of clients in Industries, Municipal and Hospitality sector

SERVICES TO PROVIDED BY CONSULTANT

- Detailed survey of proposed network of sewar line.
- Preparation of sewer network showing GL/IL.
- Location type design of manholes, intermediate sump well/lift well.
- Calculation of sewage generation.
- Type of treatment of sewage.
- Specification of mechanical and electrical equipment of sewage network STP & ETP.
- Preparation of drawing.
- Preparation of bill of quantities, detailed estimates BOQ and estimate based on MES SSR – 2020 and market analysis for Non-SSR items for sewage network STP & ETP.

FIELD OF EXPERTISE

H.O.: SCO 146-147, Sector-34A, Chandigarh-160022, T.: +91 172 5275055, 4012755
Corp. Office: 605, Bhikaji Cama Bhawan, Bhikaji Cama Place, New Delhi-110 066, Tel.: +91 11 41551444, 45524715
E-mail: induswaterways@gmail.com