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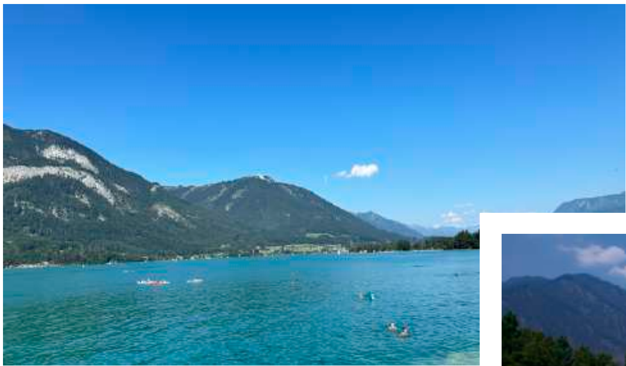
Water Resources in a Changing World: Science, Management and Policy



Editors

Dr. Vinod Kumar

Dr. Neeraj

Nature Light Publications

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Preface

We are happy to welcome the idea of publishing a book on relevant topic, "Water Resources in A Changing World: Science, Management and Policy". Further, it is good that the articles from various sub-disciplines are included in the book. The scholars from geographical and earth science have attempted to identify the current trend and to provide ideas to doing the recent study.

Water is the lifeblood of our planet—an essential resource that sustains ecosystems, supports agriculture, fuels economies, and underpins human well-being. Yet, in the face of rapid global change—driven by population growth, urbanization, climate variability, and evolving socio-political dynamics—water systems are under unprecedented stress. The urgency to understand, manage, and govern water resources sustainably has never been greater.

This edited volume, Water Resources in a Changing World: Science, Management and Policy, brings together a diverse range of perspectives from researchers, practitioners, and policymakers across disciplines and geographies.

It aims to illuminate the complex interplay between natural hydrological systems and human interventions, while offering forward-looking strategies for resilience and adaptation.

The chapters herein are organized around three core themes: the scientific foundations of water systems and change; management challenges and innovations at multiple scales; and the policy frameworks and governance mechanisms that shape water decision-making in practice. Each contribution offers both critical insight and practical guidance, reflecting the interdisciplinary nature of contemporary water studies.

This book is the product of extensive collaboration, and we are grateful to the many authors who have shared their knowledge, experiences, and visions for a more water-secure future. We also extend our sincere thanks to the peer reviewers whose feedback helped sharpen the content and arguments presented.

We hope this volume serves as a valuable resource for students, researchers, policymakers, and water professionals working to understand and respond to the complexities of water in a rapidly changing world. More importantly, we hope it inspires *new ideas, partnerships, and action toward sustainable water futures.*

Date: *30 March 2025*

Editors

Water Resources in A Changing World: Science, Management and Policy

Table of Content

Sr. No.	Title and Authors	Page No.
1	**Adapting Water Resources for a Changing World** *Mamata Ramakant Chandrakar*	01 - 06
2	**Water Quality Monitoring Techniques** *Dr. G. D. Mhaske, Dr. Ujwala G. Mhaske, Priya R. Sonawani, Jyoti Pekhale, Kirti Jadhav.*	07 - 16
3	**The scenario of water scarcity in India due to environmental changes** *Dr. Gajendrasingh Surajpalsingh Pachlore.*	17 - 20
4	**Impact of Climate Change on Water Resources in India: Challenges, Socio-Economic Implications, and Strategies for Adaptation** *Dr. Rafi Ahmed, Ansari M. Hammad, Dr. Jai Knox.*	21 - 26
5	**Water Pollution and Quality Management in India: Challenges, Impacts and Sustainable Solutions** *Dr. Rafi Ahmed, Ansari M. Hammad, Dr. Jai Knox.*	27 - 32
6	**A Review on Technological Innovations in Water Management: Solutions for a Global Water Crisis** *Shivaji G. Jetithor, Datta Ashok Nalle.*	33 - 41
7	**A Critical Study on The Problem of Spreading Waterborne Diseases Through Dissolving Chemicals and Its Effect in Vichumbe Village** *Raviprakash D. Thombre, Mr. Atharva R. Kandhare* *Ms. Nikita S. Yadav.*	42 - 54
8	**Sustainable Agriculture and Water Conservation** *Dr. Chandan Kumar Jana.*	55 - 60

9	**Water and Its Impact on Human Health** *Sachin. S. Chavan*	**61 - 63**
10	**Morphometric Analysis for the Evaluation of Ground Water Potential Zones using Geospatial Techniques: A Case Study of Hogenakkal Sub watershed, Tamil Nādu.** *Sasi.M, Dr. Sawant Sushant Anil.*	**64 - 76**
11	**Water and human health** *Sunanda Nandikol, Virupaxappa Biradar*	**77 - 85**
12	**Urbanization And Water Challenges in Future** *Dr. Dhanavanti Runwal, Dr. Chandrashekar C. Patil.*	**86 - 100**
13	**Water Resources in A Changing World: Science, Management and Policy** *Bhavana J Shirahatti, Dr. Chandrashekar C. Patil.*	**101 - 109**
14	**Demographic Transformation of Ralegansiddi Watershed Village Before and After Watershed Development** *Dr. Lagad Santosh Jabaji, Dr. Bharati Machhindra Kale*	**110 - 118**

WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Adapting Water Resources for a Changing World

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Abstract

Water is a vital resource for sustaining life, ecosystems, and economic activities. India, with its diverse geography and climate, faces both surplus and scarcity in water availability. Erratic monsoons, groundwater depletion, pollution, and climate change pose significant challenges to water resource management. This paper examines India's water resource scenario, highlighting key sources such as surface water, groundwater, and emerging alternatives like desalination and wastewater reuse.

Scientific insights into water-related challenges include climate-induced variations in monsoons, glacial retreat affecting river flows, and groundwater depletion due to over-extraction. Pollution from industrial discharge, agricultural runoff, and untreated sewage further exacerbate water stress. Integrated Water Resource Management (IWRM), rainwater harvesting, watershed management, and wastewater treatment are explored as strategic solutions for sustainable water use.

Policy and governance frameworks, including the National Water Policy, Water (Prevention and Control of Pollution) Act, 1974, and Environmental Protection Act, 1986, provide legal structures to regulate water use and pollution. State-level regulations and groundwater acts play a critical role in localized water management. Institutional stakeholders like the Central Water Commission and Ministry of Jal Shakti oversee policy implementation and resource assessment.

Future strategies must emphasize efficient water use, climate resilience, and community participation. Technological innovations such as AI-driven water management and smart distribution grids can enhance sustainability. A holistic, multi-pronged approach integrating science, policy, and local engagement is essential to ensure water security in a changing climate. Strengthening governance, investing in conservation, and fostering responsible water use will be key to India's water future.

Keywords: Climate Change; Groundwater Depletion; Pollution; Water Management; Water Resources

Introduction:

Water is a fundamental resource for life, ecosystems, and economic development. India, with its diverse climatic conditions and topographical variations, faces both abundance and scarcity of water resources. The country experiences erratic monsoons, overexploitation of groundwater, pollution, and climate change impacts, making water resource management a critical policy concern. This chapter explores the scientific, managerial, and policy aspects of water resources in India within the context of a changing world.

Water Resource Scenario in India

India accounts for about 4% of the world's freshwater resources while supporting 17% of the global population. The primary water sources include:

- **Surface Water:** Rivers (Ganga, Yamuna, Brahmaputra, Godavari, etc.), lakes, and reservoirs
- **Groundwater:** India is the largest user of groundwater in the world, particularly for irrigation
- **Rainwater:** Unevenly distributed, with significant variations across regions
- **Desalination & Recycled Water:** Emerging technologies to supplement freshwater availability

Despite this availability, India faces seasonal and regional water crises due to over-extraction, pollution, and inefficient management.

Scientific Understanding of Water Resource Challenges

1. **Climate Change and Water Resources**

- Increased variability in monsoons leading to droughts and floods
- Glacial retreat in the Himalayas impacting river flow
- Rising temperatures causing higher evaporation rates and altered rainfall patterns

2. **Groundwater Depletion**

- Over-extraction due to extensive irrigation, industrial use, and urban demand
- Declining water tables in states like Punjab, Haryana, and Rajasthan

3. **Water Pollution**

- Industrial and agricultural pollutants contaminating rivers and lakes
- Untreated sewage affecting urban water bodies
- Arsenic and fluoride contamination in groundwater

Water Management Strategies

1. **Integrated Water Resource Management (IWRM)**

A holistic approach that considers social, economic, and environmental aspects to ensure sustainable water use.

2. **Rainwater Harvesting**

- Revival of traditional water conservation methods such as stepwells, tanks, and check dams
- Government initiatives like the Jal Shakti Abhiyan promoting water conservation

3. **Watershed Management**

- Afforestation and soil conservation to enhance groundwater recharge
- Community-based approaches involving local stakeholders

4. **Wastewater Treatment and Reuse**
    - Expansion of sewage treatment plants (STPs)
    - Industrial water recycling to reduce freshwater demand

Policy and Governance

1. **National Water Policies**

➢ National Water Policy (2012) emphasizes conservation, efficient use, and demand management

➢ Atal Mission for Rejuvenation and Urban Transformation (AMRUT) to improve urban water supply

➢ Namami Gange Programme for cleaning the Ganga River

2. **Legal Framework**

➢ Water (Prevention and Control of Pollution) Act, 1974

The **Water (Prevention and Control of Pollution) Act, 1974** is a key environmental law in India aimed at preventing and controlling water pollution. Below are the main points of the Act:

Objective:

➢ To prevent and control water pollution.

➢ To maintain or restore the wholesomeness of water bodies.

➢ To establish Pollution Control Boards for regulating water pollution.

Key Provisions

➢ **Establishment of Pollution Control Boards (PCBs):**
- Central Pollution Control Board (CPCB) at the national level.
- State Pollution Control Boards (SPCBs) at the state level.

➢ **Functions of CPCB & SPCBs:**
- Monitor water pollution and set standards.
- Issue consent (permission) for industries and sewage treatment plants.
- Conduct inspections and take action against polluters.

➢ **Restrictions on Polluting Activities:**
- No person or industry can discharge pollutants into water bodies without prior approval from SPCB.

➢ **Penalties for Non-Compliance:**
- Fines and imprisonment for violating pollution norms.
- Closure of industries causing pollution.

➢ **Enforcement & Penalties:**
- First offense: Imprisonment up to 6 years and/or fine.
- Continuing offense: Additional fine per day.
- Authorities have the power to stop water supply and electricity to polluting units.

➢ **Environmental Protection Act, 1986**

The **Environmental Protection Act, 1986** is a comprehensive law enacted in India to protect and improve the environment. Below are the key points of the Act:

Objective

➢ To provide a legal framework for the protection and improvement of the environment.

➢ To prevent hazards to humans and other living beings from environmental pollution.

➢ To implement decisions made at the United Nations Conference on the Human Environment (Stockholm, 1972).

Key Provisions

➢ **Power of the Central Government**

- Take necessary measures to protect and improve the environment.
- Set environmental quality standards.
- Restrict industries and hazardous substances in specific areas.
- Regulate the handling of hazardous waste and pollutants.

➢ **Prohibition on Pollution**
- No person or industry can discharge pollutants beyond prescribed limits.
- Strict regulation of hazardous substances.

➢ **Penalties for Violations**
- Imprisonment up to 5 years and/or fine up to ₹1 lakh.
- Additional fine per day if the offense continues.
- If violations persist for more than one year, imprisonment may extend to 7 years.

➢ **Power to Close or Regulate Industries**
- Authorities can shut down polluting units or restrict their operations.

➢ **Public Participation and Awareness**
- Encourages citizen involvement in environmental protection through complaints and litigation.

Significance

➢ Acts as an umbrella law, covering air, water, and land pollution.

➢ Provides the legal basis for various environmental rules (e.g., EIA, hazardous waste management, and coastal zone regulations).

➢ Strengthens environmental governance in India.

State-Level Water Regulation and Groundwater Acts

State-Level Water Regulation and Groundwater Acts in India

Since water is a state subject under the Indian Constitution, several states have enacted their own Water Regulation and Groundwater Acts to manage water resources effectively. These laws focus on water conservation, regulation of extraction, prevention of pollution, and equitable distribution.

Key Features of State-Level Water Regulation Acts

1. Water Governance & Regulation

➢ States establish Water Regulatory Authorities to manage and allocate water resources.

➢ Example: Maharashtra Water Resources Regulatory Authority (MWRRA) Act, 2005 – First state-level water regulatory authority in India.

➢ Promotes equitable water distribution for agriculture, industry, and domestic use.

2. Control Over Water Use & Allocation

➢ Imposes permits/licenses for water extraction by industries and large consumers.

➢ Encourages efficient water usage and penalizes wastage.

3. Pollution Control & Conservation

➢ Regulates industries to prevent water pollution.

➢ Implements measures for rainwater harvesting and water recharge.

State-Level Groundwater Acts

1. Groundwater Regulation & Conservation

- Establishes State Groundwater Authorities to monitor extraction and usage.
- Example: Model Bill for the Conservation, Protection, and Regulation of Groundwater, 2017 – Framework for states to regulate groundwater.

2. **Permit System for Groundwater Extraction**
   - Requires permits for commercial groundwater use.
   - Exemptions for small farmers and domestic use in some states.
3. **Protection Against Over-Exploitation**
   - Identifies critical and over-exploited zones where groundwater extraction is restricted.
   - Encourages rainwater harvesting and artificial recharge methods.
4. **Community Participation & Local Governance**
   - Encourages Panchayats and local bodies to monitor groundwater usage.
   - Promotes traditional water conservation techniques.

State-Level Acts are

- Maharashtra Groundwater (Development and Management) Act, 2009
- Karnataka Groundwater (Regulation and Control) Act, 2011
- Andhra Pradesh Water, Land, and Trees Act (WALTA), 2002
- Punjab Groundwater Conservation Act, 2008

Significance

- Prevents unsustainable water extraction and ensures future water security.
- Encourages integrated water management by linking surface water and groundwater policies.
- Strengthens state control over water resources while involving local communities in decision-making.

Role of Institutions

- Central Water Commission (CWC) and Central Ground Water Board (CGWB) for resource assessment
- Ministry of Jal Shakti for policy coordination and implementation

Challenges and Future Directions

1. **Need for Efficient Water Use**
   - Adoption of micro-irrigation techniques such as drip and sprinkler systems
   - Incentivizing water-efficient crops and farming techniques
2. **Climate Resilience and Adaptation**
   - Enhancing flood forecasting and early warning systems
   - Infrastructure improvements for better storage and distribution
3. **Strengthening Community Participation**
   - Promoting decentralized water governance
   - Encouraging traditional knowledge integration in modern water management
4. **Technology and Innovation**
   - Use of AI and remote sensing for better water resource planning
   - Development of smart water grids for efficient distribution

Conclusion

Water resource management in India is at a crossroads, requiring a multi-pronged approach that integrates science, technology, policy, and community participation. Sustainable and equitable water management will be key to ensuring water security in the face of climate change and growing demands. Strengthening institutional frameworks, investing in conservation technologies, and fostering responsible water governance are crucial steps toward a water-secure future for India.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Water Quality Monitoring Techniques

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Abstract

Drinking water must adhere to strict requirements for cleanliness in terms of its physical, chemical and biological components. Water for different purposes has its own requirements as to composition and purity. Each body of water needs to be analyzed on a regular basis to confirm to suitability. The types of analysis could vary from simple field testing for a single analyte to laboratory based multi-component instrumental analysis. The study undergone physico chemical and biological techniques for water quality monitoring for different reasons. The parameters of water quality, including pH, EC, TDS, TH, Ca, Mg, Na, K, CO3, HCO3, Cl, F, SO4, NO3, PO4 and trace elements as B, Cu, Zn, Fe, Mn are considered.

Keywords: Water quality monitoring, Physicochemical analysis

Introduction:

Water is a plentiful natural resource because it covers three-quarters of the earth's surface. The entire volume of water on the earth is estimated to be 1360 million cubic kilometers. Water is used by the population in both urban and rural areas for drinking, sanitation, industry, agriculture etc. Water is a precious resource that must be safeguarded for future generations. There is a dearth of data on how chemicals, plastics, agricultural waste and other human waste products, which are regarded as the primary sources of contamination, affect water quality. Groundwater is commonly contaminated by agricultural muck. Groundwater and water in the unsaturated zone beneath the soil can be reliably predicted using thermodynamic and kinetic models (Garrels, 1967; Plummer et al., 1979; Drever, 1982; Velbel, 1986; Pawar, 1993 etc.). There is a lack of data on how anthropogenic variables, such as significant agricultural activity and chemical weathering, affect groundwater quality (Dugger, 2006). Contaminated groundwater can harm both human health and the environment. Thus, it is critical to understand the sources, pathways and fate of contaminants in groundwater. Understanding the relationship between agriculture and groundwater quality is therefore critical for guaranteeing agricultural practices' long-term sustainability. Wrong agricultural practices, industrial activities harm the surface and groundwater quality. Therefore, it is essential to understand the water contamination problems and need of water quality monitoring.

Collection of water Samples

A literature review revealed enough information on water sampling techniques and frequency programmes (Helmer, 1981; Handa, 1979; APHA et al., 1995; Trivedi and Goyal, 1994). Water is well known for being extremely changeable due to its outstanding solvent properties. Therefore, the following safety measures are important during collection.

- Collect and store the water sample in one-litre plastic container as plastic is resistant.
- The containers must thoroughly wash and rinsed before each collection. Use separate container for each station.
- For dug wells take the sample half an hour after pumping.
- Labell the water samples and measure the pH and EC at the field because their values could fluctuate over time. A portable conductivity metre and pH metre can use to measure the electrical conductivity and pH, respectively. Then brought the samples to the laboratory for further chemical analysis.

Analysis of Water Samples

Chemical testing is done on the groundwater samples that obtained in accordance with the described procedures. The groundwater's major and trace components were found using chemical analysis. Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), total alkalinity ($CaCO_3$), total hardness ($CaCO_3$), chlorides (Cl^{-}), fluorides (F^{-}), sulphate (SO_4^{2-}), nitrate (NO_3^{-}) and phosphates (PO_4^{3-}) are the major ions, while boron (B), copper (Cu^{2+}), zinc (Zn^{2+}), ferrous (Fe^{2+}) and manganese (Mn^{2+}) are trace elements.

- **Electrometric Methods**

pH, Electrical conductivity and total dissolved solids are analysed by electrometric method. These are checked at the field by using multi-parameter tester.

- **Volumetric Methods**

This approach is used to determine total alkalinity, total hardness, calcium, magnesium and chlorides, carbonates and bicarbonates by following the standard methods of the American Public Health Association (APHA 2005) and Trivedi et al. (1994).

- **Spectrophotometric Methods**

Sulphates, phosphates, fluoride, nitrates and boron is measured spectrophotometrically with double beam UV Visible Spectrophotometer (Shimadzu UV 1800).

- **Flame Photometric Methods**

Alkali elements such as sodium (Na) and potassium (K) are checked with the flame photometer

- **Atomic Absorption Spectrophotometric Methods**

Cu, Zn, Fe and Mn these trace elements are determined using AAS (Chem Biotech. CB-AAS-3510).

Electrometric Methods

One of the most popular techniques involves inserting an electrode into a sample. An electronic amplifier produces a modest current or voltage, which is then read on a metre scale. Here, pH and conductivity tests are typical, but other parameters, including as calcium, nitrates, chlorine, and TDS, can also be assessed using ion-specific electrodes (ISE).

pH

The pH of groundwater reflects the equilibrium between dissolved atmospheric carbon dioxide and biological activity. It has to do with dissolving general-form carbonates, bicarbonates, silicates, borates, fluorides and other salts that are dissociated in water. Most groundwater has a pH between 6 and 8.5 (Hem, 1991). High pH values are detrimental. The pH variation affects how water tastes because it is connected to fluids containing carbonate and sodium bicarbonate. Water with free acids is indicated by low pH measurements (Davies and De Wiest, 1966). On-site pH measurements were made using a portable digital metre (Multi parameter tester 35). Prior to reading, it was calibrated using a buffer solution with pH values of 4.0, 7.0 and 9.2.

Electrical Conductivity

A solution becomes conductive when it contains charged ionic species. Water is conductive because of dissolved ions and salts, which raises the amount of inorganic pollution in the water (Morrison et al., 2001). As the ion concentration rises, the solution's conductance also rises. Therefore, the conductance measurement provides information on the ion concentration (Hem, 1991). When reporting electrical conductivity values, a temperature, typically 25°C, is supplied since the specific conductance of water is a function of its temperature (Todd, 1959). Field measurements of electrical conductivity were conducted using a portable digital metre (Multi-Parameter PCS tester 35). The EC metre calibrated with a 0.01M KCl solution before the reading. Richards (1954) used the electrical conductivity (EC) values in Table 1 to grade groundwater samples for suitability for irrigation.

Table 1 Groundwater samples classification based on EC (Richards 1954)

Sr. No	EC range (µS/cm)	Water class
1	Below 250	Excellent
2	250-750	Good
3	750-2000	Permissible
4	2000-3000	Doubtful
5	>3000	unsuitable

Total Dissolved Solids (TDS)

The term "total dissolved solids" refers to all the minerals in the water. The total dissolved solids (TDS) represent the sum of all cations and anions in water. According to Davis and De-Wiest (1966), the TDS is regarded as a crucial factor in determining the appropriateness of groundwater for agricultural and drinking purposes (Table 2). A portable digital TDS meter is used to take TDS readings in the field.

Volumetric Methods:

Total Alkalinity

Table 2 Classification groundwater based on TDS (Davies and De Weist, 1966)

	Classification	Range (mg/l)
Total dissolved solids (TDS)	Desirable for Drinking	< 500
	Permissible for Drinking	5,00-1,000
	useful for Irrigation	1,000-3,000
	unfit for Irrigation	> 3,000

The ability of water to neutralise a strong acid to a particular pH is known as total alkalinity (Hem, 1991). Due to the fact that alkalinity is a capacity function as opposed to an intensity function, even neutral water can have significant alkalinity. Alkalinity has been determined using a variety of methods. Low levels of alkalinity in water can be found using the technique described by Larsen and Henely in 1955. Then, in 1960, Thomas and Lynch developed a method for calculating the carbonate alkalinity of water. Alkalinity is assessed in the current study using a straightforward acid-base titration method (APHA et al., 1985). The hydroxyl ions present in the sample as a result of dissociation or hydrolysis are assessed by titration with H2SO4/HCl using the indicators phenolphthalein and methyl orange. pH 8.3 is the pH at which phenolphthalein alkalinity (PA) occurs. When CO32- is converted to HCO3- titration. The methyl orange increases the titration's HCO3- concentration. When it reacts with acid, H2CO3 is created. Near the end of the reaction, the colour changes from yellow to orange at pH 4.5. The term "methyl orange alkalinity" describes this (TA). Adding both of these alkalinities results in total alkalinity (CaCO3).

PA as CaCO3 (mg/l) = (A x N) of HCl x 1000 x 50 / ml of sample
TA as CaCO3 (mg/l) = (B x N) of HCl x 1000 x 50 / ml of sample

Where,
A = ml of HCl with Phenolphthalein endpoint
B = ml of HCl with Phenolphthalein and Methyl orange endpoint, i.e., total HCl.

Total Hardness

Total Hardness is a measure of the water's ability to dissolve soap. Hardness in water is most frequently caused by carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium ions in the water. The amounts of calcium and magnesium, which are present along with HCO3/CO3/SO4/Cl ions, is measured using the EDTA technique (Goetz, 1950). The idea that EDTA and its sodium equivalent create a chelate, a stable soluble molecule, is the basis for the method. A solution changes when metal cations are added to it. As an alternative, EDTA could be substituted by KMnO4 in a titration procedure (Khopkar, 1995). If enough EDTA has been added to the solution, it will transform from wine red to blue (Snoeyink and Jenkins 1980).
Hardness (mg/L) = ml of EDTA used x 1000/ ml of sample
As shown in Table 3, Sawyer and McCarty (1967) divided groundwater into four classes: soft, moderately hard, hard and very hard.

Table 3 Groundwater classification based on total hardness (TH)

Classification category	**Class**	**Range**
Total hardness ($CaCO_3$)	Soft	<75
	Moderately hard	75-150
	Hard	150-300
	Very hard	>300

Calcium (Ca)

One of the most prevalent elements, calcium, is naturally present in water. It makes the water harder, and a large portion of its amounts may precipitate as $CaCO_3$ at high pH levels. High calcium content causes digestive problems in people as well as encrustation and scaling issues in sewage and water supply systems. The approach outlined below is used to calculate the quantity of calcium in groundwater.

In a conical flask, take 50 ml of sample, mix in 2 ml of NaOH solution, and then 100 mg of murexide indicator, which develop the pink-color. EDTA used to titrate the substance until the pink tint turned dark purple.

Calcium mg/l = Volume of EDTA used x 400.8/ ml of sample.

Magnesium (Mg)

All types of water normally contain magnesium. The main source of magnesium in groundwater may come from the leaching of limestone, dolomite, gypsum and anhydrite, which are silicate rocks rich in calcium and magnesium. Additionally, secondary sources include industrial and household trash. Together with calcium, magnesium is present, but its concentration is lower than calcium's, whereas the amount of magnesium in seawater is more than calcium (Holmes, 2003). The results of groundwater calcium and total hardness estimation is used to calculate magnesium.

Magnesium (Mg) mg/L = (y-x) x 400.8/ ml of sample x 1.645

Where,
y = Total Hardness burette reading
x = Calcium burette reading

Chlorides

Different methods can determine the level of chloride in groundwater. (1) Mohr's method (argentometric method), (2) Volhard's method, (3) The potentiometric technique. While the Mohr method employs $K_2Cr_2O_7$ as an indication, Volhard's technique uses KCl or NK, Cl. It is possible to meet the criteria by titrating $AgNO_3$ with glass and an Ag-AgCl electrode system in order to detect small levels of Cl (Khopkar, 1995). According to the theory behind the titration method, potassium chromate can be used to determine the endpoint of a chloride titration in a neutral or slightly alkaline solution prior to the formation of red silver chromate. Chloride concentration is estimated using the formula,

Chloride (Mg/L) = (ml x N of $AgNO_3$) x1000 x35.5 / ml of sample

Spectrophotometric Methods

Spectrophotometric techniques are used to examine sulphates, phosphates, fluoride, nitrates and boron in groundwater samples.

Sulphate

The level of sulphate in the groundwater can be found by using a variety of techniques: 1) The gravity approach, 2) the Nephelometric or turbidimetric technique, 3) The colourimetric approach,4) the Titrimetric approach (Khopkar, 1995). In the colourimetric method, sodium rhodiazote serves as the chromogenic reagent, whereas the titration method uses the interaction of BaCl with thorin as an indication (Khopkar, 1995). Because the gravimetric approach is straightforward to employ, turbidimetric and gravimetric processes are frequently used.

For SO4 analysis, a turbidimetric technique is used (Trivedi and Goel, 1994). When barium chloride is added to a hydrochloric acid media, the sulphate ion precipitates as barium sulphate (BaS04) (BaCl). One can determine the concentration of sulphate by measuring light absorption with BaS04 and comparing it to a reference curve with a colorimeter calibrated to 420 nm.

Phosphate

In this process, ammonium molybdate and phosphate ions combine to form ammonium phosphomolybdate in an acidic medium. A compound of antimony-phospho-molybdate is created when ammonium molybdate, antimony potassium tartrate and diluted phosphorus solutions combine in an acidic media. Ascorbic acid transforms this complex into a brightly coloured complex with a blue colour. The relationship between the colourimeter's colour and phosphorus content measures the intensity of blue colour at a wavelength of 690 nm (Khopkar, 1995).

Fluoride

Groundwater fluoride levels are influenced by local environmental elements such as the climate, terrain, geology, geomorphology, precipitation, evaporation etc. (Liu and Wan Hua 1991). Due to the interaction between rocks and water, wherein fluoride-bearing minerals and rocks are dissolved, fluoride is found in groundwater. The SPANDS method is used to determine fluoride content. 5 ml of SPANDS-Zirconyl-Acid reagent and 25 ml of the sample should be added. Utilize a Spectro-photometer to measure the absorbance at 580 nm.

Nitrate

Nitrate in water can come from a variety of sources, including residential waste, fertilizers, septic tank leaks and animal waste. Soil and water contamination may result from agricultural runoff and solid waste dumping sites. Nitrate-nitrogen is detected using spectrophotometric techniques like the phenol-Di-sulphonic acid method and the brucine method (NO3-N). The phenol-Di-sulphonic acid method is used to conduct the NO3-N analysis in the study. Nitro derivative, which is yellow in colour, is created when phenol-Di-sulphonic acid comes into contact with an alkaline medium. By using spectrophotometry, the wavelength of this yellow colour is determined to be 410 nm.

Boron

Although boron is necessary for plant growth, it is toxic to most plants at concentrations above 2 ppm in irrigation water and has a negative impact on plant growth at 1 ppm or below. Its concentration is primarily influenced by the type of soil layers through which it percolates and its mineralogical source (Tandon, 1993). Boron concentrations are typically high in the saline ground fluids of arid and semi-arid areas (Richards, 1968). Due to the absence of fluorine, ammonia, calcium, molybdenum, magnesium and potassium interference, the presence of boron in irrigation water can be detected colourimetrically using the carmine method. The temperature range of 20° to 35 0C had little impact. The process is based on the idea that anthraquinone colouring carmine forms a combination with boric acid in concentrated sulfuric acid. The complex takes 45 minutes to produce and maintains its peak absorbance at 585 nm. Initially, a 25 ml volumetric flask with cone-shaped H_2SO_4 was carefully filled with 2 ml of water sample, 2 drops of cone-shaped HCl, and 10 ml of cone-shaped H_2SO_4. 10 ml of carmine reagent were combined and diluted to the proper concentration after cooling at room temperature. A blank sample of distilled water was used to test absorbance at a wavelength of 585 nm after 45–60 minutes. From the standard curve, the boron content is determined.

Flame Photometric Methods

Flame emission spectrometry is sometimes known as flame photometry. Alkali metals, including sodium, potassium and lithium, as well as alkaline earth elements like Ca, Sr and Ba, can be analysed using flame photometry. Alkali elements like sodium (Na) and potassium (K) are measured using a different technique that is more frequently utilised. In this process, alkali metals are heated to a temperature where they can absorb energy. They take in heat from a source, which causes them to become excited in their atomic form. When they cool and separate, these atoms return to their original states and radiate the absorbed energy at specific wavelengths. The visible region is home to some of the wavelengths. An optical filter isolates the discrete frequency that is produced when the alkali metal solution is drawn into the flame. The emission is proportional to the quantity of excited atoms, which is the same as the soil's element concentration.

Sodium

A standard curve of absorbance against concentration is created by aspirating liquids with known NaCl concentrations. After that, the samples were aspirated, and the sodium concentration is determined by comparing the sample's absorbance to a standard curve.

Potassium

Similar to this, the standard curve for K is created using KCl, and the concentration of potassium in water samples are determined by comparing its absorbance to the standard curve.

Atomic Absorption Spectrophotometric Methods (AAS)

The A.A.S. is a widely used tool in examining water because it facilitates the quick analysis of several samples and is a practical method for multi-element analysis. The method is based on the measurement of the reduction in light intensity that occurs as atoms of the analyte element travel through a layer of vapour (De, 1990). Methods of flame atomic absorption spectrometry were employed for the analysis. Samples were collected in one-litre polythene containers by adding 5 ml Conc and HNO_3 per lit. for the flame atomic absorption photometry examination of trace elements.

HNO_3 per lit. for the flame atomic absorption photometry examination of trace elements. HNO_3 is added at the time of collection to reduce metal absorption on the container wall, to stop any biological activity, to slow down chemical compound and complex hydrolysis and to lessen constituent volatility (De, 1990). The samples were filtered through 0.45 um membrane filter paper prior to the measurement of dissolved metals. After that, standard solutions of the metals chosen for analysis were added to the samples. This standard addition method is chosen to improve accuracy for the analysis of trace metals like Cu, Zn, Fe and Mn.

Plankton analysis
(Biological parameters)

The physical and chemical characteristics of water affect the abundance, species composition, stability and productivity of the indigenous populations of aquatic organisms. The biological methods used for assessing water quality includes collection, counting and identification of aquatic organisms; biomass measurements; measurements of metabolic activity rates; toxicity tests; bioaccumulation; biomagnification of pollutants; and processing and interpretation of biological data. The work involving plankton analysis would help in:

- Explaining the cause of color and turbidity and the presence of objectionable odor, tastes and visible particles in waters.
- The interpretation of chemical analyses.
- Identifying the nature, extent and biological effects of pollution.
- Providing data on the status of an aquatic system on a regular basis.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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The scenario of water scarcity in India due to environmental changes

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Abstract

India is facing a severe water crisis due to environmental changes, rapid urbanization, and unsustainable water management practices. Climate change has altered precipitation patterns, increased temperatures, and accelerated glacier melting, leading to more frequent droughts and floods. Over-extraction of groundwater through excessive borewell digging has significantly depleted water tables, causing land subsidence and water contamination. Additionally, the absence of rainwater harvesting systems has led to reduced groundwater recharge, increased surface runoff, and heightened water stress.

The impact of water scarcity varies across regions, with Punjab and Haryana experiencing acute groundwater depletion, Rajasthan and Gujarat struggling with limited rainfall, and Tamil Nadu and Karnataka facing recurring droughts. The consequences of this crisis are profound, affecting food security, economic growth, public health, and social equity. Reduced agricultural productivity threatens livelihoods, while industrial growth is constrained by declining water availability. Moreover, inadequate access to clean water exacerbates health risks and social inequalities.

To mitigate this crisis, water conservation strategies such as rainwater harvesting, efficient irrigation, and sustainable watershed management are essential. Climate-resilient infrastructure and community engagement can further enhance water security. The Indian government has introduced initiatives like the Jal Shakti Abhiyan, Atal Bhujal Yojana, and the National Water Policy to promote water conservation and equitable distribution. However, stronger implementation and public participation are required to ensure long-term water sustainability. Addressing India's water crisis demands a multi-pronged approach integrating policy, technology, and local-level interventions to secure water resources for future generations.

Keywords: Climate change; Groundwater depletion; Government initiatives; Rainwater harvesting; Sustainability; Water scarcity

Introduction:

India, with its vast and diverse geography, is facing an unprecedented crisis: water scarcity. The country's growing population, rapid urbanization, and changing climate are exerting immense pressure on its water resources. Environmental changes, such as rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events, are further exacerbating the issue. This chapter aims to explore the scenario of water scarcity in India due to environmental changes, highlighting the causes, consequences, and potential solutions.

Causes of Water Scarcity

Environmental changes are significantly contributing to water scarcity in India. Some of the key factors include:

- **Changing Precipitation Patterns:** Climate change is altering the patterns of rainfall in India, leading to more frequent droughts and floods. This unpredictability makes it challenging to manage water resources effectively.
- **Rising Temperatures:** Increasing temperatures are leading to higher evaporation rates, reducing the availability of water in rivers, lakes, and reservoirs.
- **Glacier Melting:** The Himalayan glaciers, which feed many of India's major rivers, are melting at an alarming rate due to rising temperatures. This will eventually lead to reduced water flows in these rivers.
- **Increased Frequency of Extreme Weather Events:** Climate change is leading to more frequent and intense heatwaves, droughts, and floods, which can devastate water resources and infrastructure.

Overview of Water Scarcity in India

India is facing a severe water crisis, with over 600 million people facing high to extreme water stress. The country's water resources are dwindling at an alarming rate, and the situation is expected to worsen in the coming years. Two major reasons due to urbanization in India are - Over Digging of Bores and Absence of Rainwater Harvesting Systems.

Over Digging of Bores

The over digging of bores has significantly contributed to the water scarcity crisis in India. Some of the key issues related to over digging of bores include:

- **Depletion of Groundwater:**

The excessive extraction of groundwater through bores has led to a significant decline in the water table. This has resulted in reduced water availability for irrigation, drinking, and industrial purposes.

- **Land Subsidence:** The over extraction of groundwater has caused land subsidence in several areas, leading to structural damage to buildings and infrastructure.
- **Water Pollution:** The digging of bores has also led to the contamination of groundwater sources, making them unfit for human consumption.

Absence of Rainwater Harvesting Systems

The absence of rainwater harvesting systems has further exacerbated the water scarcity crisis in India. Some of the key issues related to the absence of rainwater harvesting systems include:

- **Loss of Rainwater:** The lack of rainwater harvesting systems results in the loss of precious rainwater, which could be used to recharge groundwater sources or meet non-potable water demands.
- **Increased Runoff:** The absence of rainwater harvesting systems leads to increased runoff, which can cause soil erosion, flooding, and water pollution.
- **Reduced Groundwater Recharge:** The lack of rainwater harvesting systems reduces the opportunities for groundwater recharge, making it difficult to replenish depleted groundwater sources.

Regional Variations noted in India

The impact of over digging of bores and absence of rainwater harvesting systems varies across different regions in India. Some of the most affected regions include:

- **Punjab and Haryana:** These states have experienced severe groundwater depletion due to excessive extraction for irrigation purposes.
- **Rajasthan and Gujarat:** These states face significant water scarcity due to limited rainfall and inadequate water harvesting infrastructure.
- **Tamil Nadu and Karnataka:** These states have experienced frequent droughts and water scarcity due to inadequate rainfall and poor water management practices.

Consequences of Water Scarcity

The consequences of water scarcity in India are far-reaching and devastating. Some of the most significant impacts include:

- **Food Security:** Water scarcity can lead to reduced crop yields, impacting food security and the livelihoods of farmers.
- **Economic Growth:** Water scarcity can hinder economic growth by limiting the development of industries that rely heavily on water, such as textiles and manufacturing.
- **Human Health:** Inadequate access to clean water can lead to the spread of water-borne diseases, such as cholera and diarrhea.
- **Social Inequality:** Water scarcity can exacerbate social inequality, as the poor and marginalized may be disproportionately affected by lack of access to clean water.

Potential Solutions

To address the issue of water scarcity in India, the following potential solutions can be explored:

- **Water Conservation:** Implementing water-saving measures, such as rainwater harvesting and efficient irrigation systems, can help reduce water waste.
- **Sustainable Water Management:** Adopting sustainable water management practices, such as watershed development and aquifer recharge, can help replenish groundwater resources.
- **Climate-Resilient Infrastructure:** Investing in climate-resilient water infrastructure, such as flood-resistant bridges and drought-resistant crops, can help communities adapt to the impacts of climate change.

- **Community Engagement:** Raising awareness about the importance of water conservation and involving local communities in water management decisions can help build a sense of ownership and responsibility for water resources.

Government Initiatives

The Indian government has launched several initiatives to address the issue of water scarcity, including:

- **Jal Shakti Abhiyan:** A nationwide campaign to conserve water and promote water harvesting practices.
- **Atal Bhujal Yojana:** A scheme to improve groundwater management and promote water conservation practices.
- **National Water Policy:** A policy framework to promote sustainable water management practices and ensure equitable access to water resources.

Conclusion

The over digging of bores and absence of rainwater harvesting systems have significantly contributed to the water scarcity crisis in India. To address this issue, it is essential to promote sustainable water management practices, improve water harvesting infrastructure, and ensure equitable access to water resources. The government's initiatives in this regard are a step in the right direction, but more needs to be done to address this critical issue.

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Impact of Climate Change on Water Resources in India: Challenges, Socio-Economic Implications, and Strategies for Adaptation

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Abstract

India, home to over 1.4 billion people, is critically dependent on its water resources for agriculture, industry, drinking water, sanitation, and power generation. However, climate change is increasingly jeopardizing the country's water availability and quality. Rising global temperatures have altered precipitation patterns, reduced glacier stocks, and increased evaporation, exacerbating water scarcity nationwide. This chapter explores the impact of climate change on India's water resources, analyzing the scientific basis behind these changes, regional disparities in water availability, and the socio-economic consequences. The unpredictable monsoon patterns, the retreat of glaciers, and higher evaporation rates threaten surface and groundwater supplies. The socio-economic implications are profound, particularly for agriculture, public health, energy production, and migration. The chapter also discusses potential strategies for adaptation and mitigation, including efficient water management, infrastructure development, ecosystem restoration, and policy reforms. To ensure water security and sustainable development, India must adopt an integrated approach to water resource management, focusing on resilience, conservation, and cooperation at all levels.

Keywords: Climate Change, Water Resources, Agriculture, Water Scarcity, Adaptation and Mitigation

Introduction

India, with more than 1.4 billion inhabitants, depends significantly on its water resources for agriculture, industry, drinking purposes, sanitation, and power generation. With its agricultural dependence and major water-intensive sectors, water is critical to India's survival and prosperity. Climate change increasingly threatens the country's water quality and availability. As temperatures rise worldwide, India has to deal with unstable monsoons, declining glacier stockpiles, and increased water scarcity. This chapter explores how climate change affects India's water resources, the science involved in such changes, regional variations in water availability, and the socio-economic impacts of such changes.

The Science of Water and Climate Change in India

India's water comes from various reservoirs, such as rivers, groundwater, glaciers, and monsoons. It possesses some of the largest river systems in the world, like the Ganges, Brahmaputra, and Indus, but climate change is severely affecting the water in these systems.

1. Shifts in Precipitation Patterns

Climate change has resulted in extreme changes in the rainfall pattern in India. Whereas some areas have experienced heavy, out-of-season rains, others have experienced prolonged dryness. The monsoon, which accounts for almost 80% of India's yearly precipitation, has become irregular, with floods and droughts happening more frequently. These are consequences of a shift in atmospheric pressure patterns brought about by increased global temperatures. Rainfall uncertainty has significantly impacted farm productivity, water storage, and river runoff.

2. Greater Evaporation and Lower Water Storage

As temperatures rise, evaporation has accelerated, resulting in more water loss in rivers, lakes, and reservoirs. Furthermore, higher temperatures result in a greater demand for irrigation, making water usage even less efficient. Although groundwater remains a critical resource in India, particularly agriculture, the higher evaporation and lower groundwater recharge rates exacerbate water scarcity.

3. Dependency on Glacier Melting and Snowmelt

India's north, specifically in the Himalayas, is dependent on glacial melt to provide water to a majority of its rivers, such as the Ganges, Indus, and Brahmaputra. Glaciers in this area are quickly retreating due to increased temperature levels, risking the long-term integrity of snowmelt supplies. As the glaciers retreat, they will first contribute to increased river flow, which will cause flooding, but gradually, the flow will diminish, affecting water supply in crucial dry seasons, particularly for irrigation in agriculture and hydropower generation.

Regional Impacts on Water Resources

Climate change impacts on water resources in India are not the same because of its diversified geography. Varying climatic, topography, and socio-economic conditions result in different regional challenges.

1. North India (Himalayan Region and the Ganges Basin)

The Himalayan glaciers, which feed some of India's major rivers, are fast melting because of increasing temperatures. This may result in short-term spikes in river flows and flooding in places such as Uttarakhand and Himachal Pradesh. However, in the long term, the decrease in glacial melt will drastically decrease water availability, particularly in the dry summer. The Ganges, the lifeline of millions, might also come under immense stress over the next few decades.

2. Western and Central India (Maharashtra, Gujarat, and Madhya Pradesh)

These parts already experience extensive water stress due to less-than-sufficient rains and dependence on groundwater. Global warming should accentuate this even more by producing extended dry seasons, more intensely in places such as Maharashtra and Gujarat. Extended water deficiencies are impacting the economy, specifically in agriculture, for crop production for high-water-yield crops like sugarcane and straining already minimal amounts of groundwater sources.

3. South India (Tamil Nadu, Karnataka, Andhra Pradesh)

South India, especially the peninsular region, dramatically relies on the monsoon and inter-seasonal rivers. The region's irrigation systems, which depend on water storage from monsoon rains, are threatened by irregular rainfall. The Krishna, Cauvery, and Godavari rivers are experiencing growing competition for water, compounded by shifting precipitation patterns and growing demand. With increasing droughts, large portions of South India are experiencing a severe water shortage.

4. Bengal and Orissa in Eastern India

East India, particularly West Bengal and Orissa, witness's monsoon rain heaviness. Due to higher sea levels and intense monsoons that bring major flooding in low-lying regions, waterlogging and flooding are issues plaguing the area. Flooding has intensified and become a regular occurrence, destroying crops, homes, and infrastructure.

Socio-Economic Impacts

Climate change's effects on water resources in India have far-reaching socio-economic implications, and the effects are suffered by the vulnerable sections of society.

1. Agriculture

Agriculture employs over 50% of India's labor force and is based significantly on water. Climate change has challenged traditional cropping schedules, with unpredictable rainfall and extended droughts endangering food crops. Declining yields, particularly in water-hungry crops such as rice, sugarcane, and cotton, drive farmers further into financial hardship. The agriculture sector, which is mainly dependent on rain fed irrigation, is susceptible to shifts in precipitation regimes.

2. Water Scarcity and Public Health

Water scarcity is already a concern in large parts of India, and climate change will aggravate it. Groundwater over-extraction has caused aquifer depletion, with some areas, such as parts of Punjab and Rajasthan, experiencing groundwater tables dipping to unsustainable levels. In the urban context, the high population growth rate and the effects of climatic change through water stress have decreased water accessibility for household uses. This contributes negatively to the health of citizens, as it results in a high incidence of waterborne disease outbreaks based on contaminated water sources.

3. Energy Generation

India's energy generation is similarly water-intensive. Hydropower generates approximately 14% of the nation's total electricity generation. However, decreased river flow, altered precipitation regimes, and lower snowmelt from glaciers jeopardize hydropower's future promise. Further, the increase in temperatures affects the efficiency of thermal power stations, which depend on water for cooling.

4. Migration and Conflicts

Water scarcity caused by climate change can cause internal displacement and migration, especially from rural to urban regions. As agricultural yields are reduced due to water scarcity, most farmers have to leave their farms, causing rural-to-urban migration. Moreover, competition for water resources in transboundary river basins (e.g., the Indus and Ganges basins) may heighten tensions among states and nations, resulting in possible conflicts.

Strategies for Adaptation and Mitigation

India must adopt integrated water management approaches that address sustainability, resilience, and cooperation to adapt to and mitigate the effects of climate change.

1. Water Conservation and Efficient Use

India must embrace water-saving technologies in agriculture, including drip irrigation and rainwater harvesting, to prevent water wastage. Moreover, promoting water-efficient technologies in industries and urban centers will help preserve this precious resource.

2. Infrastructure Development

Investment in climate-resilient water infrastructure, including improved water storage, flood protection, and efficient irrigation, will cushion the effects of floods and droughts. Rehabilitation of existing irrigation schemes and development of rainwater harvesting will reduce reliance on groundwater.

3. Ecosystem Restoration

Wetlands, mangroves, and watersheds can be restored to enhance water quality, increase water retention, and create natural flood and drought buffers. Ecosystem-based water management should be given priority to reduce climate impacts and conserve biodiversity.

4. Policy and Governance

India must implement holistic water policies incorporating climate change adaptation measures. Collaborative governance at the federal, state, and local levels is necessary to manage common water resources. Transboundary water treaties with neighboring nations, especially on the Indus and Ganges River basins, are required to avoid conflicts and ensure the fair sharing of water resources.

Conclusion

Climate change seriously threatens India's already precarious water supply;

consequently, it affects public health, energy generation, agriculture, and socioeconomic stability. With water as the fulcrum of social and economic well-being, it is of utmost importance for India to effectively address the issues posed by climate change to safeguard its prosperity. The consequences of climate change, such as changed precipitation patterns, more severe droughts, and more flooding, directly impact water availability and allocation; this has enormous implications for livelihoods and food security, especially for the vulnerable. To address this complex challenge, India's approach should be integrated, involving scientific work, technical advancement, ethical water management techniques, and international cooperation. We should invest in research and development for better insight into climate change effects on hydrological cycles and making data-driven policy decisions. Some other practices include technological developments, rainwater harvesting, wastewater treatment, and efficient irrigation systems, which maximize existing water supplies and minimize wastage. Sustainability must also be developed by raising community awareness and promoting participation in water conservation initiatives. Due to the transboundary nature of many rivers and water bodies, cooperation with neighboring countries is also essential. Joint management policies will allow countries to work together to address shared water concerns and enhance regional water security. In conclusion, a comprehensive strategy is needed within the broad framework of scientific, technological, and community-based approaches supported by international cooperation to ensure India's water security amidst climate uncertainty. All of these initiatives shall build India's path toward a resilience-building exercise against nature that can help preserve natural resources for future generations while promoting environmental sustainability and economic backing.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Water Pollution and Quality Management in India: Challenges, Impacts and Sustainable Solutions

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Abstract

Water pollution and quality in India have emerged as major issues impacting environmental sustainability and public health. The immense geography of the country, with its large number of rivers, lakes, and groundwater resources, has traditionally supplied critical water for agriculture, industry, and human use. Yet, fast industrialization, urbanization, farming practices, and inefficient waste management have caused the deterioration of these water bodies. This chapter explores the dynamics of water pollution in India, identifying the primary causes, including industrial effluents, untreated sewage, agricultural runoff, and solid waste disposal. The consequences of water pollution are far-reaching, impacting human health, economic productivity, and biodiversity. Waterborne ailments, long-term diseases due to pollutants like heavy metals and pesticides, and the destruction of aquatic organisms are some of the significant environmental and health problems arising from water-polluting sources.

Governments in India have attempted measures to curb water pollution through multiple government programs like the National Mission for Clean Ganga and Swachh Bharat Mission, in addition to local community programs that aim at cleansing and maintaining water bodies. Even with progress, there are challenges, especially in policy enforcement and the practice of sustainable methods. The chapter highlights the necessity of an integrated approach that encompasses the reinforcement of policy frameworks, investment in technology for wastewater recycling and treatment, public awareness, and

community involvement in water management. Only by working together can India secure the sustainable management of its water resources, safeguard public health, and restore the environmental balance needed for the health of future generations.

Keywords: Water Pollution, Water Quality, Industrial Effluents, Agricultural Runoff, Sustainable Water Management.

Introduction

Water is a vital resource at the heart of all life. It is fundamental in determining ecosystems, maintaining agriculture, underpinning industrialization, and delivering drinking water for everyday human use. In India, with its extensive and varied geography, water holds a position of critical significance, not merely for sustenance but for the development of its economy as well. Yet, the quality of Indian water has been increasingly put at risk by pollution, non-sustainable extraction, and inferior management practices. This chapter discusses the dynamics of water quality and pollution in India, looking at the causes, effects, and emerging trends and tackling the challenges arising from the evolving patterns of water pollution.

The Significance of Water Quality in India

Water quality directly impacts the health, productivity, and well-being of any given society. In India, water is particularly important given the population size, the large agriculture sector, and the pace of industrialization. Clean water is essential for human health, and its quality impacts a broad array of sectors, from agriculture to industry to everyday life. And yet, for all its importance, India has numerous challenges in keeping water quality high. One of the leading causes of the nation's water woes is the irony of water abundance. India boasts the world's most prominent rivers in terms of water volume: The Ganges, Yamuna, Brahmaputra, and Godavari. These rivers and many lakes, ponds, and reservoirs were the backbone of the nation's agriculture, industry, and civilization in the past. However, the nature of water in such bodies has been deteriorating steadily over time due to increasing population, augmented industrial activities, urbanization, and lack of adequate waste disposal policies.

Water Pollution in India: A Growing Concern

Water pollution is one of the most serious issues that India is confronting today. A 2018 National Green Tribunal (NGT) report states that almost 70% of India's water resources are polluted with untreated sewage, industrial effluent, and agricultural runoff. All these pollutants are a major risk to human health and the environment. Some of the primary causes of water pollution in India are:

Industrial Effluents: With accelerated industrialization, India has experienced a sudden rise in the discharge of poisonous chemicals, heavy metals, and other industrial effluents into its water bodies. This pollution is usually aggravated by the absence of proper treatment plants in most industries, resulting in the extensive contamination of rivers and lakes. In industrial centres such as Mumbai, Delhi, and Kolkata, untreated or partially treated industrial effluents drain into water bodies, contaminating them with lead, mercury, arsenic, and other toxic chemicals.

Sewage and Wastewater: A significant chunk of India's population resides in urban cities with nonexistent or dilapidated sewage and wastewater management systems. An estimated 62 million liters of untreated sewage is discharged into India's water bodies daily. Sewage systems in urban centers such as Delhi, Mumbai, and Chennai are usually congested and outdated, with untreated sewage directly dumped into rivers, lakes, and streams.

Agricultural Runoff: Farming is a source of livelihood for many Indians, but it is also the most common source of water pollution. Large-scale use of chemical fertilizers and pesticides results in runoff, which pollutes the surrounding water bodies with nitrogen, phosphorus, and toxic chemicals. It results in eutrophication, where too many nutrients in the water cause the formation of toxic algae, reducing the oxygen content and killing aquatic organisms.

Disposal of Solid Waste: Solid waste disposal is another problem of great concern. Rivers, especially the Ganges, suffer heavily from unplanned dumping of plastic waste, chemicals, and untreated refuse. Religious practices, whereby offerings are made in the form of gifts to rivers and water bodies, tend to contribute to pollution.

Impact of Water Pollution

The impacts of water pollution in India are long-reaching and dire, affecting human and environmental health. Polluted water supplies are the key drivers of waterborne diseases such as cholera, dysentery, and typhoid, which kill thousands of people each year. According to the World Health Organization (WHO), waterborne diseases cause an estimated 1.5 million deaths every year in India.

Health Effects: Polluted water causes various health problems, especially in rural communities with scarce clean water. Heavy metals such as arsenic and lead, which are present in most contaminated water, cause a variety of chronic diseases, including cancer, kidney impairment, and developmental disabilities in children. The presence of pesticides and fertilizers in drinking water also has long-term health effects, including neurological disorders and hormone imbalance.

Economic Impacts: Water quality degradation also has significant economic impacts. Water-dependent agriculture is negatively impacted by water source pollution. Crop yields are impacted by poor water quality, as irrigation water tends to have pollutants that harm crops and soil fertility. In addition, water-dependent industries like textiles, chemicals, and food processing experience interruptions due to the unavailability of usable water.

Ecological Impacts: The ecological health of rivers, lakes, and aquatic environments is also threatened. Pollution causes biodiversity loss, as many aquatic species cannot thrive in contaminated water. One of India's most sacred rivers, the Ganges, contains several marine species, such as the Ganges River dolphin, which is found to be under threat. The degradation of this ecosystem has cascading effects on livelihoods in the locality, as fishingdependent communities cannot maintain their lifestyle.

Efforts to Combat Water Pollution

Understanding the gravity of the water pollution situation, the Indian government and other non-governmental organizations (NGOs) have launched several programs to combat water pollution. Some of the most notable initiatives are:

National Mission for Clean Ganga (NMCG): Launched in 2014, the NMCG is the most ambitious government program to clean the Ganges River. The mission aims to minimize pollution by sewage treatment plants, solid waste management, and plantation along the river. Although the program has made some headway in some areas, critics say it requires more substantial implementation and more emphasis on industrial effluents.

Swachh Bharat Mission (Clean India Mission): Initiated in 2014, the Swachh Bharat Mission targets enhancing sanitation and minimizing the creation of untreated waste. By improving waste management infrastructure, encouraging rural sanitation, and generating awareness, the mission indirectly helps enhance water quality.

Water Quality Monitoring: The Central Pollution Control Board (CPCB) periodically monitors the water quality of rivers, lakes, and other water bodies throughout the country. With programs such as the National Water Quality Monitoring Programme (NWQMP), India can determine the levels of different pollutants in water and implement corrective measures where required.

Community-led Initiatives: Various local communities and grassroots organizations are rejuvenating water bodies. These efforts, sometimes with the support of NGOs, include community involvement, education, and the active participation of local citizens in cleaning and conserving water sources. Efforts such as the "Clean Yamuna Campaign" in Delhi, "Save Ganga" in Uttar Pradesh, and "River Rejuvenation Projects" in Tamil Nadu have gained large-scale support and have been yielding positive outcomes.

Policy Frameworks: The Indian government has enacted various laws and regulations to safeguard water resources. The Water (Prevention and Control of Pollution) Act of 1974 and the Environment Protection Act of 1986 have been at the core of controlling and regulating water pollution. Implementation has, however, proved difficult because of the absence of enforcement mechanisms and political will.

The Way Forward: Sustainable Water Management

Though considerable efforts have been put into tackling water pollution in India, the journey ahead is still full of challenges. The way forward from these challenges is through the adoption of sustainable water management practices, which include:

Wastewater Recycling and Treatment: Effective implementation of wastewater treatment systems, particularly in cities, is essential. This would lower the volume of untreated sewage discharged into water bodies. Recycling and reusing treated wastewater for industrial, agricultural, and non-potable purposes could also alleviate pressure on freshwater resources.

Public Education and Awareness: It is crucial to generate awareness of the need for water conservation and the prevention of water pollution. Public education campaigns, local participation, and encouraging sustainable agriculture can effectively control water pollution locally.

Strengthening Policies and Enforcement: Stricter enforcement of water pollution control laws and policies is necessary to reduce industrial effluent discharge and regulate agricultural runoff. Strengthening the capacity of institutions responsible for water quality management, such as the CPCB and state pollution control boards, is essential for effective implementation.

Integrated Water Resource Management: For sustainable water use, integrated water management systems must consider the economic, environmental, and social implications. These systems must also address supply and demand management so that water is used efficiently and equitably in different sectors.

Conclusion

Water quality and pollution processes in India are a profound challenge, not just for environmental sustainability but also for public health. The nation's previously plentiful and comparatively pristine water supplies are becoming increasingly vulnerable to industrial effluent, agricultural runoff, and urban contamination. Such pollutants, such as untreated sewage, chemicals, heavy metals, and plastics, have caused the pollution of rivers, lakes, and groundwater, seriously impacting ecosystems and human health. Waterborne illnesses caused by contaminated water remain a significant source of morbidity and mortality, particularly in rural communities where safe drinking water is not readily available.

A multifaceted, holistic solution to this crisis must be adopted. Policy reforms should be strengthened to implement more stringent regulations on industrial effluents, agricultural runoff, and waste disposal. Technological advancements in water treatment, wastewater reuse, and pollution control can curtail contamination and improve the quality of water bodies. Community involvement is also crucial for the sustainable management of water resources. Public education, water conservation, and local communities' engagement in water conservation initiatives can reduce pollution and improve a sense of responsibility among people.

Finally, stringent enforcement of current regulations is imperative. With weak enforcement policies, legislation intended to regulate pollution becomes useless, and industries and people can ignore environmental standards. Overall, protecting India's water is everyone's business. Only together—government institutions, industries, and people—can India protect its water future and provide health for its people and the planet for generations.

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A Review on Technological Innovations in Water Management: Solutions for a Global Water Crisis

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Abstract

Water is a fundamental resource essential for human survival, economic growth, and environmental sustainability. However, increasing water demand, climate change, and pollution present significant challenges to its availability and quality. Technological innovations have emerged as pivotal solutions for effective water management, offering advanced methods to monitor, conserve, and utilize water resources efficiently. This paper explores key technological advancements, including the use of remote sensing, Geographic Information Systems (GIS), smart irrigation, desalination, and Artificial Intelligence (AI). These innovations provide real-time data, predictive analytics, and automated solutions that enhance decision-making and resource allocation. The integration of these technologies supports water security, promotes sustainability, and mitigates the impacts of natural disasters. Through case studies and practical applications, this paper highlights how technological solutions are transforming water management practices globally. The findings underscore the importance of continued investment in innovative technologies to address the growing challenges of water scarcity and ensure a sustainable water future.

Keywords: Water Management, Technological Innovations, Remote Sensing, GIS, Smart Irrigation, Desalination, Artificial Intelligence, Sustainability, Water Security, Climate Change.

Introduction

Water is a fundamental resource for human survival, economic growth, and environmental sustainability. However, increasing water demand, climate change, and pollution pose significant challenges to its availability and quality. The global water crisis poses significant threats to human health, economic development, and environmental sustainability due to increasing demand, climate change, and pollution. With the world's population projected to reach 9.7 billion by 2050, freshwater resources are under immense pressure, exacerbated by agriculture, industry, and urbanization. Climate change disrupts the water cycle, affecting availability and quality, while pollution from agricultural runoff, industrial waste, and domestic sewage degrades water quality, harming human health and ecosystems. In response to these challenges, technological innovations have emerged as crucial tools for effective water management. By integrating advanced technologies, it is possible to monitor, conserve, and efficiently utilize water resources.[1]

Why Water Management is Crucial

1. Ensuring Water Security:

Water management helps ensure reliable access to clean water for drinking, sanitation, hygiene, agriculture, industry, and ecosystems.

2. Mitigating Climate Change:

Effective water management strategies help adapt to climate change by enhancing water storage, reducing flood risks, and promoting water-efficient practices.

3. Protecting Water Quality:

Water management involves implementing measures to prevent pollution, treating wastewater, and maintaining healthy watersheds.

4. Supporting Economic Development:

Water management is essential for agriculture, industry, and energy production, which are critical to economic growth and development.

5. Maintaining Ecosystems:

Water management helps preserve aquatic ecosystems, biodiversity, and ecosystem services, which are vital for human well-being.

Key Benefits of Water Management:[2]

1. **Improved Water Efficiency:** Water management promotes water-saving practices, reducing waste and optimizing water use.
2. **Enhanced Water Quality:** Effective water management ensures clean water for human consumption, agriculture, and ecosystems.
3. **Increased Food Security:** Water management supports irrigation, agriculture, and food production, reducing the risk of food shortages.
4. **Reduced Flood and Drought Risks:** Water management helps mitigate the impacts of extreme weather events, protecting communities and infrastructure.
5. **Supports Human Health:** Access to clean water and sanitation, ensured through water management, is essential for preventing water-borne diseases and promoting public health.

Implementing Effective Water Management:

1. **Integrated Water Resource Management (IWRM):** Adopt a holistic approach that considers social, economic, and environmental factors.
2. **Water-Efficient Technologies:** Promote the use of water-saving technologies and practices in agriculture, industry, and urban areas.
3. **Water Conservation:** Educate communities on the importance of water conservation and promote water-saving behaviors.
4. **Watershed Management:** Protect and restore watersheds to maintain water quality, prevent erosion, and support biodiversity.
5. **Climate-Resilient Water Infrastructure:** Invest in water infrastructure that can withstand the impacts of climate change, such as sea-level rise and extreme weather events.

Innovations such as remote sensing, Geographic Information Systems (GIS), smart irrigation systems, desalination techniques, and Artificial Intelligence (AI) have transformed traditional water management practices. These technologies provide real-time data, predictive analytics, and automated solutions to enhance decision-making and resource allocation. With their application, governments, industries, and farmers can address water scarcity, improve water quality, and mitigate the impacts of natural disasters like floods and droughts. .[3]

Furthermore, AI-driven models analyze vast datasets for better forecasting, while satellite-based remote sensing offers invaluable insights into hydrological patterns. Smart irrigation optimizes agricultural water use, reducing wastage and promoting sustainability. Desalination technologies contribute to increasing freshwater supplies in arid regions. Together, these innovations play a pivotal role in achieving water security and supporting sustainable development goals. .[4]

This article explores key technological advancements in water management, with a focus on their applications, benefits, and future prospects. Relevant studies and reports provide evidence of their effectiveness and highlight their potential to revolutionize water resource management across the globe.

Materials and Methods

This review was conducted using a systematic approach to collect, analyze, and synthesize relevant information on technological innovations in water management. The following methods were applied:

1. Literature Search and Data Collection

A comprehensive search was conducted using databases such as Google Scholar, Science Direct, ResearchGate, and PubMed. Keywords used for the search included "Water Management Technologies," "Remote Sensing in Water Management," "Smart Irrigation Systems," "Desalination Technologies," and "AI in Water Management."

Peer-reviewed journal articles, conference proceedings, government reports, and case studies published in the last two decades were prioritized.

2. Selection Criteria

Studies were selected based on their relevance to technological advancements in water management. Preference was given to articles discussing practical applications, case studies, and comparative evaluations of different technologies.

Duplicates, non-English publications, and articles lacking clear methodologies were excluded.

3. Data Analysis

Collected data was categorized based on technological innovations, their applications, and the geographic regions of implementation. Comparative analysis was conducted to assess the effectiveness, sustainability, and scalability of different technologies. Statistical data, if available, was extracted to evaluate the quantitative impact of technologies on water management.

4. Synthesis and Interpretation

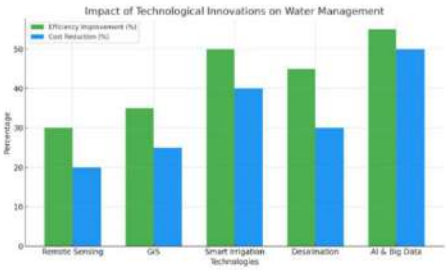
The findings from the reviewed literature and case studies were synthesized to provide insights into the current state of technological innovations in water management.

Recommendations for future research and policy implementation were formulated.

Results

Modern Innovations in Water Management:

1. **Internet of Things (IoT) Sensors:** IoT sensors monitor water quality, pressure, flow rate, and other parameters in real-time, enabling prompt action to address issues.
2. **Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML algorithms analyze data from IoT sensors and other sources to predict water demand, detect leaks, and optimize water treatment processes.
3. **Big Data Analytics:** Advanced data analytics platforms process large datasets to identify trends, patterns, and insights that inform water management decisions.
4. **Cloud Computing:** Cloud-based platforms enable remote monitoring, data storage, and collaboration among stakeholders, facilitating more efficient water management.
5. **Mobile Applications:** Mobile apps provide citizens with convenient access to water quality information, leak reporting tools, and personalized water usage data.
6. **Drones and Satellite Imaging:** Drones and satellite imaging technologies monitor water resources, detect leaks, and assess water quality, reducing the need for physical inspections.
7. **Advanced Water Treatment Technologies:** Innovations like membrane bioreactors, advanced oxidation processes, and nanotechnology-based treatments improve water quality and reduce energy consumption.
8. **Smart Water Grids:** Smart water grids integrate IoT sensors, AI, and data analytics to optimize water distribution, reduce leaks, and improve overall efficiency. .[5]



Graph 1: Impact of Various Technological Innovations on Water Management.

Remote Sensing and GIS Applications in Hydrology

Remote sensing and Geographic Information Systems (GIS) play a pivotal role in hydrological studies. By utilizing satellite imagery and aerial surveys, these technologies provide real-time data on precipitation, soil moisture, and groundwater levels. GIS integrates this data for spatial analysis, aiding in watershed management, flood forecasting, and drought prediction. Additionally, remote sensing supports climate modeling by tracking changes in water bodies and snowmelt patterns. .[6]

Remote Sensing (RS) Applications:

1. **Land Use/Land Cover (LULC) Mapping:** RS helps identify and map different land use/land cover types, such as forests, agricultural areas, and urban regions.
2. **Soil Moisture Estimation:** RS techniques estimate soil moisture levels, which is essential for hydrological modeling and water resource management.
3. **Flood Mapping and Monitoring:** RS enables rapid flood mapping and monitoring, helping emergency responders and water resource managers.
4. **Water Quality Assessment:** RS helps assess water quality by estimating parameters like chlorophyll, suspended sediments, and water temperature.
5. **Snow Cover and Glacier Monitoring:** RS monitors snow cover and glacier extent, which is crucial for hydrological modeling and water resource management. .[7]

GIS Applications:

1. **Watershed Delineation:** GIS helps delineate watersheds, which is essential for hydrological modeling and water resource management.
2. **Hydrological Modeling:** GIS enables the development of hydrological models, which simulate water flow, sediment transport, and water quality.
3. **Flood Risk Mapping:** GIS helps create flood risk maps, which identify areas prone to flooding and support emergency planning and response.
4. **Water Resource Management:** GIS supports water resource management by integrating data on water supply, demand, and quality.
5. **Environmental Impact Assessment:** GIS helps assess the environmental impact of hydrological projects, such as dams and water diversion schemes.

Integration of RS and GIS

1. **Data Integration:** RS data is integrated with GIS to analyze and visualize hydrological phenomena.
2. **Hydrological Modeling:** RS data is used to parameterize and validate hydrological models developed in GIS.
3. **Flood Mapping and Monitoring:** RS data is integrated with GIS to rapidly map and monitor floods.
4. **Water Resource Management:** RS data is used to support water resource management decisions made in GIS.

Benefits:

The integration of Remote Sensing (RS) and Geographic Information System (GIS) in hydrology offers numerous benefits, including improved accuracy of hydrological models and water resource management decisions. RS and GIS enable rapid data collection, analysis, and visualization, increasing the efficiency of hydrological studies and water resource management. This integration also provides valuable insights, supporting informed decision-making in hydrology and water resource management. Furthermore, RS and GIS are cost-effective alternatives to traditional hydrological data collection methods, making them a valuable tool for managing water resources. .[8]

Smart Irrigation and Precision Agriculture

Smart irrigation systems leverage sensors, weather data, and soil moisture measurements to optimize water usage. Drip and sprinkler irrigation methods are integrated with automated controllers that ensure crops receive the right amount of water at the right time. Precision agriculture employs drones and satellite imaging to monitor crop health, predict irrigation needs, and minimize water wastage. This sustainable approach boosts agricultural yield while conserving water. .[9]

Feature of Smart Irrigation:

1. **Real-time Monitoring:** Sensors monitor soil moisture, temperature, and humidity, providing real-time data for irrigation decisions.
2. **Automated Irrigation Control:** Smart irrigation systems adjust water application based on weather forecasts, soil conditions, and crop water requirements.
3. **Precision Watering:** Smart irrigation delivers water directly to the roots, reducing evaporation and runoff.
4. **Water Conservation:** Smart irrigation optimizes water use, reducing waste and conserving this valuable resource.

Precision Agriculture

1. **Crop Monitoring:** Sensors, drones, and satellite imaging monitor crop health, growth, and development.
2. **Variable Rate Application:** Precision agriculture applies fertilizers, pesticides, and water at variable rates, optimizing crop yields and reducing waste.
3. **Yield Mapping:** Precision agriculture creates detailed yield maps, helping farmers identify areas for improvement.
4. **Data-Driven Decision Making:** Precision agriculture provides farmers with data-driven insights, enabling informed decisions on crop management, irrigation, and inputs.

Benefits

Smart irrigation and precision agriculture offer numerous benefits, including increased crop yields through optimized crop growth, water conservation by reducing waste, reduced chemical use through precision fertilizer and pesticide application, and improved farm efficiency by streamlining operations and reducing labor and input costs. These benefits are made possible by technologies such as IoT sensors, which monitor soil conditions, drones and satellite imaging, which capture high-resolution crop data, and Artificial Intelligence (AI), which analyzes data to provide insights for informed decision-making.

Desalination and Alternative Water Sources

Desalination technologies convert seawater into freshwater through methods like reverse osmosis and electrodialysis. Innovations in membrane technology and energy recovery systems have made desalination more energy-efficient and cost-effective. Additionally, treated wastewater, rainwater harvesting, and atmospheric water generation provide alternative water sources, especially in arid regions. .[10]

Desalination and Alternative Water Sources

Desalination

1. **Reverse Osmosis (RO):** Uses semipermeable membranes to remove salt and other minerals from seawater.
2. **Multi-Stage Flash Distillation (MSF):** Uses heat to vaporize seawater, then condenses the vapor to produce fresh water.
3. **Multi-Effect Distillation (MED):** Uses a series of vessels to distill seawater, producing fresh water.

Benefits

1. **Diversified Water Supply:** Reduces dependence on traditional water sources.
2. **Increased Water Security:** Enhances water availability, especially in water-scarce regions.
3. **Reduced Environmental Impact:** Decreases the strain on natural water sources.
4. **Economic Benefits:** Creates new industries, jobs, and revenue streams.

AI and Big Data in Water Monitoring and Forecasting. [11, 12,13 14]

Artificial Intelligence (AI) and Big Data analytics enhance water management by analyzing vast datasets from sensors, satellites, and historical records. AI algorithms predict water demand, detect leaks in distribution networks, and optimize reservoir operations. Machine learning models forecast droughts, floods, and water quality issues, enabling proactive decision-making. Furthermore, AI-powered chatbots and applications provide real-time water usage recommendations to consumers.

Applications of AI and Big Data

1. **Predictive Modeling:** AI algorithms analyze historical data to predict water demand, flow rates, and quality.
2. **Real-time Monitoring:** Big Data analytics process real-time sensor data to detect anomalies and alert authorities.
3. **Water Quality Forecasting:** AI models predict water quality parameters, enabling proactive measures to prevent pollution.
4. **Flood Forecasting:** Big Data analytics and AI models predict flood events, enabling timely evacuations and emergency response.

Benefits

1. **Improved Accuracy:** AI and Big Data analytics enhance predictive modeling accuracy, reducing uncertainty.
2. **Real-time Decision-Making:** Big Data analytics enable real-time decision-making, ensuring prompt response to water-related events.
3. **Optimized Water Management:** AI-optimized predictive models improve water resource allocation, reducing waste and conserving water.

4. **Enhanced Public Safety:** AI-powered flood forecasting and water quality monitoring ensure timely warnings, protecting public health and safety.

Technologies

1. **Machine Learning (ML) Algorithms:** Analyze large datasets to identify patterns and make predictions.
2. **Deep Learning (DL) Models:** Process complex data, such as sensor readings and satellite images.
3. **Internet of Things (IoT) Sensors:** Collect real-time data on water parameters, such as flow rate, quality, and level.
4. **Cloud Computing:** Enables scalable and on-demand processing of large datasets.

Conclusion

Effective water management is imperative to ensure water security, mitigate climate change impacts, and support sustainable development. Technological advancements such as remote sensing, GIS, AI, smart irrigation systems, and desalination technologies offer innovative solutions to address water scarcity, improve water quality, and optimize resource allocation. These tools enable data-driven decision-making, enhancing resilience against floods, droughts, and pollution. Furthermore, integrating these technologies into water management strategies can significantly contribute to achieving global water sustainability goals. Moving forward, fostering collaboration between governments, industries, and research institutions will be essential to maximize the potential of these innovations and secure a reliable water supply for future generations.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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A Critical Study on The Problem of Spreading Waterborne Diseases Through Dissolving Chemicals and Its Effect in Vichumbe Village

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Abstract

The earth is the only planet in the solar system where we are able to discover water. The world's primary commodity for existence is water. Access to pure drinking water has historically been one of the cornerstones of superb public health. Polluted water can also be an indicator of illnesses transmitted by water; consequently, safe water is not just limited to drinking water. The treatment of water is needed due to the value of hygienic and chemical purity in water for human health. Due to the probability that an array of pathogenic microorganisms that because waterborne diseases may be introduced through contact by drinking water. The most significant obligation is to continually evaluate the water supply system's drinking water quality. The current study looks on the poor quality of tanker water that arrives to several populations in Vichumbe Village during the summer, rainy season, and winter. In this study, the level of ph., temperature, viscosity, hardness, alkaline levels, chlorides, fluorides, nitrate, iron, and silica in water samples are among the various physio- chemical characteristics as that are evaluated. This water specimen will show that the spread of waterborne illnesses such diarrhea because typhoid fever, and dysentery can be triggered by poor water quality.

Keywords: Water Quality, Infectious Agent, Water Utility, Waterborne Disease

Introduction

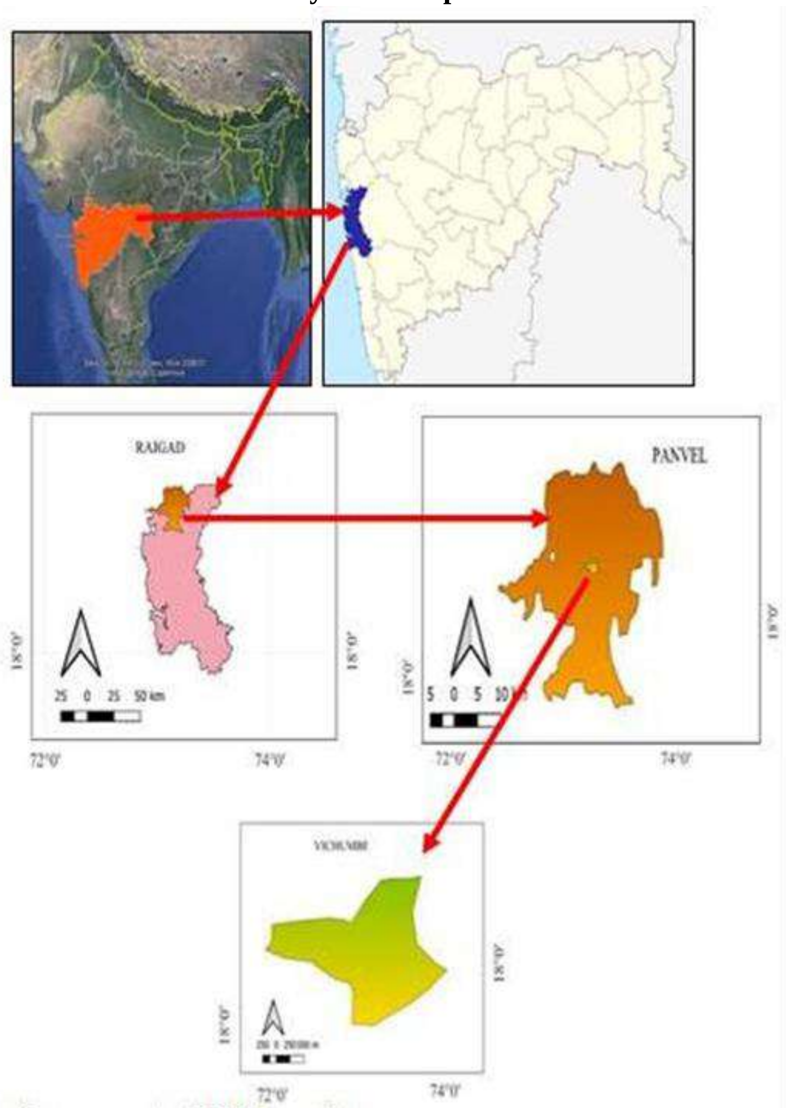
Water is one of the most important things which is required for life and in the universe the earth is only planet which is having water. Water means the clear liquid, without color and taste, which falls from the sky as rain and it is necessary for animals and plant

life. Waterborne means which is carried or transmitted by water and especially by drinking water. Waterborne illness is because of disease-causing microbes or pathogens. Many developing countries do not have proper water treatment plants, especially in rural areas. In some places because of less water resources people have neither the money nor the time to afford purifiers or other water treatment mechanisms. These waterborne diseases affect mainly the children and other people due to poor hygiene and weak immunity.
A report by the World Health Organization, 159 million people depend on surface water. An essential source of drinking water is not accessible to nearly 844 million individuals. Protozoa, bacteria, intestinal parasites, and other microorganisms that penetrate the human system through the digestive tract walls can all cause disorders that are passed on by water. Whether bathing, washing, drinking water, or eating food that was brought into contact with contamination, illnesses transmitted by water can spread. Viruses are responsible for the spread of a variety of aquatic infections. Other various waterborne diseases are spreading because of viruses. Minimal daily water we need its range between 1 to 3L per person per day for hydration, perhaps as little as 2-3L for food preparation, 6-7L for personal hygiene, and 4-6L for laundry. According to UNICEF (2015), just 660 million people, or 9% of the population of the globe, donot have access to "improved" sources of drinking water. In 1990, this number was 24%. 90% of child deaths occurred over the past 40 centuries. In it, pneumonia, malaria, newborn illnesses, and dysentery are the main causes of mortality.

Geographical location of vichumbe
Vichumbe coordinates are as follows:
Longitude: 73.132543 E
Latitude: 18.987123 N
The GPS position is 18059'N and 7307'E.

Study Area
Vichumbe is a town in the Panvel Taluka in the Raigad District of the Indian state of Maharashtra. It is located near New Panvel. Vichumbe town is a part of the cidco Smart city NAINA project. There are 6,332 people living there in total.2820 women and 3,512 men make up the remainder of the population. Vichumbe Village has a 76.69% literacy rate, with 80.67% men and 71.74% females being literate. In the neighborhood of Vichumbe, there are around 1624 homes. Vichumbe Gramm Panchayat is the government organization, and Mrs. Namrata Akash Patil is the Sarpanch. Marathi is the official language. It is a part of the Konkan area. There is a probability of humidity in the air because it is close to the Arabian Sea. It is located 5 km from Panvel's district headquarters. (Tahsildar Office) and 69 km from Alibag, the district headquarters. According to data from 2009, Vichumbe village also has a gram panchayat. Latitude 18.98 North and Longitude 73.13 are the geographic boundaries of the region. It covers 119 Hectares of land. A total of 75 hectares are utilized for agriculture, of which 75 hectares are irrigated and 24 hectares are not. It experiences 133.46 wet days (36.56% of the time) and receives around 261.01 millimeters (10.28 inches) of precipitation yearly.

Study Area Map:



Weather and environment of Vichumbe

Vichumbe endures tropical monsoons. Vichumbe's average temperature ranges from 28 to 35 degrees. The average humidity is 64%, there are a total of 217 dry days each year, and the UV index is 7. The indicator reads 1011 megabytes. About 49% humidity is deemed to be very humid.

Water scarcity in Vichumbe

The primary reason is Cidco's sewage water, which has been polluting the nearby Gadhi river and creating the worst state of water resources. In particular areas, the water does not reach all the way to the end during the summer due to low levels of water and low water pressure, and it could require more machinery to generate sufficient force there. In the meanwhile, depending on tankers carrying water to make up for the

In the meanwhile, depending on tankers carrying water to make up for the water supply deficit is hurting family units due to the costly prices they ask.

Tap water supply

Tanker water supply in study area

Statement of problem

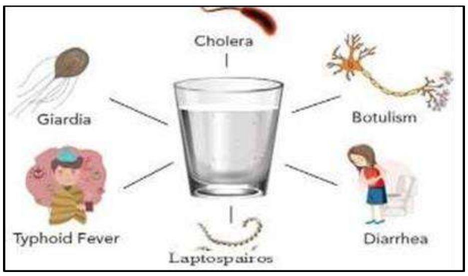
The most crucial component for life is water. We should drink enough water each day for good health. Good Dehydration may affect your ability to think clearly, cause your body to overheat, and result in constipation and kidney stones. Dehydration can be prevented by drinking water. It is being noted that the majority of tankers delivering water to people get their water from drainage systems; this water may be harmful to your health and in some instances may even cause serious medical conditions. My research focuses on the tanker water and how it affectsthe health of the Vichumbe village residents.

Origin of Research Problem

Vichumbe village is located in Panvel tahsil of Raigarh district in Maharashtra, India. It is situated 5km away from sub-district headquarter Panvel (tehsildar office) and 69km away from district headquarter Alibag. As per 2009 stats, Vichumbe village is also a gram panchayat.

The total geographical area of village is 119 hectares. Vichumbe has a total population of 6,332 peoples, out of which male population is 3,512 while female population is 2,820. Literacy rate of Vichumbe village is 76.69% out of which 80.67% males and 71.74% females are literate. There are about 1,624 houses in Vichumbe village. Whether water is utilized for drinking, household usage, food production, or recreational activities.

This service is particularly critical in healthcare institutions where a lack of sufficient water, sanitation, and hygiene services exposes both patients and employees at danger of infection andsickness. There is a water shortage in the area where I live.



There is no municipal corporation water in Vichumbe village. Consequently, many rely on tankers and ground water. It was noticed that both our society and the other societies in Vichumbe village had a high sickness rate. In such locations, cholera, diarrhea, dysentery, hepatitis A, and typhoid are prominent diseases. After the doctor had examined you, drinking heated water was suggested. Therefore, I have determined that the effects of dissolved chemicals in drinking water on the residents of Vichumbe Village should be the subject of my investigation.

Water Borne Diseases

Importance of Research

The health of people is seriously threatened by poor water quality. Every year, 2 million individuals lost their lives due to diarrheal illness alone. According to estimates, 88% of the load falls mostly on children in countries that are developing and is attributed to hazardous water supply, sanitation, and hygiene. My study is crucial for preventing the spread of this sickness. Numerous lives can be saved through supplying more people with access to clean drinking water, appropriate sanitary facilities, and better hygiene practices.

Objectives

- To analyze the supply of drinking water
- To Assement of Water Quality
- To find out the Health Impact Assessment.

Methodology

This study aims to study the impact of impure water in Vichumbe village, to study the supply of water in study area. For studying this impact, we are collecting data from various primary and secondary sources. For analyzing the impact of impure water and fault in function of supply I collect data using Questionnaire in form of Google forms. Interviews with the village people, tanker suppliers and resource water owner.

Assumptions

1. Assumptions are those things, which is possible or accepted as true by researcher and peers who will read the dissertation.
2. It applies only on the people of Vichumbe Village
3. Those people will use only Tanker water for drinking and other purposes.
4. Those people are getting sick frequently.
5. This is the study of finding impact of tanker water.

Assumptions are those things, which is possible or accepted as true by Researcher and peers who will read your dissertation.

Limitations

1. This research is based on the citizen of Vichumbe village only
2. This research is analyzing tanker waters quality.
3. This research will analyze the waterborne disease only.

Hypothesis

There is no significant relationship between the presences of dissolved chemicals in water Sources and the incidence of waterborne diseases in Vichumbe Village. The presence of dissolved chemicals in water sources is significantly associated with an

Increased incidence of waterborne diseases in Vichumbe Village.

Review of Literature

R. D. Arnone and J. P. Walling described that combined sewer systems (CSSs) that transport a combination of pathogen-filled rainwater and sanitary wastewater through a single pipe to a publicly operated treatment plant for treatment before release to surface waterways. According to the USEPA, CSSs are prevalent in older communities in the Northeast and Great Lakes areas and may be identified in 32 states (including the District of Columbia). When capacity is surpassed during times when there is moderate to severe rainfall, combined sewer overflows (CSOs) happen

I. R. Joh, H. Wang, H. Weiss, and J. S. Weitz, suggested we discover an additional control parameter, which we call the pathogen enhancement ratio, which controls whether outbreaks result in epidemics or endemic disease states. It is related to the shedding rate of infected people. According to our model, reducing the number of affected people may be less successful than decreasing the pathogen density in aquatic reservoirs in the case of waterborne infections.

A. Shannon, W. Bohn, M. Elimelech, G. Georgiadis, J. Marinas, and M. Mayes told Here, we showcase some of the research and technology currently being investigated for improved water disinfection and decontamination, as well as measures to boost water supplies through safe wastewater re-use and effective desalination of sea and brackish water.

S. Batterman, J. EIsenberg, R. Hardinetal. describe that in particular, we argue that one problem with interventions to reduce infectious disease incidence and emergence, particularly those that are water-associated, is that efforts are generally directed against proximal causes of infection transmission, paying less (and often insufficient) attention to the more distal causal factors. These issues represent major gaps that cannot be resolved by simply boosting funding for water supply and sanitation facilities.

Kaustubh Karande explained that for a well-managed water supply, it's essential to manage the waste that is generated wastewater in addition to the infrastructure. This research illustrates the lack of wastewater treatment plants before disposal in the majority of the Communities.

Shailendar Kumar Maryada and others publishers described because there are not sufficient resources allocated in India to clean up lakes. All of this is as a consequence of the lack of a lake cleanup strategy by the government or any other organization. The possibility of illness spreading, which is already present in the world around us, is imminent. which, like the Corona virus, none of us are aware.

Water Resource Status in Vichumbe In 2023

Panvel, an Indian city, receives water from the Dehrang Dam, which is predicted to dry out by the first week of June. The predicament is becoming worse in VICHUMBE. There is a lot of growth going on, which causes the population to grow, which raises the need for water.

In the Indian state of Maharashtra, the Morbe Dam is a gravity-based structure on the Dhavari River close to the town of Khalapur. The city of Navi Mumbai gets its water mostly from More Lake. It was constructed by the Maharashtra government's water supply and sanitation department.

During the Monsoon the Gadeshwar dam overflows. The place can be reached by entering New Panvel and via the Sukhapur-Nere Road.

The Precipitation and Temperature in Vichumbe

Table No. 1.

Category	Resolution	Period
Precipitation	Half Hourly/0.1 deg (11 kms) grid	2001-2023
Precipitation	Daily/ 0.25 deg (28 kms) grid	1901-2023
Temperature	Monthly/ 0.5 deg (55 kms) grid	1901-2022
Temperature	Daily/1 deg (111 kms) grid	1951-2023

Total area of Vichumbe is 119 Hectares as per the data available for the year 2009Total sown /agricultural area is 75 Hectares. About 75 Hectares is irrigated area. About 24 hectares is in non-agricultural use. About 20 hectares is culturable waste land.

Table 2

Sr. No	Category	Hectare
1	Total sown/agricultural area	75 hectares
2	Non-agricultural use	24 hectares
3	Culturable waste	20 hectares
4	Total Area in Vichumbe	119 Hectare

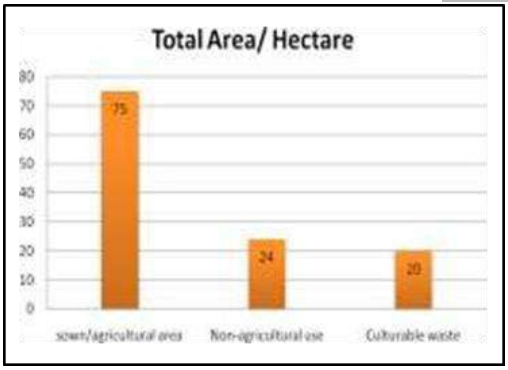


Figure No. 1

While collecting data it was received the information that is most important for this study. In it we can see there is 31.7% Tanker water is used, 36.6 % people use boring water.26.8% lake water is used for drinking. 5% People use well for drinking purposes.

Table No. 3

Sr. no.	Water Resources	Used %
1	Boring	36.6
2	Tanker	31.7
3	Well	5
4	Lake	26.8

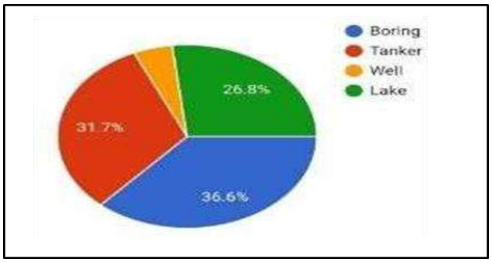


Figure No. 2

The water is infected then the people of that area will be sick. 48.8% of the peoplesay that water is safe for drinking; other 30% of people say that water is not safe and 22.5% of people say that they have no idea whether it is safe or unsafe.

Table No. 4

Sr. No	Quality of Water	Suggestion percentage
1	Safe Water	48.8
2	Not Safe	29.2
3	No Idea	22

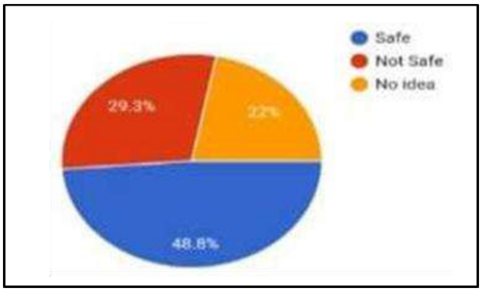


Figure No. 3

For assessing the quality of water some people use the cloth to remove the dirt, some people use bleach, some use the water filter. During the questionnaire it was asked that whether they use the water filter or not. But the village Vichumbe some people cannot afford the w and the other after filter so sometimes because of impure water they get sick. 97.5% Residents use water filter and other 2.5% family do not use water filter.

Table No. 5

Sr. no.	Source for cleaning	Source %
1	Water Filter	97.5
2	Other	2.5

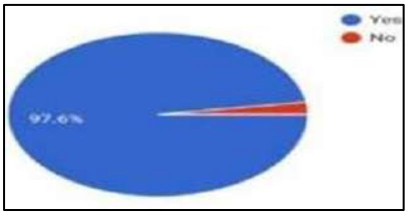


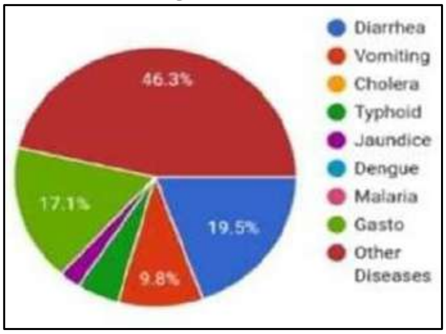
Figure No 4

Water is the most important factor of life. The pure water is the boon for healthy life, but the impure water could be the cause of so many diseases. Like Diarrhea, Vomiting, Cholera, Typhoid, Jaundice, Dengue, Malaria, Gastro, Other diseases. In other diseases like dysentery, loose motions, stomach ache. Here we can see 45% of the people are suffering from other diseases, 20% suffered from Diarrhea, 10% experiencing Vomiting, 17.5% feeling Gastro, 5.5% Typhoid and 2% experiencing Jaundice

Table No. 6

Sr. no	Suffering Diseases	% of disease
1	Diarrhea	10
2	Vomiting	17.5
3	Cholera	0
4	Typhoid	2
5	Jaundice	2
6	Dengue	0
7	Malaria	0
8	Gastro	5.5
9	Other Disease	20%

Figure No 5

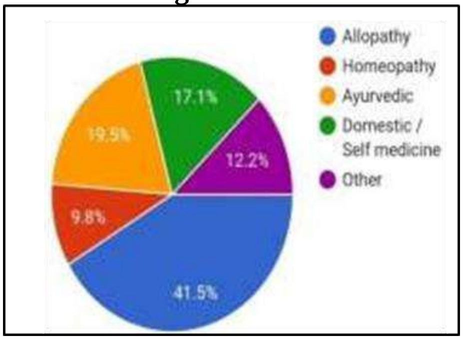


During survey it was observed that while getting sick, the people take different types of medicines, like Allopathy, Homeopathy, Ayurveda, Domestic or self-medicines and other. While getting sick 42.5% people of Vichumbe use Allopathy or the English Medicine. 10% use Homeopathy, 20% use Ayurvedic, 17.5 % use domestic or self-medicine and 10% use other medicines.

Table No. 7

Sr. No.	Types of Medicines	% of medicines
1	Allopathy	41.5
2	Homeopathy	9.8
3	Ayurvedic	19.5
4	Domestic	17.1
5	Other	12.2

Figure No 6

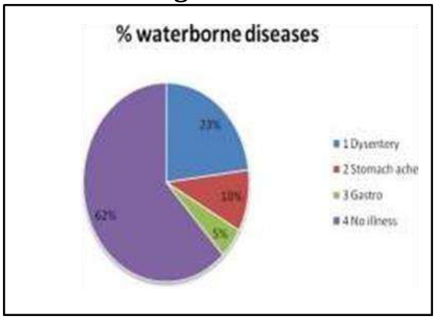


Due to impure water the waterborne diseases get active. Frequently use of infected water makes the people sick. In the Area 23% were sick because of dysentery and 10% by stomach ache and 5% suffered from Gastro.

Table No. 8

Sr. no	Type of water borne diseases	% of disease
1	Dysentery	23
2	Stomach ache	10
3	Gastro	5
4	No illness	62

Figure No 7

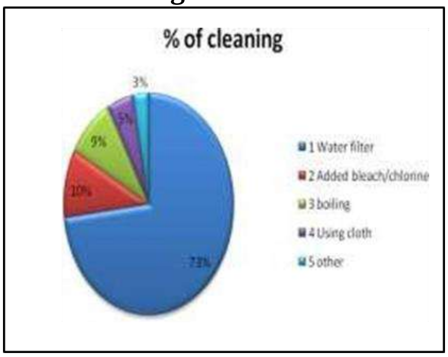


If the water is spreading diseases, then it is important to make it clean. 73% people use a waterfilter, 10 % use chlorine and 5% boil to clean it. These are common methods to clean the water.

Table No. 9

Sr.no	Methods of cleaning	% of cleaning
1	Water filter	73
2	Added bleach/chlorine	10
3	Boiling	9
4	Using cloth	5
5	Other	3

Figure No. 8

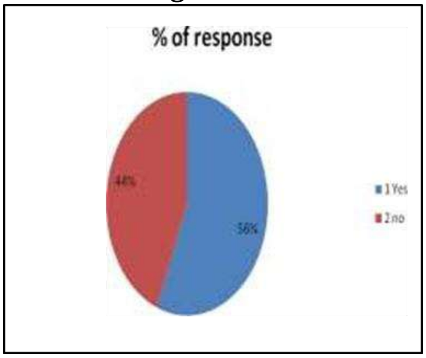


Clean water is the most important requirement of the public. Definitely the government should take the action for it but the public initiative is very important thing.56.1% people complainedto the concerned authority and 43.9% people do not care about it

Table No. 10

Sr. no	Complained the authority	% of response
1	Yes	56.1
2	No	43.9

Figure No. 9



Samples Analysis

Three samples from the Centre for Research, Consulting, and Technical Services are evaluated as part of this study in the lab at KBP College. The first sample is tap water, as shown by the certificate of analysis. The pH level as of right now is 7.93. As we can see, the pH of regular bottled water should be between 6.5 and 7.5, but the sample of tap water has greater pH than is typical. Because it is closest to 8, the pH level in the test indicates that it is unfit for drinking. The pH range of ocean water is 8 to 8.1.

Sample 1: Tap water

Water that comes from a public water system and is delivered by pipes or other built-in conveyances is referred to as "tap water."

Ph level in Tap water

Tap water's Ph varies greatly depending on its sources, processing, and distribution methods. As a result, tap water's pH will vary. Is tap water safe to drink if the pH level is outside of defined ranges. The organizations acknowledge that there is no specific health rationale for this range, yet continued use of this water can be harmful to health. There are not so many cases where the pH level alone caused tap water to be unsafe. The suggested pH range of 6.5 to 9.5 for tap water does, however, take into account the fact that most systems seek to keep their pH levels above 7 to reduce the impacts of corrosion in their treatment facilities and pipe distribution network.

TDS Level in water

Today, the water treatment facilities discharge dangerous substances into the drinking water that we get. As a consequence, the water's inherent minerals are removed. The correct filtering method must be used in this circumstance to get rid of the impurities and make the water safe to drink. Total dissolved solids (TDS), which are still in water after the usual filtering procedure, are the principal pollutants that are present. Total dissolved solids are contaminants that are greater than 2 microns.

Sample-2 - Boring water

It is found that pH level is 7.87, after sample test of boring water. Actually, bore water comes from groundwater which in turn comes from rain that has naturally seeped into the ground and is stored in spaces between soil and rocks. From the result it is evident that the pH is well within permissible limit pH (6.5 to 8.5) has no direct adverse effects on health, however a lower value below 4 will produce sour taste and higher value above 8.5 bitter taste.

Sample 3 – Tanker Water

Private water tankers have become more prominent in the water delivery supply chain which makes it especially challenging to ensure water quality and prevent the spread of waterborne illness.

Comparison of Resource water, Tanker water and Tap water

Cities around the globe have been and continue to grow at a rapid pace, fueled by population growth and migration from rural areas. In many cases, water-provision infrastructure in the form of piped networks fails to keep up with the pace of urbanization and increasing demands for water quantities, e.g., resulting in unconnected areas, intermittent supply, and water-quality issues.

Measurement of pH

The pH is important parameter of water, which determines the suitability of water for various purposes such as drinking, bathing, cooking, washing and agriculture etc. The pH level of water having desirable limit is 6.5 to 8.5 as specified by the BIS. Pure water is said to be neutral, witha pH of 7. Water with a pH below 7.0 is considered acidic while water with pH greater than 7.0 is considered as basic or alkaline.

Conclusion, Future Scope and Recommendation

Conclusion

The conclusion drawn from the statement suggests a correlation between the presence of dissolved chemicals in water sources and an elevated occurrence of waterborne diseases in Vichumbe Village. If this correlation is based on empirical evidence and scientific studies, it highlights a critical issue that demands attention and intervention. The implications of such a connection may include:

- **Health Risks:**

The increased incidence of waterborne diseases implies a potential threat to the health of the community in Vichumbe Village. Waterborne diseases are often caused by pathogens present in contaminated water, and the role of dissolved chemicals in facilitating the growth and spread of these pathogens should be addresse

- **Water Quality monitoring:**

The conclusion emphasizes the importance of regularly monitoring the quality of water sources in Vichumbe Village. Understanding the specific dissolved chemicals present and their concentrations can help identify sources of contamination and guide remediation efforts

- **Public Health Intervention:**

Given the association with waterborne diseases, public health interventions may be necessary to reduce the impact on the community. These interventions could include water treatment, education on safe water practices, and the promotion of hygiene to prevent the spread of waterborne diseases.

- **Environmental Impact Assessment:**

Understanding the sources of dissolved chemicals in water requires a comprehensive environmental impact assessment. This involves identifying potential sources of pollution, such as industrial discharges, agricultural runoff, or improper waste disposal, and implementing measures to mitigate these sources.

- **Collaboration and Advocacy**

Addressing water quality issues often requires collaboration between local communities, government authorities, and environmental organizations. Advocacy for policies that regulate and monitor water quality can contribute to long-term solutions.

Future scope

Build community partnership

- Development of community partnership leads to higher attention and support from the general public. Conscious individualities frequently come more involved in decision-making and restoration efforts.
- Similar involvement builds a sense of community, helps reduces conflicts and increase commitment to the conduct necessary to meet environment pretensions.

Conduct Educational Programs

- The degree of public education and participation in the planning process can greatly impact the success of awareness of water related issues.
- There are numerous ways to involve and educate the public in environmental operations, confirmation of citizen review groups and recommendatory panels can gain public support from the milepost.

Effective implementation and follow-ups

- The water management planning should be enforced in dynamic and adaptive manner.
- Long –term monitoring of water quality, the expanse provided by the government for Improving water status and their response to perpetration conduct linked in the plan is vital.

Recommendations

Water quility monitoring and testing: Establish a comprehensive water quality monitoring program to regularly test and analyze water samples from various sources in Vichumbe village. Collaborate with relevant health and environmental agencies to ensure the testing process adheres to established standards.

Community Health Services: Enhance healthcare facilities in Vichumbe to provide prompt diagnosis and treatment for waterborne diseases. Develop a system for regular health check-ups and medical support for the community to address health issues arising from water contamination.

Alternative Water sourcce: Explore and implement alternative water sources such as rainwater harvesting, wells, or safe groundwater to reduce reliance on contaminated water bodies. Introduce filtration and purification systems at the community level to ensure access to clean and safe drinking water.

Check and maintain water tanks on a regular basis: Make sure you follow the essential safety precautions, such as alerting someone when you enter and exercising caution while using motorized pumps in confined spaces like asphyxiation

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Sustainable Agriculture and Water Conservation

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Abstract

Sustainable agriculture is farming in such a way to protect the environment, aid and expand natural resources and to make the best use of non-renewable resources. Sustainable agriculture consists of environment friendly methods of farming that allow the production of crops or livestock without causing damage to human or natural systems. It "considers long-term as well as short-term economics because sustainability is readily defined as forever, that is, agricultural environments that are designed to promote endless regeneration".[1] It balances the need for resource conservation with the needs of farmers pursuing their livelihood. [2] Many indigenous tribes incorporated intercropping into their agriculture, which is a practice where multiple crops are planted together in the same area. This strategy allows crops to help one another grow through exchanged nutrients, maintained soil moisture, and physical supports for one another. Climate change and other factors have increased pressure on natural water resources. This is especially the case in manufacturing and agricultural irrigation. Many countries have successfully implemented policies to conserve water conservation.

Keywords: Sustainable agriculture, Crop rotation, Water conservation, Irrigation

Introduction

Sustainable agriculture is a holistic approach to farming that aims to produce food and fibre while protecting natural resources like soil, water and biodiversity. The term "sustainable agriculture" was defined in 1977 by the USDA as an integrated system of plant and animal production practices having a site-specific application that will, over the long term.[3] It reduced environmental impact like less pollution, reduced greenhouse gas emissions and improved soil health. Sustainable agriculture is a type of agriculture that focus on producing long term crops and livestock while having minimal effects on the environment. It also focuses on maintaining economic stability of farms and helping farmers improve their techniques and quality of life. There are many farming strategies that are used that help make agriculture more sustainable. Some of the most common techniques include growing plants that can create their own nutrients to reduce the use of fertilizers and rotating crops in fields which minimizes pesticide use because the crops are changing frequently. Sustaining agricultural productivity depends on quality and availability of natural resources like soil and water. Agricultural growth can be sustained by promoting conservation and sustainable use of these scarce natural resources through appropriate location specific measures. Indian agriculture remains predominantly rainfed covering about 60% of the country's net sown area and accounts for 40% of the total food production. Thus, conservation of natural resources in conjunction with development of rainfed agriculture holds the key to meet burgeoning demands for food grain in the country. Sustainable farmers also utilize water management systems, such as drip irrigation that waste less water. Water is considered as the most critical resource for sustainable agricultural development worldwide. Irrigated areas will increase in forthcoming years, while fresh water supplies will be diverted from agriculture to meet the increasing demand of domestic use and industry. Sustainable agriculture also seeks to address the contamination of surface water and groundwater. Large-scale agriculture often produces pollutants, such as agrochemical runoff and pathogen-laden animal waste, that seep into bodies of water and damage the surrounding environment, affecting both wildlife and humans. Soil erosion also degrades water quality, and the loss of productive topsoil reduces crop yields and the total land available for agriculture. Some farmers use buffer plants near waterways to absorb polluting nutrients before they can leach into bodies of water. The efficiency of irrigation is very low, since less than 65% of the applied water is actually used by the crops. It is a valuable resource that is essential for the survival of life on our planet.

Objectives of sustainable agriculture

The main objectives of sustainable agriculture are:

1. To conserve natural resources by using available resources and minimizing the use of non-renewable resources.
2. To produce safe and high-quality food.
3. To promote sustainable livelihoods for farmers by encouraging them to use sustainable farming techniques.
4. To protect the health and safety of farmworkers, local communities and society.
5. To provide sufficient financial reward to the farmer to enable continued production.
6. To reduce waste and pollution.

Benefits of sustainable agriculture

Sustainable agriculture has a wide range of benefits for the environment, farmers and society. Some key benefits are as follows:

1. Improved soil health and fertility:

Sustainable agriculture practices promote the use of organic matter and natural fertilizers,which enhance soil health and fertility. It leads to improved crop yields, better quality food and increased resilience to drought and other climate changes.

2. Environmental protection:

Sustainable agriculture reduces the negative impacts of conventional farming on the environment, such as soil erosion, water pollution and biodiversity loss. It promotes the conservation of natural resources and uses farming practices that minimize environmental impact.

3. Food security:

Sustainable agriculture can improve food security by promoting local and regional food systems and reducing dependence of global food markets. It also can help to ensure that people have access to nutritious food, even in times of crisis.

4. Economic benefits:

It provides economic benefits to farmers, rural communities and consumers. It can also help to create new jobs and stimulate economic growth by reducing the cost inputs, increasing crop yields and promoting local food systems.

5. Improved public health:

It can improve public health by reducing exposure to harmful pesticides and other chemicals. It also promotes the use of healthy organic food.

6. Biodiversity conservation:

Sustainable agriculture practices promote biodiversity conservation by protecting and restoring natural habitats, planting diverse crops and reducing the use of harmful chemicals that can harm wildlife.

There are 7 key practices of sustainable agriculture aiming for environmentally and economically viable farming. These are (i)Integrated Pest Management (IPM). (ii)Crop Rotation and Diversity. (iii) Soil Management. (iv)Water Management. (v)Agroforestry. (vi) Organic Farming and (vii) Renewable Energy Use.

Water conservation:

Water conservation is a major facet of sustainable agriculture. Globally, about 70 percent of all available freshwater resources are used for agriculture. Methods of reducing water waste can involve improving water storage practices to prevent evaporation losses and seepage and planting drought-resistant crops or crops that are appropriate for the climate. Some sustainable farmers seek to implement reduced-volume irrigation, which provides slow streams of water to meet the water needs of specific crops while lessening water waste. Water scarcity has become a major issue, especially for the agricultural sector due to the increasing demands of a growing global population and the effects of climate change. Water conservation is an essential aspect in promoting effective resource use, environmental responsibility, and long-term food security in sustainable agriculture. The main objectives of water conservation are to ensure sustainable water resource management, reduce water scarcity, protect water ecosystems and promote efficient water usage for future generations.

Sustainable water resource management:

Water conservation aims to use water resources efficiently and sustainably. It helps to maintain the health and integrity of aquatic ecosystems by ensuring that there is enough clean water available for wild life and natural habitats. Water conservation involves implementing strategies and technologies to reduce unnecessary water consumption and waste, such as rain water harvesting, greywater recycling and efficient irrigation techniques. It can lead to economic benefits by reducing water cost, promoting sustainable agriculture and supporting industries that rely on water resources. Water conservations are necessary in agriculture. It helps adapt to the changing climate patterns, ensuring food security amidst unpredictable rainfall and extreme weather events.

Modern water conservation techniques:

In the context of India, a country grappling with the dual challenges of water scarcity and the need to boost agricultural productivity, modern water conservation techniques are not just innovations but necessities. The advancements in irrigation technology have been pivotal in this regard. Drip irrigation, one of the most significant advancements, epitomizes efficient water use in agriculture. In drip irrigation, water is delivered directly to the roots of plants in a slow and steady manner, minimizing evaporation and ensuring that the plants receive water and nutrients in the most efficient way possible [4]. The adoption of drip irrigation in India has been growing, particularly in water-stressed states like Maharashtra and Gujarat, driven by both government initiatives and farmer awareness.

Sprinkler systems, another technological advance, have also gained popularity in India. These systems simulate rainfall and are particularly useful in uneven terrains where traditional irrigation methods are impractical. Sprinklers distribute water more evenly and can lead to significant water savings compared to surface irrigation methods [5]. The Government of India has been promoting sprinkler systems through various schemes and subsidies, recognizing their potential in enhancing water use efficiency in agriculture. Subsurface irrigation is a less common but highly efficient irrigation method where water is applied below the soil surface, directly to the root zone. This method has the advantage of reducing evaporation losses and minimizing weed growth. However, its adoption in India is limited due to higher initial costs and the need for technical expertise [6]. Beyond advancements in irrigation technology, water-efficient agricultural practices are equally crucial in conserving water. Crop rotation and diversification are traditional practices that have been revitalized in the modern context. Rotating crops and diversifying plantings can improve soil health, reduce pest and disease pressures, and lead to more efficient use of water. In India, initiatives like the National Food Security Mission have been encouraging farmers to diversify crops, especially in regions dominated by water intensive crops like rice and wheat. Soil moisture management is another vital aspect of water efficient agriculture. Practices such as conservation tillage, maintaining soil organic matter, and using soil moisture sensors can optimize water use and enhance crop yields [7]. ICAR has been promoting soil moisture conservation techniques through training and extension activities. Mulching and cover cropping are simple yet effective techniques for conserving soil moisture [8].

Table 1. Modern water conservation techniques

Technique	Description	Reference
Rainwater Harvesting	Collecting and storing rainwater for reuse before it reaches the ground	9
Drip Irrigation	Delivering water directly to the roots of plants, minimizing evaporation and runoff	10
Greywater Recycling	Reusing water from sinks, showers, and washing machines for gardening and flushing toilets.	11
High Efficiency Toilets	Toilets designed to use significantly less water per flush than standard toilets	12
Water Sensitive Urban Design	Integrating the urban water cycle, including stormwater, groundwater, and wastewater management into urban design.	13
Smart Irrigation Systems	Utilizing advanced technologies like sensors and IoT for efficient irrigation management.	14
Artificial Recharge of Aquifers	Techniques like percolation tanks, recharge wells, and rain gardens to replenish groundwater.	15
Desalination	Removing salts and minerals from saline water to produce fresh water.	16
Water Footprint	Reduction Strategies to reduce water use and waste in industries and agriculture.	17
Rooftop Gardens	Using green roofs to absorb rainwater and reduce runoff.	18

Conclusions

There are many benefits of sustainable agriculture and overall, they can be divided into human health and environmental benefits. In terms of human health, crops growth through sustainable agriculture are better for people. Due to lack of chemical pesticides and fertilizers, people are not being exposed to or consuming synthetic materials. It offers a range of benefits for the environment, farmers and society. Conservation of water in agriculture has become increasingly crucial for the health of environment and the sustainability of agriculture. Importance of water conservation in agriculture is required to ensure a sustainable future for all. We promote sustainable water management practices.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Water and Its Impact on Human Health

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Abstract

Water is a fundamental component of human health, playing a important role in physiological functions, disease prevention, and overall well-being. It is essential for hydration, digestion, circulation, temperature regulation, and detoxification. Access to clean and safe water is vital, as contaminated water sources can lead to the spread of waterborne diseases such as cholera, dysentery, and typhoid. Furthermore, inadequate water supply contributes to poor hygiene and sanitation, exacerbating health risks in communities. Climate change, pollution, and population growth pose increasing threats to water quality and availability, necessitating sustainable water management practices. Ensuring safe drinking water through filtration, sanitation, and conservation efforts is critical to improving public health outcomes worldwide. This paper explores the intricate relationship between water and human health, emphasizing the need for global policies and technological advancements to secure water safety for present and future generations.

Keywords: Water, Pollution, Health

Introduction

Water is an important component of life, playing a vital role in maintaining human health. It is crucial for physiological processes, hydration, sanitation, and disease prevention. Access to clean and safe water is a fundamental human right, yet millions of people around the world suffer from water scarcity and contamination. Water is a fundamental element of life, essential for sustaining human health. It plays a critical role in physiological functions, hydration, sanitation, and preventing diseases. Ensuring access to clean and safe water is a basic human right, yet many people worldwide face challenges due to water scarcity and contamination. Water pollution is mainly concentrated in industrialization, agricultural activities, natural factors, and insufficient water supply and sewage treatment facilities. First, industry is the main cause of water pollution, these industries include distillery industry, tannery industry, pulp and paper industry, textile industry, food industry, iron and steel industry, nuclear industry and so on.

Importance of Water in Human Health

Water serves numerous essential functions in the human body, including:

- **Hydration:** Water is necessary for maintaining body temperature, transporting nutrients, and removing waste.
- **Digestion and Metabolism:** It aids in digestion, the absorption of nutrients, and metabolic functions.
- **Circulatory System:** Water is a key component of blood, helping transport oxygen and nutrients throughout the body.
- **Joint and Muscle Function:** It lubricates joints and muscles, reducing friction and preventing injuries.
- **Detoxification:** The kidneys use water to filter and eliminate toxins through urine.

Water-Related Diseases

Contaminated water is a major public health concern and can lead to various diseases, including:

- **Waterborne Diseases:** Caused by consuming contaminated water, including cholera, typhoid, and dysentery.
- **Water-Washed Diseases:** Result from inadequate hygiene due to insufficient water supply, such as trachoma and scabies.
- **Water-Based Diseases:** Infections caused by organisms living in water, such as schistosomiasis.
- **Chemical Contamination:** Exposure to heavy metals (lead, arsenic) and industrial pollutants in water can lead to chronic illnesses like cancer and neurological disorders.

Water Quality and Sanitation:

Ensuring water quality is essential for human health. Key measures include:

- **Water Purification:** Boiling, filtration, and chemical treatment (chlorination) to remove contaminants.
- **Waste Management:** Proper disposal of industrial and household waste to prevent water pollution.
- **Sanitation and Hygiene:** Use of toilets, handwashing with clean water, and wastewater treatment to prevent disease spread.
- **Water Conservation:** Sustainable use of water resources to maintain a stable and safe water supply.

Global Water Crisis and Its Impact on Health:

The global water crisis refers to the increasing scarcity of clean, accessible water for drinking, sanitation, agriculture, and industry. It is driven by a combination of factors, including population growth, climate change, pollution, poor water management, and geopolitical conflicts. Pollution exposure experienced by children during critical periods of development is associated with height loss in adulthood (Zaveri et al., 2020). Here are some key aspects of the crisis.Water scarcity affects billions of people worldwide, leading to malnutrition, dehydration, and poor sanitation. Climate change, population growth, and industrialization exacerbate the crisis, making it essential to implement sustainable water management policies and improve infrastructure.Various toxic chemicals, organic and inorganic substances, toxic solvents and volatile organic chemicals may be released in industrial production. If these wastes are released into aquatic ecosystems without adequate treatment, they will cause water pollution (Chowdhary et al., 2020)

Conclusion:

Water is indispensable for human health, and access to clean water is critical for preventing diseases and ensuring well-being. Governments, organizations, and individuals must work together to safeguard water resources, improve sanitation, and promote hygiene practices to protect public health and the environment. Water pollution is a significant cause of childhood diseases. Air, water, and soil pollution together killed 940,000 children worldwide in 2016, two-thirds of whom were under the age of 5, and the vast majority occurred in low- and middle-income countries (Landrigan et al., 2018)

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Morphometric Analysis for the Evaluation of Ground Water Potential Zones using Geospatial Techniques: A Case Study of Hogenakkal Sub watershed, Tamil Nādu.

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Abstract

Watershed basin development is required to assess regional characteristics and identify potential groundwater recharge zones (Avinash, Deepika, & Jayappa, 2014). Geographical information systems (GIS) have emerged as an effective tool for defining drainage patterns and groundwater potential, as well as for planning. Quantitative morphometry has long been recognized as an important component of the hydrological process. The basin's morphometric parameters can address linear, areal, and relief aspects. The morphometric parameters of the basin can address linear, areal, and relief aspects. The current study is primarily concerned with geometry, with a focus on the evaluation of morphometric parameters such as stream length (Lu), length ratio, bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), elongation ratio (Re), circularity ratio (Rc), relative/basin relief(T), relief ratio (Rh), ruggedness no. (Rn) (Waikar & Nilawar, n.d.). SRTM (Shuttle Radar Topographic Machine) DEM (Digital Elevation Model) of 30m resolution was used to analyze the hydrological drainage characteristics of all 33 sub-watersheds of the Hogenakkal River basin in Tamil Nadu. Sub watershed morphometric parameters - linear, areal, and relief - were computed using established mathematical equations and GIS techniques (Avinash et al., 2014)

Keywords: Sub-watersheds, Morphometric analysis, Groundwater potential zones, Geospatial Analysis, Hydrology.

Introduction

Groundwater is an important source of irrigation, particularly in Asia's southern tropical region (semi-arid). In Southern India, where agriculture is the dominant activity and the climate is semi-arid, there is an increasing reliance on groundwater for irrigation due to low annual rainfall (Bhagwat, Hegde, & Shetty, 2018). Factors such as increasing population, urbanization, and unintended use, among others, have an impact on land and water resources. Water resources need to be used wisely in this age of global warming and potential drought threats. Morphometric analyses are useful for observing hydrological behavior, interpreting basin geometry, and obtaining information about the basin's geological and geomorphological behavior (Özcan, Musaoğlu, & Türkeş, 2018). The drainage parameters and drainage patterns provide surface and subsurface information to help understand how drainage morphometry affects landforms and their characteristics. The drainage parameters and drainage patterns provide surface and subsurface information to help understand how drainage morphometry affects landforms and their characteristics. The occurrence, transport, and storage of groundwater are all influenced by the region's geological and geomorphological history. While physiographic features like relief and slope show how much runoff and infiltration there is in each location, and geomorphological aspects (Kumar, Jayappa, & Dinesh, 2010). Utilizing all natural resources for sustainable development and improved living is the goal of the watershed approach to planning, development, and management. Several techniques, including artificial groundwater recharge, have been proposed to stop the groundwater table's decline. Identification of prospective groundwater recharge zones is crucial for sustainable ground watershed development operations, to stop groundwater depletion, and to increase groundwater supplies (Bhagwat et al., 2018). The watershed's size, shape, physiography, soils, soil erosion zones, land use/landcover, hydrogeological context, etc. are important considerations in planning and development (Rajasekhar, Raju, & Raju, 2020).

Through quantitative specifications of basin geometry, morphometric analysis is a valuable tool for assessing and comprehending the behavior of hydrological systems. To detect different hydraulic properties of a drainage basin and then investigate a correlation with lithological qualities, morphometric parameters are pertinent and helpful. The morphometric factors make it easier to rank sub-watersheds according to their potential for groundwater (Yadav, Dubey, Szilard, & Singh, 2018) Conventional approaches have been used to study the morphometric properties of numerous river basins and subbasins worldwide. The current study employs geospatial technology to analyze the Hogenakkal River Basin, which is the principal downstream stream of the Kaveri River in Karnataka, India. The Hogenakkal River basin in Tamil Nadu, India, covers a total drainage area of 401 km2. It is a fifth-order stream with a 299.88 km overall channel length. The linear aspects, such as the stream length ratio, bifurcation ratio, and stream length, have been used to quantitatively compute the basin characteristics. Using the established mathematical equations, areal factors such as drainage density, stream frequency, circulatory ratio, elongation ratio, and relief aspects such as relative relief, relief ratio, and roughness number are calculated, and potential groundwater sites have been discovered in the Hogenakkal River basin, in India (Jothimani, Abebe, & Berhanu, 2022).

Study Area

Hogenakkal (12°07′15″N 77°46′40″E) is a hamlet in the Pennagaram taluk of Dharmapuri district, in the Indian state of Tamil Nadu (Fig.1). Located on the Kaveri River in South India, Hogenakkal is a waterfall that separates the districts of Chamarajanagar in Karnataka and Dharmapuri in Tamil Nadu. The distance between it and the district headquarters of Dharmapuri and Chamarajanagar is 46 km (29 mi) and 199 km (124 mi), respectively. As the land descends in elevation, the Kaveri River, which originates at Talakaveri in the Brahmagiri hills of the southern Indian Ghats, gains speed. As other tributaries feed into it on the way down, it gets bigger. As it cuts through the rocky landscape near Hogenakkal, the Kaveri, which is now a sizable river, lowers and produces a multitude of waterfalls. The water falls up to 20 meters (66 feet) in certain areas. Because the river conveys sediment, the area downstream is fertile. A 60 square mile (160 km2) is created at Hogenakkal when the river expands out over a large stretch of sandy beaches before flowing south to the Mettur Dam. the Stanley Reservoir Lake. This 1934 project produced hydropower and enhanced irrigation. Water temperatures range from 13 to 27 °C (55 to 81 °F) in the winter and from 23 and 34 °C (73 and 93 °F) in the summer. In this area, the alkaline-carbonatites complex is most commonly found. In the studied region, different kinds of soil are present, including red ferruginous, gravel, and black or mixed loams. There is 815 mm of rain on average every year.

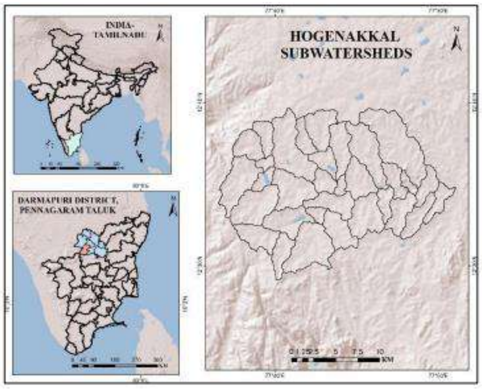

Figure 1. The study area of the Hogenakkal sub-watershed, Tamil Nādu.

The Krishna Raja Sagar Dam (KRS Dam) located in Mandya (12025’29’’N, 76034’20” E), Karnataka was built across river Kaveri in 1924, which is a main source of irrigation and drinking water in places for all of Mysore, Mandya, almost the whole of Bangalore City. In the state of Tamil Nadu, which has its own Mettur dam in the Salem district, the water discharged from this dam is also utilized as a significant water source. The filling period is from June to September, and the depletion period is from October to May. This construction plays a significant role in increasing the groundwater potentiality zone, which indistinctively identifies the potential sub-watersheds in the Hogenakkal River basin.

Data And Methodology

Data

The Hogenakkal River basin's watershed has been defined for the current study using SRTM DEM (30m- Spatial resolution) data that was taken from the Bhuvan portal. ArcGIS version 10.4 was used to define the sub-watersheds of the Hogenakkal river basin, and the ArcSWAT plugin generated the sub-watersheds by figuring out the pour-point. Examining the quantitative morphometric traits was done to (Shekar & Mathew, 2022) 33 sub-watersheds of the Hogenakkal catchment. The processing of the DEM, comprising fill, flow direction, flow accumulation, stream definition, stream to features, etc., is shown in Figure 2. Sub-watersheds (SW 1 to SW 33) are grouped using the ArcGIS 10.5 program according to factors such as stream length, order, and number. The linear, relief aspect and aerial aspect morphometric feature groups were examined and categorized (Shekar & Mathew, 2022).

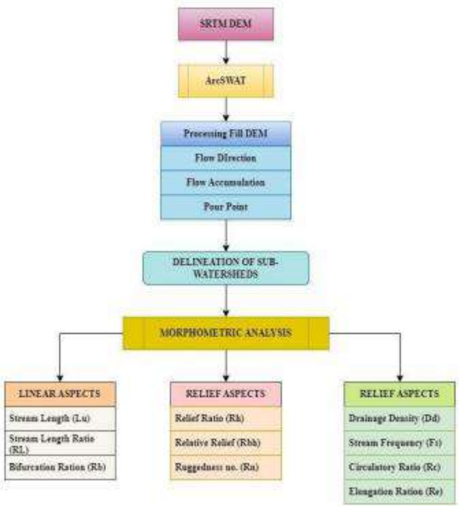

Figure 2. Methodology of the Morphometric analysis of Hogenakkal sub-watersheds.

Morphometric Analysis:

The measuring and quantitative analysis of the size, shape, and configuration of landforms is known as morphometric analysis. The quantitative and physical components of a watershed are often covered by its morphometric features. It is based on natural, unchanging standards that are static across time. The three types of aspects would be linear, relief, and areal. Runoff, peak discharge, and soil erosion concerns are directly or indirectly correlated with them (Abdeta, Tesemma, Tura, & Atlabachew, 2020). Different researchers have inculcated various formulas (Table 1) to determine each aspect of the morphometric analysis, which was used to determine the groundwater potential zones.

Linear Aspects

Stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio are examples of the linear components of the morphometric analysis of the basin. Stream length exposes information about surface runoff. Areas with greater slopes and finer textures are characterized by streams that are significantly shorter in length. Typically, streams with longer lengths have flatter gradients (Waikar & Nilawar, n.d.). The surface flow and discharge are impacted by stream length ratio (Waikar & Nilawar, n.d.). The bifurcation ratio is the number of stream segments of a specific order divided by the number of segments of the next higher order (Rb). (Schumann & Moller, 2015) viewed the bifurcation ratio as a measure of relief and dissections. (Strahler, 1957) shown that, apart from regions where geology predominates, the bifurcation ratio demonstrates a moderate range of variance for different locations or diverse environmental conditions (Ghosh & Jana, 2018; Waikar & Nilawar, n.d.). The bifurcation ratio (Rb) for basins whose geological characteristics do not affect the drainage pattern is typically between 3 and 5(Ghosh & Jana, 2018).

Relief Aspects

The measures of the relief properties denote the various spatial characteristics of the landform pattern, including its altitude, alignment, degree of dissection, slope, nature of the drainage network, and spacing (Ghosh & Jana, 2018). The relief characteristics measured include relief ratio, relative relief, and roughness number (Waikar & Nilawar, n.d.). ("EVOLUTION OF DRAINAGE SYSTEMS AND SLOPES IN BADLANDS AT PERTH AMBOY, NEW JERSEY | GSA Bulletin | GeoScienceWorld," n.d.) defined the relief ratio as the ratio of the highest relief to horizontal distance along the longest dimension of the basin perpendicular to the major drainage line. It assesses the overall steepness of a drainage basin and indicates the severity of erosion processes acting on the basin's slopes (Ghosh & Jana, 2018). The Rh usually rises as the drainage area and watershed size of a specific drainage basin decrease (Waikar & Nilawar, n.d.). Denudational properties are comprehended using relative reielf, providing the changes in topographic altimeter. Typically, ruggedness refers to the topography's degree of undulation (Ghosh & Jana, 2018). It is the product of the maximum basin relief (H) and the drainage density (Dd), both of which have the same unit. When both variables are large and the slope is steep, the roughness number has a remarkably high value (Waikar & Nilawar, n.d.).

Aerial Aspects

It pertains to the whole area projected onto a horizontal plane that contributes overland flow to the channel segment of the specified order and includes all tributaries of lower order. It includes drainage density, stream frequency, circularity ratio, elongation ratio, and overland flow length. (Waikar & Nilawar, n.d.). Horton (1932) proposed that drainage density (Dd) is a significant predictor of the linear scale of landform features in stream-eroded topography. It is the ratio of total channel segment length for all orders inside a basin-to-basin area, expressed in kilometers per kilometer squared. The drainage density reveals the proximity of channel spacing, hence providing a quantitative estimate of the average length of stream channel in the entire basin. Dissected topography is associated with a high drainage density (Dd). Less than 2 denotes very coarse drainage texture, 2–4 is associated with coarse drainage, moderate (4-6), fine (6-8), and >8 is very fine texture (Ghosh & Jana, 2018). Stream frequency (Fs) is the total number of stream segments per unit area. It demonstrates a positive association with drainage density in the watershed, indicating a rise in stream population as drainage density increases. Circularity Ratio is the ratio of a basin's area to the area of a circle with the same circumference as the basin's perimeter. Elongation ratio is the ratio between the diameter of a circle with the same area as the drainage basin and its greatest length. Re-values typically range from 0.6 to 1.0 over a vast array of climatic and geologic conditions. Re-values close to one indicate normally modest relief, whereas values in the 0.6–0.8 range are frequently linked with considerable relief and steep terrain slopes. ("Strahler, A. (1964) Quantitative Geomorphology of Drainage Basins and Channel Networks. In Chow, V., Ed., Handbook of Applied Hydrology, McGraw Hill, New York, 439-476. - References - Scientific Research Publishing," n.d.). These values fall into three distinct categories: (a) circular (>0.9), (b) oval (0.9-0.8), and (c) less elongated (0.7).

Results And Discussion

After demarcation, there were 33 sub-watersheds in the Hogenakkal catchment area. Each subwatershed's linear, aerial, and relief parameters were calculated. This research will aid in the identification of groundwater zones in Hogenakkal sub-watersheds. Table 2 lists the linear, relief, and aerial parameters of the individual sub-watersheds. Figures 3, 4, and 5 show the classification of linear, relief, and aerial aspect maps of the sub-watersheds.

Table 1. Morphometric parameters, formulas, and references, to evaluate the groundwater potential zones of Hogenakkal sub-watersheds

S.NO.	MORPHOMETRIC PARAMETERS	FORMULA	REFERENCE
LINEAR ASPECTS	Stream Number	Nu = Total no. of streams	Strahler (1964)
	Stream Order	N = Total no. of streams in each order	Strahler (1964)
	Stream Length	Lu = Length of the stream (Km)	Horton (1945)
	Stream Length Ration	Rl=Lu/Lu-1. Lu= Total stream length, Lu-1=Stream Length of next lower order	Horton (1945)
	Bifurcation ration	Rb=Nu/Nu+1; Nu=Total no. of streams, Nu+1=Number of segments of the next higher-order	Schumm (1956)
AERIAL ASPECTS	Drainage Density	Dd=Lu/Au; Lu = Total length of the stream, area of watershed	Horton (1945)
	Stream Frequency	Fu=N/A; N Total no. of streams, A Area of watershed	Horton (1945)
	Circulatory ratio	Rc =4πA/P2; A= area of watershed, P=Perimeter of the basin Phi=3.14	Miller (1953)
	Elongation ratio	$Re=2\sqrt{\frac{A}{\pi}}/Lb$; A= Area of watershed, Lb=Maximum Basin Length, Phi=3.14	Schumm (1956)
RELIEF ASPECTS	Relative relief	Tr= H/L H= Highest elevation, L=Lowest elevation	
	Relief ratio	Rh=H/Lb; H=Relative relief, Lb= Basin length	Schumm (1956)
	Ruggedness No.	Rn= D*Tr/1000; D= Drainage density, Tr= Relative relief	Schumm (1956)

Table 2. Linear, relief, and aerial aspects of Hogenakkal sub watersheds.

SWs	LINEAR ASPECTS			RELIEF ASPECTS			AERIAL ASPECTS			
	Length Ratio	Bifurcation Ratio	Stream Length	Relative Relief	Relief ratio	Ruggedness No.	Drainage Density	Stream Frequency	Circulator Ratio	Elongation Ration
SW 1	1.62	1.1	12.621	1.15	0.000236	1.16	1008	1	87.92	0.0006110
SW 2	0.97	1.25	6.213	1.09	0.000213	1.32	1207.55	2.27	138.16	0.0007280
SW 3	0.483	1.25	5.482	1.14	0.000126	1.33	1165.32	1.86	276.32	0.0005840
SW 4	0.63	0.8	13.503	1.14	0.00017	1.43	1250.35	1.94	213.52	0.0006900
SW 5	10.16	8	11.372	1.05	0.000466	1.39	1324.5	2	25.12	0.0007100
SW 6	1.71	1.25	5.295	1.16	0.000212	1.32	1140.571	1.86	87.92	0.0005460
SW 7	0.89	2.2	13.841	1.10	0.000162	1.37	1240.55	1.73	138.16	0.0005510
SW 8	0.02	0.01	2.541	1.01	0.000012	1.11	1121.03	1.23	125.6	0.0002147
SW 9	2.43	1.8	18.198	1.12	0.0003	1.09	973.67	1.5	75.36	0.0006313
SW 10	0.67	0.8	40.95	1.12	0.000151	1.56	1391.53	2.53	188.4	0.0005880
SW 11	0.54	0.33	25.637	1.12	0.000151	1.38	1227.82	2.24	213.52	0.0006260
SW 12	4.5	4	7.835	1.08	0.000318	1.14	1059	1.8	62.8	0.0007460
SW 13	1.8	2	2.437	1.11	0.00021	1.38	1245	1.17	75.36	0.0005220
SW 14	1.46	0.8	20.873	1.14	0.00029	1.19	1044.33	1.67	113.04	0.0008650
SW 15	0.01	0.01	2.489	1.24	0.000117	1.59	1279.69	1.78	401.92	0.0006030
SW 16	5.84	1.33	3.944	1.07	0.000407	0.87	812.33	1	37.68	0.0007450
SW 17	5.56	3	15.017	1.16	0.000361	0.96	829.67	0.33	37.68	0.0006100
SW 18	0.87	1.2	6.357	1.09	0.000219	1.34	1227.55	1.73	138.16	0.0007490
SW 19	5.2	3	13.283	1.08	0.000332	1.06	986	1.75	50.24	0.0006960
SW 20	1.37	2	1.883	1.05	0.000388	0.99	941.5	3	25.12	0.0005870
SW 21	0.5	0.67	8.85	1.17	0.000175	1.29	1106.29	1.48	263.76	0.0007770
SW 22	1.03	1.33	7.056	1.10	0.000225	1.39	1262.1	2.1	125.6	0.0007280
SW	4.77	3	2.649	1.12	0.00025	1.52	1360.2	1.8	62.8	0.000578

23					6					0
SW 24	0.99	1.17	7.984	1.10	0.00019	1.36	1233.7	0	125.6	0.0006180
SW 25	1.47	1.25	6.801	1.18	0.000228	1.49	1263.56	2.11	113.04	0.0006560
SW 26	0.78	0.86	19.302	1.14	0.000207	1.22	1072.64	1.29	175.84	0.0007690
SW 27	1.51	1	23.232	1.16	0.000188	1.28	1106.25	1.375	100.48	0.0005210
SW 28	0.63	0.8	13.646	1.13	0.0002	1.37	1213.2	1.93	188.4	0.0007740
SW 29	4.08	2.5	13.883	1.13	0.000231	1.48	1305.83	1.83	75.36	0.0005640
SW 30	1.16	1.29	21.256	1.12	0.000204	1.55	1384.1	2.1	125.6	0.0006520
SW 31	0.87	0.75	9.399	1.15	0.000183	1.33	1156.917	1.25	150.72	0.0006240
SW 32	3.65	2	12.337	1.10	0.000249	1.14	1035.5	1.5	75.36	0.0006280
SW 33	1.8	1.33	7.47	1.08	0.00027	1.14	1059.5	1.83	81.6	0.0006680

Linear Aspects

Stream length, stream length ratio, and bifurcation ratio include the linear parts of basin morphometric analysis. Table 2 lists the linear parameters of the sub-watershed.

➢ **Stream Length (Lu)**

The lengths of stream segments in a sub-watershed were measured, and the total length of stream segments decreased as stream order increased (Tiwari & Kushwaha, 2021). The 15th sub-watershed has the longest stream at 40.95 kilometers. Generally, longer stream lengths indicate a flatter gradient. The overall length of stream segments is often greatest in first-order streams and decreases as stream order increases. Stream order 1 in sub-watershed 15 is 25.72, stream order 2 is 9.10, and stream order 3 is 6.14. The alteration may suggest high-altitude streams, lithological variety, and relatively steep slopes. Observing stream order confirms Horton's law of stream number, which states that the number of stream segments in each order forms an inverse geometric sequence with order number (Waikar & Nilawar, n.d.).

➢ **Stream Length Ratio (RL)**

The RL values between different order streams in the basin indicate that there are differences in slope and topography (Waikar & Nilawar, n.d.). The ratio of 25 sub-watersheds is 10.16:1.56, which is rather high, allowing for percolation (Bhagwat et al., 2018). The change in the stream length ratio values in the provided order indicates their geomorphic maturity (Tiwari & Kushwaha, 2021).

➢ **Bifurcation Ratio (Rb)**

The values of the mean bifurcation ratio of different sub-watersheds range from 0.01 to 8, with sub-watershed 17 having the lowest value and sub-watershed 25 having the highest value, indicating the variation of structural control in drainage development of different regions in some of the sub-watersheds. Lower Rb values imply fewer structural disruptions and the drainage pattern has not been altered, whereas higher Rb values show strong structural control over the drainage pattern (Tiwari & Kushwaha, 2021).

Relief Aspects

Basin/ Relative Relief (R)

With a maximum height of 951 meters and a minimum elevation of 678 meters, the land has moderate to extremely steep slopes. The relative relief for sub-watersheds 5 and 15 ranged between 1.05 and 1.24.

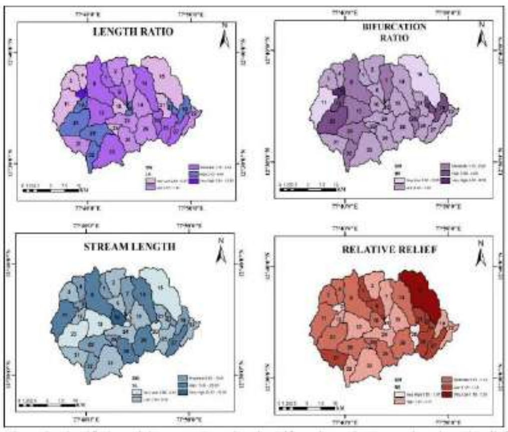

Figure 3. Classified; Aerial aspect – Length ratio, Bifurcation ratio, Stream length, and Relief aspect– Relative relief of Hogenakkal sub-watersheds.

Relief Ratio (Rh)

The Rh typically increases as the drainage area and watershed size of a specific drainage basin decrease. Consequently, sub-watershed 5 has a relief ratio of 0.47, and its area is 2 square kilometers. The sub-watersheds have a Rh value of 7.25, indicating moderate relief and slope.

Ruggedness number (Rn)

In the present investigation, the range of ruggedness values is 1.59 to 0.87. When both factors are large and the slope is steep, the roughness number is extremely high. SW-15, SW-10, and SW-30 had the greatest values of roughness, indicating a high sensitivity to soil erosion.

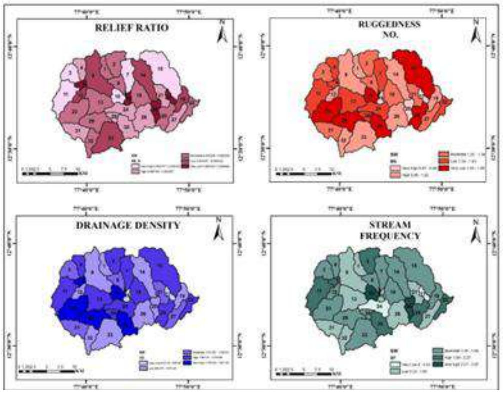

Figure 4. Classified; Relief aspects – Relief ration, Ruggedness no. and Aerial Aspects- Drainage Density, Stream frequency of Hogenakkal sub-watersheds.

Aerial Aspects

- **Drainage density (Dd)**

High drainage density is observed in impermeable sub-surface material and is influenced by variables that determine the typical length of the stream. (Tiwari & Kushwaha, 2021). The drainage density ranges from 812.33(SW-16) and 1355.53 (SW-10). A low drainage density results in a coarse drainage texture, whereas a high drainage density results in a fine drainage texture.

- **Stream Frequency (Fs)**

Observations indicate that the first-order stream has the highest frequency and that the frequency decreases as the stream order increases. The SW 20's maximum stream frequency is 3. As the stream order grows, the frequency of the stream drops. In-stream order 1, the frequency of the stream is five, and it reduces progressively from stream order 2 to stream order 4. In the sub-watershed, the stream frequency value ranges from 3 (SW-20) to 0 (SW-24).

- **Circulatory Ratio (Rc)**

The Rc is influenced by basin slope, geological features, and stream length and frequency. The circularity ratio (Rc) varies between 25.12 and 401.92. This high circularity ratio value indicates the mature stage of topography.

- **Elongation Ratio (Re)**

The lowest ratio values of a watershed imply strong relief and a sharp slope, whereas the greatest ratio value suggests low relief and a gentle slope. The values for the elongation ratio range from 0.0005210(SW-27) to 0.0008600. (SW-14). Low relief corresponds typically to Re values near unity.

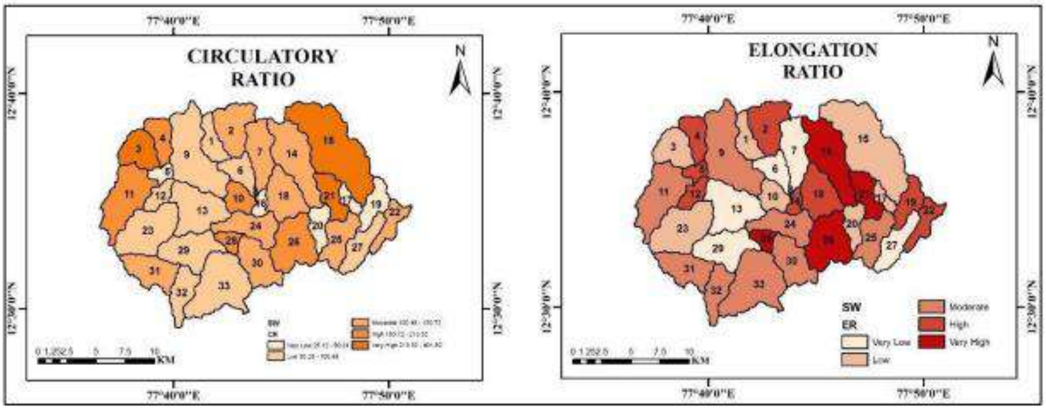

Figure 5. Classified; Aerial aspects – Circulatory ratio, Elongation ratio of Hogenakkal sub watersheds

Parameters	Values	SW
Stream Length	40.15	SW -15
Stream Length	Ration 10.16:1.56	SW -25
Bifurcation Ration	0.01 – 8	SW 17 - SW 25
Basin Relief	1.05 - 1.24	SW 5 - SW 15
Relief Ratio	0.47	SW 5
Ruggedness No.	1.59 to 0.87	SW-15, SW-10, SW- 30
Drainage Density	812.33 - 1391.53	SW 16 - SW 10
Stream Frequency	3	SW – 20
Circulatory Ratio	25.12 - 401.92	SW 20 - SW 15
Elongation Ratio	0.0005210 - 0.0008650	SW - 14, 27 to SW - 14

Table 3. Morphometric analysis of Hogenakkal sub-watersheds.

Conclusion

In this study, analysis of morphometric parameters (Table 3), it was determined that morphometric parameters are a suitable substitute for determining deficit and surplus zones of groundwater in river basins (Yadav et al., 2018). This work provides a critical analysis of several morphometric parameters in terms of their value range, implication, and overlap, as well as input data quality (Sukristiyanti, Maria, & Lestiana, 2018). The morphometric examination of the drainage networks of all 33 sub-watersheds reveals a dendritic drainage pattern, where the variance in stream length may suggest streams coming from a high altitude, lithological variation, and relatively steep slopes. In conjunction with the length of the stream, the coarser drainage density indicates impermeable subsurface materials. The basin's bifurcation ratio, length ratio, and stream order show that it is a third-order basin with a homogenous nature, which may indicate the absence of structural or tectonic influence. A relief ratio shows a smaller drainage area, with moderate to extremely steep basin slopes, indicating greater runoff and less percolation. The area is well-drained by 1st and 2nd order streams with the maximum drainage area, resulting in a rough landscape with somewhat deep incised valleys. This finally indicates that the slope is extremely rough and prone to soil erosion. As the stream frequency is moderate and the channels are maturing, this indicates that the basin has moderate relief. According to the morphometric research, the sub-watersheds of Hogenakkal have a moderate groundwater potentiality. The morphometric study gives information and a database for strategic planning and hazard management zone demarcation decisions. The morphometric study gives information and a database for strategic planning and hazard management zone demarcation decisions Through an understanding of the relationship between basin morphometry and subsurface structure, it is possible to conclude that the central portion of the Hogenakkal sub-watersheds is likely to have moderate to high groundwater potential that can be utilized to assist the residents of the surrounding villages.To define the groundwater potentiality zone, this study only evaluates morphometric characteristics, with each aerial, relief, and linear parameter given careful consideration. By introducing additional characteristics in each aspect, additional categorization of the high groundwater potential zone may be possible. Further research on prioritizing may aid in classifying the sub-watershed from low to extreme groundwater potentiality zones, which will be used for further analysis, assisting the government in future sustainable management planning. In addition, it may aid in appraising the region's groundwater potential and identifying appropriate water harvesting sites. In the Hogenakkal watershed, which is an important tributary to the Cauvery River basin, morphometric analysis (Biswas, Das Majumdar, & Banerjee, 2014) Has a broader application in watershed prioritization and management, soil erosion studies, groundwater potential evaluation, and flood hazard risk education.

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WATER RESOURCES IN A CHANGING WORLD: SCIENCE, MANAGEMENT AND POLICY

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Water and human health

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Abstract

Water is essential for human health, playing a critical role in hydration, digestion, circulation, and overall bodily functions. It regulates body temperature, aids in nutrient absorption, and removes toxins. Drinking pure water will avoid waterborne diseases, improving hygiene, and supporting overall well-being.

Contaminated water can lead to serious health risks, including infections, gastrointestinal diseases, and long-term health complications. Proper water management, sanitation, and hygiene practices are necessary to ensure safe water access and reduce health risks. Climate change, pollution, and water scarcity further impact water quality and availability, making sustainable water use and conservation vital for public health.

Ensuring equitable access to clean water, promoting water-efficient practices, and strengthening policies for water management are key steps in safeguarding human health and well-being.

Keywords: Water, contamination, water born-disease, purification

Introduction

Water is a vital necessity for the human body, comprising appropriately 80% of its total composition, while we can survive for several days without food, but without water we can't survive a day, it is an integral part of body tissues such as fat, muscle and bone also serves as a fundamental component of essential bodily fluids, including blood, digestive juices, sweat and urine.

Water is needed daily since the human body cannot store it. The body constantly loses water through the skin, lungs, feceas, urine, hence requiring regular replenishment, However, the required daily intake varies based on factors such as body size, diet, metabolism, environmental conditions, climate and lifestyle of each individual person, in a day basis, human loses 2.5-3 litres of water because of heat and other physiological process, which must be replaced to maintain good health.

Approximately 1.1 billion people worldwide lacks access to safe drinking water, in developing countries, impure water accounts for 80% of the illness, leading to around 2.2 million deaths annually. Sea water constitutes 97% of the earth's total water, leaving only 3% as fresh water. Of this freshwater, appropriately 69% is stored in ice, while 30% exists as ground water. However, just 0.25% of fresh water is readily accessible as surface water in lakes and rivers.

Therefore, ground water is the primary sources of safe drinking water, it contains various dissolved metals and other substances that are beneficial to the body, but only within certain limits.

The deeper understanding of waters' role reveals its vital functions in the body.

- It maintains the integrity of every cell
- It keeps the mucous membranes in the mouth and respiratory tract moist.
- It ensures blood remains fluid, allowing it to flow through vessels while delivering nutrients and oxygen.
- Its aids in the removal of metabolic wastes
- It helps regulate fluid and electrolytes balance
- It plays a key role in maintaining body temperature,
- It supports bladder functions by flushing out bacteria's
- Water contributes to healthy digestion by ensuring the proper composition of faecal matter, helping to prevent constipation.
- It enhances an individual's appreances by keeping the skin moisture and maintaining a healthy texture
- It supports the proper functioning of the eys, spinal cord and amniotic fluid through its shock-absorbing properties.1

I. Waterborne diseases and public health risks

Access to safe and readily available water is crucial for public health, whether for drinking, household use, food preparations or recreation. Proper water supply, sanitation and effective water resources management can significantly enhance a country's economic growth and play a key role in reducing poverty.

The UN General Assembly recognized water and sanitation as basic human rights in 2010. Everyone has the right to enough safe, clean, easily accessible, and affordable water for personal and household use.

Drinking Water Services

Sustainable Development Goal (SDG) target 6.1 aims to provide safe and affordable drinking water for all. This is measured by access to safely managed drinking water, which means water comes from reliable sources, is available when needed, and is free from harmful contaminants.

In 2022, 6 billion people had access to safely managed drinking water.

However, 2.2 billion people still lacked this essential service:

- 15 billion people had basic water services, meaning they used improved sources but had to travel up to 30 minutes to get water.
- 292 million people relied on limited or unimproved sources, requiring more than 30 minutes to collect water.
- 296 million people depended on unprotected wells and springs.
- 115 million people collected untreated water from lakes, ponds, rivers, and streams.

Disparities in Water Access

There are still major differences in access to clean water based on geography, culture, and economic status. These gaps exist not only between rural and urban areas but also within cities and towns. People living in low-income, informal, or illegal settlements often struggle to access safe drinking water compared to other residents.

Water and Health

Unsafe water and poor sanitation can spread diseases like cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. The lack of proper water and sanitation services increases health risks, especially in healthcare facilities where both patients and staff are more vulnerable to infections.

Poor handling of urban, industrial, and agricultural wastewater has left millions exposed to dangerously contaminated or chemically polluted drinking water. Naturally occurring chemicals, such as arsenic and fluoride in groundwater, can be harmful, while substances like lead may enter drinking water from old or damaged pipes.

Each year, about 1 million people die from diarrhea caused by unsafe drinking water, poor sanitation, and inadequate hand hygiene. However, diarrhea is preventable, and improving these conditions could save 395,000 children under five each year. When water is scarce, people may use less for handwashing, increasing the risk of diarrhea and other infections.

While diarrhea is the most common illness linked to unsafe water, other diseases also pose serious risks. In 2021, over 251.4 million people needed treatment for schistosomiasis, a disease caused by parasitic worms that spread through contaminated water.

In many areas, insects that breed in water, such as mosquitoes, spread diseases like dengue fever. Some of these disease-carrying insects thrive in clean water rather than dirty water, with household water containers often becoming breeding sites. A simple solution, like covering water storage containers, can help reduce insect breeding and prevent water contamination at home.

Economic and Social Impact

When clean water is available from safe and convenient sources, people spend less time and effort collecting it. This allows them to focus on work, education, and other productive activities. It also improves personal safety and lowers the risk of musculoskeletal problems by eliminating the need for long, difficult, or dangerous trips to fetch water.

Access to safe water also helps reduce healthcare costs. With fewer water-related illnesses, people spend less on medical treatment and can remain healthy and economically active.

Children are particularly at risk of waterborne diseases, but access to clean water improves their health. As a result, they attend school more regularly, leading to better education and long-term benefits for their future.

Challenges and Future Solutions

At the current pace, achieving universal access to basic drinking water by 2030 would require efforts to double, while safely managed water services would need a six-fold increase. Climate change, water scarcity, population growth, and urbanization are already straining water supplies, with over 2 billion people living in water-stressed areas—a number expected to rise.

Reusing wastewater for water, nutrients, and energy is becoming essential. While widely practiced, much of it lacks proper treatment, posing health and environmental risks. However, safe wastewater management can boost food production, improve water security, and support a circular economy.

Dependence on groundwater and alternative sources like treated wastewater is increasing, while climate change is making rainwater collection less reliable. Sustainable water management is crucial to maintaining supply and quality.

WHO's Response

As the global authority on public health and water quality, WHO leads efforts to prevent waterborne diseases by advising governments on regulations, health targets, and development strategies.

WHO sets water quality guidelines for drinking water, wastewater reuse, and recreational safety, emphasizing risk management. Since 2004, its **Drinking Water Quality Guidelines** have promoted a framework that includes setting health-based targets, implementing **Water Safety Plans**, and ensuring independent monitoring.

WHO supports countries with resources, regulations, and surveillance improvements Since 2014, it has evaluated household water treatment products to ensure they protect against diarrheal diseases and strengthen national policies.

In partnership with **UNICEF**, WHO addresses water and sanitation in healthcare facilities. In 2015, they developed **WASH-FIT**, a tool to help small healthcare facilities in low- and middle-income countries assess risks and take targeted actions. A 2023 report provides steps to improve WASH services in healthcare settings.2

II. Role of water in food security and nutritions

The HLPE report on water for food security and nutrition (FSN) was gratefully acknowledged, and it was reminded that:

- There is an inherent connection between water, food security, and nutrition;
- Water is necessary for the progressive realization of the rights to safe drinking water, sanitation, and adequate food in the context of national food security;
- Improving FSN requires advancing gender equality and women's empowerment in relation to water.

Water: A Key Pillar for Food Security and Sustainable Growth

Water is fundamental to ecosystems and plays a crucial role in ensuring food security and nutrition for current and future generations. It supports agriculture, fisheries, and livestock while also being essential for food processing and preparation. Clean drinking water enhances nutrient absorption, directly impacting human health. Beyond food, water fuels economic growth, creates employment opportunities, and improves financial access to food for billions worldwide.

However, various regions face challenges such as water scarcity, growing demand, climate change, ecosystem degradation, and inequitable distribution, which threaten food production and access.

Achieving the 2030 Sustainable Development Goals requires strategic water management. Governments and stakeholders must work together, adopting both nature-based and community-driven approaches to safeguard water resources and ensure sustainable food security for all.

The Committee recommended

1. **Sustainable Water Management for FSN**

- Promote ecosystem conservation, restoration, and sustainable management through participatory approaches.
- Improve data collection and conduct evidence-based assessments of water demand and supply to support effective planning and investment.
- Prevent and reduce pollution, protect water bodies, and ensure water quality for domestic, agricultural, and food-related uses through appropriate policies and incentives.

2. **Enhancing Policy Coherence for Water and FSN**

- Strengthen water policies to comprehensively integrate FSN concerns across sectors, ensuring transparency, accountability, and alignment with the rights to safe drinking water, sanitation, and adequate food.
- Explicitly incorporate water considerations in national FSN strategies.
- Improve coordination among sectoral policies related to water, including agriculture, land, energy, and mining, to enhance FSN outcomes.

3. **Ensuring Equal Access to Water, Prioritizing the Vulnerable, and Empowering Women and Youth**

- Promote equal access to water and land for food producers, ensuring responsible investments that support livelihoods and FSN needs.
- Protect the rights of marginalized communities through legislation, policies, and programs.
- Ensure water-related policies, reforms, and investments prioritize FSN, particularly for vulnerable populations.
- Prevent the use of water as a tool for political or economic pressure.
- Address gender-specific water needs, empowering women in water governance and decision-making.
- Invest in improving access to safe drinking water, sanitation, hygiene, and food safety while reducing health risks and burdens, especially for women and girls.

4. **Enhancing Water Efficiency and Agricultural Productivity for FSN**

- Optimize agricultural water use by incorporating rainwater, runoff, groundwater, treated wastewater, and soil moisture into efficiency strategies.

- Invest in modernizing and expanding sustainable rainfed and irrigated systems, prioritizing smallholder food producers and considering regulated public-private partnerships.
- Improve water efficiency at the basin level, minimizing negative impacts on land use, water availability, and quality.
- Strengthen community and water user organizations to adopt water-saving practices, storage, reuse, and safe disposal methods, supporting climate-resilient and sustainable agriculture.

5. Building Resilience to Water Variability for FSN

- Strengthen the resilience of agriculture, particularly rainfed systems.
- Mitigate food price volatility in water-stressed, food-importing countries through risk management strategies, including insurance, social protection, early warning systems, and emergency reserves.
- Preserve and integrate traditional knowledge on sustainable water management to enhance livelihood resilience.

6. Advancing Knowledge, Technology, and Innovation for Water and FSN

- Promote cross-sectoral platforms for research, knowledge exchange, and voluntary technology transfer, engaging local communities and farmers.
- Invest in technological and institutional innovations for sustainable water use in agriculture.
- Strengthen national capacities to encourage innovation and adoption of locally adapted water management practices.
- Develop water information systems and monitoring mechanisms, incorporating gender-sensitive data for informed decision-making.
- Launch cost-effective awareness campaigns to build consensus on water challenges, particularly for FSN.

7. Strengthening Inclusive Governance and Collaboration for Water and FSN

- Establish transparent governance mechanisms to balance water use priorities, applying integrated water resource management.
- Ensure inclusive participation in water governance, empowering local communities, indigenous peoples, and water user organizations.
- Promote sustainable groundwater management through monitoring and controlled withdrawals.
- Foster cooperation on transboundary water management, respecting national sovereignty and existing agreements while considering FSN impacts.

8. Upholding Human Rights in Water and FSN

- Ensure compliance with international human rights obligations, recognizing the link between safe water, sanitation, and food security.

- Assess the impact of water and land policies on the right to water and food, prioritizing marginalized communities and indigenous peoples.
- Integrate water considerations into CFS policy instruments where applicable.2

III. Emerging contaminants and water treatment innovations

Clean water is a basic human right and a vital resource for life. However, growing water scarcity and pollution present significant challenges globally. With increasing demand, particularly in urban and industrial areas, advanced technologies are being developedto tackle these issues and ensure sustainable water treatment.

Current challenges in water treatment:

Contamination is a major challenge in water treatment, with pollutants like heavy metals, pesticides, pharmaceutical and microplastics posing serious health risk. Additionally, pathogens such as bacteria and viruses can infiltrate water sources, causing outbreak of waterborne diseases.

Aging infrastructure and resource constraints hinder efforts to deliver cleanwater. Many treatment facilities are outdated, inefficient and require major upgrades. And population growth and industrialization put additional pressure on water resource, innovativesolutions are essential to meet increasing demand.

Innovative water treatment technologies:

The water treatment industry has adopted advanced technologies to effectively tackle contamination and improve treatment efficiency:

- **Membrane Technologies**

Techniquessuch as reverse osmosis and nanofiltration are widely used to remove contaminant like salts, heavy metals and organic compounds. These methods are highly effective in desalination, municipal water treatment and industrial applications, ensuring improved water quality and reliable contaminant removal.

- **Advanced Oxidation Processes (AOPs)**

AOPs are crucial for tackling contaminants that withstand conventional treatments, using powerful chemical reactions,AOPs break down complex pollutants such as pharmaceuticals and endocrine disruptors enabling municipalities and industries to comply with stringent water quality regulations.

- **Bioremediation**

Bioremediation, which utilizes microorganisms to break down water pollutants, provides an eco-friendly alternative to traditional methods. It is especially effective in degrading organic contaminants like oils and hydrocarbons and is widely used in areas facing significant natural contamination challenges.

- **Electrochemical Water Treatment**

Electrochemical treatments have recently gained popularity, especially in areas with limited clean water access. By using electrical currents to oxidize pollutants, these methods reduce chemical usage and minimize sludge production, making them ideal for small-scale and decentralized systems.

- **Role of Dosing Pumps in Water Treatment**

Chemical dosing pays a vital role in water treatment by ensuring precise delivery of purifying agents like coagulants and disinfectants, Dosing pumps enable accurate application, enhancing contaminant removal and protecting public health. Modern pumps feature real-time monitoring for automated adjustments, improving efficiency and consistency, Example: waste water treatment plants use dosing pumps to precisely dispense coagulants ,enhancing water clarity ,quality and treatment effectiveness while minimizing sludge production.3

Emerging trends in water treatment:

- **Smart Water Systems**

With the advancements of the internet of things, smart water systems now use data analytics to monitor water quality in real time, detect issues early, and automate adjustments. This real time data helps operators make informed decisions, enhancing water safety and lowering operational costs, additionally; predictive maintaince prevents breakdowns and reduces maintenance expenses, improving overall system efficiency.

- **Decentralized Water Treatment**

Decentralised water treatments systems, which operate near the point of use, are essential for rural and remote communities as well as high demand urban areas. They reduce reliance on extensive pipelines, loweringenergy consumptions and maintaince costs. Additionally, these systems promote equity y ensuring clean water access in isolated regions.

- **Energy Recovery Technologies**

Minimizing energy consumption in water treatment is crucial for sustainability. Energy recovery systems, including those harnessing water flow and using energy-efficient membranes help facilities reduce their carbon footprint and operational costs. These innovations are key to ensuring a sustainable and cost-effective future for water treatment.

- **Regulatory and Environmental Considerations**

Evolving water quality regulations are reshaping the water treatment landscape prioritizing public health and environmental safety. Compliance is crucial and many innovations are designed to help facilities meet these strict standards.Modern water treatment emphasizes sustainability, resource conservation and waste reduction, with new technologies ensuring these goals are met while maintaining high water quality.4

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Urbanization And Water Challenges in Future

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Abstract

Urbanization, the process of population migration to cities, is a global phenomenon that significantly impacts water resources. As cities grow, the demand for water increases, creating pressure on available freshwater sources. The expansion of urban areas often leads to the alteration of natural landscapes, affecting the natural water cycle. Increased impermeable surfaces, such as roads and buildings, reduce groundwater recharge and lead to higher surface runoff, resulting in more frequent and severe flooding.

The demand for water in urban settings not only surpasses local supply but also strains existing infrastructure. Water treatment plants, pipelines, and storage facilities often become overwhelmed, reducing the quality and availability of water. Additionally, untreated wastewater is commonly released into rivers and lakes, further degrading water resources and leading to pollution. In many regions, urban areas often rely on distant water sources, leading to environmental degradation of these areas and increasing the cost of water supply.

Urbanization also contributes to the contamination of water through industrial activities, agriculture, and untreated sewage systems. Overexploitation of aquifers and surface water bodies exacerbates the depletion of local water resources, threatening long-term sustainability. In areas where water scarcity is already an issue, rapid urban growth can result in severe water shortages, affecting public health, economic development, and social stability.

Mitigation strategies, such as water conservation practices, sustainable urban planning, and the development of efficient water management systems, are essential to minimize the adverse effects of urbanization on water resources. Adopting innovative technologies and integrated water resource management approaches can help balance urban growth and water sustainability, ensuring equitable access to clean water for future generations.

Keywords: Smart water management, Rain gardens, Water resources, Water quality, Sustainable development

Introduction

Urbanization refers to the increasing population density in cities and the expansion of urban areas. This global trend is contributing to significant challenges related to water management, as cities struggle to provide clean, adequate water to their growing populations while managing water resources effectively. Some of the key challenges urban areas face regarding water include:

1. Water Scarcity

As cities grow, the demand for water increases. Urban areas often have to draw water from distant sources, and sometimes, these sources are overexploited, leading to depletion of local water resources. Additionally, climate change is exacerbating the situation, leading to reduced rainfall in some regions, further increasing water scarcity.

2. Water Pollution

With urban growth come increased industrial activity, sewage production, and the use of harmful chemicals, all of which can pollute water sources. Untreated or inadequately treated wastewater can contaminate rivers, lakes, and groundwater, making water unsafe for consumption. Urban areas with inadequate sanitation infrastructure are especially vulnerable to water pollution.

3. Increased Runoff and Flooding

The expansion of cities often leads to extra impervious outsides like roads and buildings, which prevent rainwater from being immersed into the ground. This increases surface runoff, which can overwhelm drainage systems, leading to flooding. The lack of proper stormwater management also worsens water quality, as runoff may carry pollutants into water bodies.

4. Inefficient Water Use

Many urban areas do not have efficient water distribution systems, leading to waste and overuse. Old pipes, leaks, and lack of proper infrastructure in slums or informal settlements can exacerbate the issue. Furthermore, growing populations place stress on water supply systems, reducing the overall efficiency of water usage.

5. Equitable Access to Water

Urbanization often leads to inequality in water access. Low-income communities, especially in rapidly growing cities in developing countries, might lack access to reliable water services. These communities may have to trust on casual water sources, such as isolated vendors or illegal associates, which can be expensive and unsafe.

6. Energy-Intensive Water Supply

Delivering water to urban areas, especially when the source is far away, requires substantial energy for pumping, purification, and distribution. As cities expand and more water needs to be transported, energy use increases, contributing to higher greenhouse gas emissions and added costs.

7. Climate Change Impact

Climate change worsens water challenges in urban areas by altering rainfall designs and growing the frequency of life-threatening weather events like droughts and floods. Cities may experience longer dry spells, while intense storms may lead to flash floods, both of which put additional strain on water management systems.

Addressing Water Challenges in Urban Areas:
To mitigate these challenges, cities can implement several strategies:

1. **Sustainable Urban Planning:** Integrating water management into urban planning can ensure that cities are designed to be water-efficient, using techniques like green roofs, permeable pavements, and water harvesting systems.
2. **Investing in Water Infrastructure:** Upgrading old pipes, expanding wastewater treatment plants, and improving stormwater administration systems can enhance water distribution and quality.
3. **Promoting Water Conservation:** Public awareness campaigns and incentives for using water-saving appliances can help reduce consumption.
4. **Stormwater Management:** Implementing systems like rainwater harvesting, permeable pavements, and green spaces can help manage runoff and reduce flood risks.
5. **Wastewater Treatment and Recycling:** Encouraging the treatment and reuse of wastewater can supplement freshwater supplies, especially in water-scarce areas.
6. **Adapting to Climate Change:** Cities must invest in resilient infrastructure that can withstand the impacts of extreme weather events, and plan for long-term changes in water availability due to climate change.

Effective urban water management is essential for sustainable cities and addressing the pressing water challenges posed by rapid urbanization.

There are a few more considerations that can enhance the solutions:

1. **Smart Water Management Technologies**

➢ **Data Analytics:** Using sensors and smart meters in water systems can help monitor usage patterns, detect leaks, and even forecast water demand. This data can help cities manage water more effectively by ensuring resources are allocated where needed and reducing waste.

➢ **AI for Predictive Maintenance:** Predictive tools powered by AI can be used to detect faults in infrastructure before they cause major problems, saving costs and preventing water loss.

2. **Community Involvement**

➢ Appealing local societies in water conservation struggles is crucial. Educating people about the importance of water conservation and offering incentives to reduce water use can go a long way. Moreover, local knowledge can sometimes offer valuable insights into managing water systems effectively, especially in informal settlements.

3. **Green Urban Infrastructure**

➢ In addition to green roofs and permeable pavements, creating more urban green spaces (parks, trees, etc.) helps with stormwater absorption, reduces urban heat islands, and promotes biodiversity, all while improving the completesuperiority of life for residents.

4. **International Collaboration**

- Cities facing similar water challenges, especially in the setting of global climate modification, can benefit from sharing knowledge, technologies, and best practices. International cooperation could help cities in developing nations leapfrog to more sustainable water management technologies, bypassing some of the inefficient practices of the past.

5. **Water Governance and Policy Reform**

- Effective governance and regulation are necessary for equitable distribution, investment in infrastructure, and ensuring water quality standards are met. Cities can benefit from clearer policies that balance growth with sustainability, including water pricing models that incentivize conservation.

6. **Nature-Based Solutions**

- Leveraging nature-based solutions (NBS), such as wetlands or forests, to manage water systems can provide ecological benefits and help in the natural filtration of water. These solutions can be integrated alongside traditional engineering solutions for more holistic water management.

By embracing a comprehensive approach, cities can become more resilient to water challenges, mitigate the impact of rapid urban growth, and ensure that water resources are managed in a sustainable and equitable way.

A. Water supply and demand in growing cities

The stability between water supply and demand in growing cities is a critical issue, as urbanization leads to increasing pressure on water resources. Managing this balance effectively is essential for ensuring that cities can meet the needs of their populations while preserving water resources for future generations. Below are the key factors to consider regarding water supply and demand in growing cities:

1. **Increased Water Demand**

As cities grow, both in population and economic activity, their water demand rises. This can occur in several ways:

- **Population Growth:** Larger populations require more water for domestic use, including drinking, sanitation, and cooking.
- **Industrial Expansion:** As cities become industrial hubs, factories and businesses increase water consumption for production processes, cooling, and other uses.
- **Commercial and Recreational Activities:** Urban areas often have growing demand for water in commercial sectors (e.g., hotels, restaurants, and shopping centers) and recreational areas like parks, golf courses, and sports facilities.
- **Lifestyle Changes:** As income levels rise and lifestyles evolve, water consumption patterns also shift. More people may use water for appliances (dishwashers, washing machines, etc.) or recreational activities, further driving demand.

2. Limited or Overextended Water Supply

Meeting the growing water demand becomes a challenge when the available water supply is limited or stretched thin due to a variety of factors:

- **Geographic Limitations:** Water sources, such as rivers, lakes, or groundwater, may be distant from urban centres or insufficient to meet growing demand. Some cities may face challenges due to the geographic location of water bodies, limiting easy access to water.
- **Climate Change:** Changing weather patterns can affect the availability of water. Droughts may reduce rainfall or stream flow, while extreme weather events can damage infrastructure. In many parts of the world, climate change is intensifying the water stress on already limited resources.
- **Pollution:** Contaminated water sources, caused by industrial discharge, sewage, or agricultural runoff, can reduce the usable supply of clean water, putting further strain on existing sources.
- **Overexploitation:** In some cities, water supplies are overused. Groundwater extraction can lead to the depletion of aquifers, resulting in sinking water tables and the need to drill deeper wells, which increases costs.

3. Water Loss and Inefficiency

Even in areas with abundant water resources, inefficient water distribution systems can contribute to supply problems:

- **Leaky Infrastructure:** In many growing cities, aging or poorly maintained pipes and infrastructure lead to significant water losses through leaks. Studies suggest that up to 30-50% of water may be lost before it even reaches consumers due to inefficiency in water delivery.
- **Wastage:** Inefficient irrigation practices, excessive water use by households, and water-intensive industries contribute to increased demand, while the supply remains limited.

4. Equitable Distribution

Water demand is not always equally distributed within a city. Growing urban populations often include low-income communities and informal settlements that may have limited or no access to clean water, while wealthier districts have greater access. This creates disparities in water availability, potentially leading to:

- **Water Shortages:** Poor communities might rely on expensive and unsafe water sources, such as private vendors, illegal connections, or contaminated wells, while wealthier areas have adequate water supply.
- **Social Tensions:** Disparities in water access can lead to conflict between different socio-economic groups or between communities and municipal authorities.

5. Challenges of Managing Water Supply in Growing Cities

As urban populations grow, managing the increasing demand for water while maintaining an adequate supply becomes more difficult. Key challenges include:

- **Urban Sprawl:** The spread of urban areas often leads to inefficient and disjointed water delivery systems that are difficult to maintain and expand. New development areas may not have access to existing infrastructure, leading to higher costs and more resource-intensive solutions.

- **Planning and Infrastructure:** Planning for future water demand requires accurate forecasting and investment in new infrastructure. Expanding water treatment plants, improving distribution networks, and developing new sources of water can be time-consuming and costly.
- **Competing Interests:** In many cities, different sectors (households, industries, agriculture) compete for limited water supplies. Ensuring that each sector receives a fair share while protecting the environment requires careful management and regulatory policies.

Strategies for Managing Water Supply and Demand in Growing Cities

1. Efficient Water Management

- **Smart Water Metering:** Introducing smart meters in households and businesses can help track water usage patterns, detect leaks, and identify opportunities for conservation.
- **Water-Efficient Technologies:** Encouraging the use of water-saving appliances (e.g., low-flow toilets and faucets), water-efficient irrigation techniques, and wastewater recycling technologies can help reduce overall consumption.

2. Diversifying Water Sources

- **Alternative Water Sources:** Cities can invest in alternative sources of water, such as desalination, rainwater harvesting, or treated wastewater for non-potable uses like irrigation and industrial processes.
- **Groundwater Recharge:** Implementing techniques for replenishing depleted aquifers, such as artificial recharge through managed infiltration basins, can help maintain groundwater supplies.

3. Water Pricing and Regulation

- **Fair Water Pricing:** Implementing tiered pricing can encourage conservation by charging higher rates for excessive use. Pricing should reflect the true cost of water, including infrastructure maintenance and environmental costs.
- **Regulation:** Enforcing regulations to control water waste in industries, agriculture, and households can help reduce demand. For example, using treated wastewater for irrigation or industrial cooling can significantly reduce the demand for potable water.

4. Infrastructure Investment

- **Upgrading Infrastructure:** Investing in modernizing aging infrastructure and expanding water supply systems can reduce leakage and increase the reliability of water delivery.
- **Stormwater Management:** Implementing systems that capture and treat stormwater for non-potable uses can ease pressure on freshwater supplies.

5. Public Awareness and Education

- **Conservation Campaigns:** Educating the public about the importance of water conservation and providing incentives for reducing water use can help cities manage demand more effectively.

- **Community Involvement:** Engaging local communities in water conservation efforts, particularly in low-income neighbourhoods, can help ensure equitable access and sustainable water use.

B. Infrastructure challenges in water distribution:

Infrastructure challenges in water distribution are a critical issue in many growing cities and urban areas. These challenges arise from outdate, inefficient, and underdeveloped water distribution systems that often struggle to meet the needs of rapidly expanding populations. Below some of the key infrastructure challenges faced in water distribution systems, along with potential solutions:

1. Aging and Deteriorating Infrastructure

- **Problem:** Many cities have water distribution networks that are old and in need of significant upgrades. Pipes, pumps, and treatment facilities may have been installed decades ago, and over time, they deteriorate due to wear and tear, corrosion, or material fatigue. This can lead to frequent leaks, water loss, and reduced efficiency in delivery.
- **Impact:** Aging infrastructure increases maintenance costs, water loss, and system failures. It also results in reduced water quality, as old pipes can contaminate the water supply.
- **Solution:** Regular maintenance, proactive replacement of outdate infrastructure, and investment in modern materials and technologies (e.g., corrosion-resistant pipes, smart sensors) can help mitigate this issue. Cities can prioritize replacing the most problematic sections of the water distribution system.

2. Water Loss and Leakage

- **Problem:** One of the most significant challenges in urban water distribution is water loss due to leaks and inefficient systems. Leaking pipes are common in older networks, and this issue is exacerbated by poor maintenance or lack of monitoring systems. It is estimated that in some regions, up to 30-50% of the water delivered to cities is lost through leaks before it reaches consumers.
- **Impact:** Water loss puts additional pressure on water sources, reduces system efficiency, and leads to increased operational costs. Furthermore, untreated water leaking from old pipes can contaminate clean water supplies.
- **Solution:** Advanced leak detection technologies, such as acoustic sensors, and real-time monitoring systems can help identify and repair leaks promptly. A more comprehensive strategy involves replacing outdate pipes and upgrading the entire distribution network to reduce losses.

3. Limited Capacity and Overloaded Systems

- **Problem:** Many cities' water distribution systems were designed for populations that are much smaller than they are today. Rapid urbanization has led to a situation where existing systems are unable to handle the increased demand for water. The result is overburdened infrastructure that struggles to meet the needs of residents, particularly during peak demand periods.

- **Impact:** Overloaded water distribution systems can lead to poor water pressure, inconsistent water supply, or even complete system failures. Additionally, the lack of capacity makes it harder to incorporate new infrastructure for growing areas.
- **Solution:** Upgrading and expanding the water distribution system to handle growing demand is essential. This includes increasing the capacity of pipelines, treatment plants, and storage facilities to ensure that water can be distributed effectively to all areas, including expanding urban zones.

4. Inadequate or Non-Existent Water Metering

- **Problem:** Many cities lack proper water metering infrastructure, which makes it difficult to monitor individual or community water usage accurately. This lack of metering can lead to inefficiency in water allocation and excessive water consumption, as users are not incentivized to conserve.
- **Impact:** Without accurate data on water usage, it's challenging to detect leaks, track consumption patterns, and promote water-saving practices. Moreover, municipalities may struggle to bill users fairly or detect instances of water theft.
- **Solution:** Installing smart water meters for both residential and commercial users can provide detailed insights into consumption patterns, help detect leaks, and improve billing accuracy. Implementing tiered pricing structures based on usage can also encourage water conservation.

5. Water Contamination and Pollution

- **Problem:** Water distribution systems are vulnerable to contamination, especially when they are old or not well-maintained. Contaminants can enter the system through leaking pipes, inadequate filtration, or poorly maintained treatment plants. In some cases, runoff from urban areas can contaminate water sources.
- **Impact:** Contaminated water can lead to serious public health risks, including outbreaks of waterborne diseases. This is especially problematic in low-income areas where access to clean water is already limited.
- **Solution:** Improved treatment technologies, such as advanced filtration and UV disinfection, can help ensure that water is clean and safe for consumption. Regular testing of water quality, proper pipe maintenance, and investing in pollution control measures can reduce contamination risks.

6. Lack of Resilient Infrastructure

- **Problem:** Many water distribution systems are not resilient to natural disasters, such as floods, earthquakes, and extreme weather events. Climate change is increasing the frequency and intensity of such events, further straining water infrastructure.
- **Impact:** Infrastructure that is not resilient to extreme weather can fail during disasters, leaving large

populations without access to water. The recovery process can be lengthy and costly.

- **Solution:** Building more resilient infrastructure, such as flood-proof pipes, earthquake-resistant water treatment plants, and backup power systems, can ensure that water distribution systems remain functional during and after disasters. Furthermore, cities can invest in disaster preparedness and response plans to minimize disruption.

7. Inequitable Access to Water

- **Problem:** Growing urban populations often mean that water distribution is unequal. Low-income communities, especially in informal settlements, may have limited or no access to water through official distribution systems. Instead, they may rely on expensive private vendors or illegal connections, which often deliver water that is not safe to drink.
- **Impact:** Inequitable access to water can exacerbate social inequalities and lead to public health issues, as some residents may lack access to clean water and sanitation. It also creates tensions between communities and municipal authorities.
- **Solution:** Cities should prioritize expanding water infrastructure into underserved areas, including slums and informal settlements. This may involve building new pipelines, providing affordable water access, and ensuring that sanitation infrastructure is in place to prevent contamination.

8. High Operational Costs

- **Problem:** Running and maintaining water distribution systems comes with high operational costs, particularly when systems are inefficient or poorly maintained. High costs can lead to higher water prices for consumers, and in some cases, the system may be financially unsustainable.
- **Impact:** Higher water prices can disproportionately affect low-income communities, leading to further inequities in water access. Unsustainable systems may also face chronic funding shortages, impacting long-term water availability.
- **Solution:** Governments and municipalities can seek innovative financing models, including public-private partnerships, to invest in water infrastructure upgrades. They can also implement more cost-efficient technologies and processes to reduce operational costs, such as automation, energy-efficient pumps, and water reuse strategies.

C. Storm water management and flood resilience

Storm water management and flood resilience are critical components of urban planning and environmental protection, especially as climate change increases the frequency and intensity of extreme weather events. Here’s an overview of both concepts:

Stormwater Management

Stormwater management involves controlling the flow of rainwater or melted snow that doesn’t soak into the ground, known as runoff. The goal is to prevent flooding, water pollution, and erosion while promoting groundwater recharge. Effective stormwater management often uses a variety of strategies and technologies, such as:

1. **Green Infrastructure:**

- **Rain gardens:** Vegetated areas designed to capture and infiltrate stormwater.
- **Permeable pavements:** Pavement materials that allow water to pass through and into the ground, reducing runoff.
- **Bios wales:** Shallow, vegetated channels designed to convey and treat stormwater.
- **Green roofs:** Vegetated roof systems that absorb rainwater and reduce runoff.

2. **Retention and Detention Systems:**

- **Retention ponds:** Basins that hold stormwater, allowing it to infiltrate slowly over time.
- **Detention ponds:** Temporary storage systems that hold excess runoff and release it at a controlled rate to prevent downstream flooding.

3. **Stormwater Conveyance Systems:**

- **Storm drains and sewers:** Designed to direct water away from urban areas to prevent local flooding.
- **Culverts:** Large pipes or tunnels used to carry stormwater under roads, railways, or other infrastructure.

4. **Water Quality Best Management Practices (BMPs):**

- These include filters, traps, and treatment wetlands to remove pollutants from stormwater before it reaches rivers or lakes.

Flood Resilience

Flood resilience refers to a community's ability to prepare for, respond to, and recover from flooding events. Building flood resilience involves both natural and human-made approaches, including:

1. **Floodplain Management:**

- Zoning laws and land-use planning to restrict development in high-risk flood areas.
- **Flood maps:** Used to assess flood risk and inform decisions about where to build.

2. **Infrastructure Adaptations:**

- **Flood barriers and levees:** Physical barriers that protect cities from rising floodwaters.
- **Floodwalls:** Similar to levees but often designed for urban areas with high population density.
- **Elevating buildings:** Raising structures above predicted flood levels to prevent damage.

3. **Early Warning Systems and Community Preparedness:**

- **Flood forecasting:** Using data models to predict rainfall and flooding events.
- **Emergency response plans:** Coordinating evacuations and providing resources during a flood event.

4. **Ecosystem-based Solutions:**

- **Wetlands restoration:** Wetlands act as natural sponges that absorb floodwaters and reduce the impact of floods.
- **Coastal mangrove restoration:** In coastal areas, mangroves help absorb the energy of storm surges and reduce flooding risk.

5. **Resilient Urban Design:**

- **Flood-resistant infrastructure:** Ensuring roads, utilities, and other key infrastructure can withstand flooding without significant damage.

- **Floating homes and adaptive buildings:** Designing buildings that can float or adapt to varying water levels, particularly in flood-prone areas.

Integration of Stormwater Management and Flood Resilience

Effective stormwater management supports flood resilience by ensuring that water is handled efficiently during both normal rainfall and extreme weather events. Combining green infrastructure with traditional engineering solutions (such as levees and detention basins) provides a multi-layered approach to reducing flood risk.

For example, a city might implement a combination of rain gardens and permeable pavements to reduce runoff, while also building floodwalls or upgrading drainage systems to handle large storm events. Cities are also increasingly integrating nature-based solutions, like wetland restoration or urban forests, into their flood resilience strategies.

D. Wastewater treatment and reuse

Wastewater treatment and reuse are crucial components in managing water resources, particularly in areas facing water scarcity or environmental stress. The process involves several stages of treatment, followed by the potential reuse of treated water for various purposes, reducing the demand for fresh water.

1. Wastewater Treatment

Wastewater treatment typically involves physical, chemical, and biological processes to remove contaminants from wastewater. The treatment process can be divided into several stages:

a. Primary Treatment:

- **Purpose:** Removal of large solids (like debris, paper, and plastic) and sediment from the wastewater.
- **Process:** The water passes through screens and settling tanks, where heavier solids settle at the bottom and lighter materials float on the surface and are removed.

b. Secondary Treatment:

- **Purpose:** Further reduction of suspended solids and organic matter.
- **Process:** Biological processes are used, typically involving bacteria and microorganisms that break down organic matter in the wastewater. This stage often occurs in aeration tanks, where the water is mixed with air to encourage bacterial activity.

c. Tertiary Treatment:

- **Purpose:** Removal of remaining contaminants such as nutrients (nitrogen and phosphorus) and pathogens.
- **Process:** Advanced treatment methods like filtration, chemical treatment, and ultraviolet (UV) light are used to further purify the water. This stage may also include disinfection to kill any remaining pathogens.

d. Sludge Treatment:

- **Purpose:** Manage and treat the sludge (solid waste) generated during the treatment process.
- **Process:** Sludge is treated separately, often through methods like anaerobic digestion, drying, or

composting, before being disposed of or reused.

2. Wastewater Reuse

Treated wastewater can be reused for various applications, reducing the demand for potable water and promoting sustainability. Some common reuse options include:

a. Agricultural Irrigation:

Treated wastewater can be used for irrigation, reducing the need for freshwater for crops. However, the level of treatment must meet safety standards to avoid contamination of crops and soil.

b. Industrial Use:

Industries often use large amounts of water in processes like cooling, cleaning, and manufacturing. Reusing treated wastewater in such operations helps conserve fresh water and reduce operating costs.

c. Landscape Irrigation:

Reused wastewater can be used for watering parks, golf courses, and public green spaces. It's an effective way to maintain landscapes without tapping into potable water resources.

d. Potable Reuse:

In some cases, highly treated wastewater can be further purified to meet drinking water standards, a process known as direct potable reuse (DPR) or indirect potable reuse (IPR). This is more common in areas with extreme water scarcity and involves advanced treatment techniques like reverse osmosis, UV disinfection, and advanced oxidation processes.

e. Environmental Restoration:

Reusing treated wastewater can also help maintain natural ecosystems, like wetlands or rivers, particularly in areas where water resources are scarce.

3. Benefits of Wastewater Treatment and Reuse

- **Water Conservation:** Reduces the reliance on freshwater sources, especially important in arid regions.
- **Environmental Protection:** Proper treatment helps protect ecosystems and prevent the contamination of water bodies.
- **Cost Savings:** Reusing treated wastewater can save costs for industries, municipalities, and farmers.
- **Energy Efficiency:** Modern treatment methods are increasingly energy-efficient, and reused water can contribute to energy savings in various sectors.

4. Challenges and Considerations

- **Public Perception:** There may be resistance to the reuse of treated wastewater, especially for potable uses, due to concerns about safety and health.
- **Health and Safety Standards:** Stringent regulations must be followed to ensure that treated wastewater is safe for its intended use.
- **Infrastructure Requirements:** Significant investment is needed to develop the necessary infrastructure for wastewater treatment and reuse.
- **Quality Control:** Ensuring that treated water meets specific standards for different uses (agriculture, industrial, potable) can be complex and requires advanced treatment systems.

5. Innovative Technologies for Wastewater Treatment and Reuse

- **Membrane Filtration:** Techniques like reverse osmosis and Nano filtration are effective at removing contaminants, enabling high-quality reuse.
- **Electrocoagulation:** A process that uses electrical charges to remove particles and contaminants from wastewater.
- **Advanced Oxidation Processes (AOPs):** These methods use powerful oxidants to break down organic pollutants that may be difficult to remove through conventional treatment.

Objectives:

1. **Assess Future Water Demand:** To analyse the projected increase in water demand due to continued urban growth, considering factors such as population expansion, industrialization, and lifestyle changes. This will help determine future water needs for urban populations.
2. **Evaluate the Effects on Water Availability:** To investigate how urbanization will impact the availability of local freshwater sources, including rivers, lakes, and groundwater, considering factors like over-extraction, pollution, and climate change.
3. **Examine Urban Water Management Practices:** To evaluate current and potential water management strategies in urban areas, with a focus on improving water supply systems, distribution networks, and wastewater treatment technologies for future sustainability.
4. **Study Water Quality Trends:** To assess the future quality of water sources in urban environments, considering the impact of population growth, industrialization, and inadequate waste management on water pollution.
5. **Promote Water Conservation and Efficiency:** To explore effective water conservation methods and technologies that could help reduce water usage per capita, ensuring that urban populations can meet their water needs without overexploiting resources.

By addressing these objectives, the study seeks to contribute to the development of resilient and sustainable urban environments that harmonize with natural ecosystems.

Conclusion:

In summary, wastewater treatment and reuse play a critical role in sustainable water management, providing an alternative source of water while reducing the environmental impact of wastewater disposal. The advancement of treatment technologies and the adoption of water reuse strategies are key to addressing global water scarcity challenges.

Balancing water supply and demand in growing cities requires integrated strategies that address both the supply-side challenges (e.g., water scarcity, pollution) and demand-side factors (e.g., population growth, industrial expansion). A holistic approach that combines technological innovation, efficient infrastructure, effective regulation, and community involvement is essential for ensuring that cities can meet the water needs of their growing populations sustainably.

Water distribution infrastructure faces several challenges in rapidly urbanizing areas, ranging from aging systems to inequitable access. Addressing these challenges requires a combination of **upgrading infrastructure, adopting new technologies, and implementing efficient management practices**. Cities that proactively invest in improving water distribution systems will not only ensure reliable and safe water for their residents but also increase their resilience to future challenges, including climate change and population growth.

Storm water management and flood resilience are interconnected elements of sustainable urban development, and they become even more crucial as cities face increased rainfall, rising sea levels, and other climate-related challenges. Balancing infrastructure, nature, and community preparedness is key to minimizing the impacts of storms and floods.

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Water Resources in A Changing World: Science, Management And Policy

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Abstract

In a world being rapidly changed by urbanization, population increase and climate change, water resources are a growing concern. Water is under unprecedented pressure from shifting weather patterns, global warming and increasing demand. Water makes a society and its financial system paintings. Vanham stated that freshwater is turning into increasingly scarcer and inadequately disbursed which possess a principal danger to the surroundings and human fitness, especially in water shortage hotspots which might be already vulnerable to floods, droughts, and water pollution. This paper highlights strategies to manipulate water sources more sustainably through strategies together with water conservation, green irrigation, and the application of technology like water recycling and desalination. It underlines the significance of integrated water aid management (IWRM) frameworks in making sure both equitable distribution and lengthy term sustainability of water resources. The function of governance and policy and international cooperation also is burdened, with the want to create transboundary water agreements and to guard water sources that international locations percentage. In addition, social media web sites permit a mess of voices to be heard, particularly people from marginalized communities which can be often more negatively affected by environmental destruction. This method allows a greater holistic technique to environmental troubles by using selling collaboration and facts sharing between scientists, affected communities, and environmental activists.

Keywords: Water Scarcity, Sustainable Water Management, Climate Change, Hydrology, Water Governance, Integrated Water Resources Management (IWRM)

Introduction

Water is a lifestyles-giving resource that underpins ecosystems, helps human fitness, drives monetary growth and nourishes agriculture. It is the essential constructing block of civilizations. But inside the modern generation, ensuring sustainable management of water assets has become increasingly difficult and pressing. Water availability and nice is below stress due to a couple of factors such as population boom, urbanization, weather change, water pollution and geopolitical conflicts. Water resources will thus come to be ever extra scarce and increasingly difficult to manipulate. We want a comprehensive coverage that mixes true policy frameworks, excellent management strategies, and scientific research to address those problems. In a swiftly converting international, this method will ensure that water sources are used sustainably and its blessings are shared equitably.

The Science of Water Resources

Water Problems: The need for Scientific Research Scientific research plays an important role in understanding and solving problems related to water. A significant part of the evaluation of water availability is hydrological research, which covers water distribution and flow on the planet. Hydrologists monitor water quality, rainfall patterns, river flow and groundwater levels. In many areas, rising temperatures and changing precipitation patterns are predicted to worsen water scarcity and make droughts more frequent and intense (IPCC, 2021). Other climate change consequences include modified seasonal water availability and diminished snowpack and glacier melt, critical freshwater sources in numerous areas (Miller et al., 2018). Scientific studies are vital to recognize resolving water-related problems. One main detail of the assessment of water availability is hydrological research, which makes a speciality of the distribution and motion of water on our planet. Hydrologists song water excellent, rainfall styles, river flows and groundwater stages. Climate change projections indicate that growing temperatures and converting styles of precipitation may worsen water scarcity in many parts of the sector, growing the incidence and intensity of droughts (IPCC, 2021). Climate green control of water assets is vital to cope with the troubles of pollution, unequal get proper of entry to, and water shortages. Water manipulate techniques may be divided into two number one categories: deliver-thing and speak to for-side. Deliver-aspect management refers to techniques collectively with desalination, inter-basin transfers, and water storage that growth the quantity of water to be had. Demand-aspect manipulate's primary dreams are to lower water intake and enhance water performance (Grafton et al., 2018). Demand-side responsibilities include encouraging the usage of water-inexperienced irrigation systems, recycling and reusing water, and enforcing water-saving era in homes and businesses. Encourages equitable distribution, and decreases warfare. Overexploitation is another problem that wishes to be addressed for sustainable water management. For instance, in many regions of the sector, groundwater components are being exhausted at an unsustainable price. Water tables drop and aquifers get salinized due to over-extraction for urban water supply and irrigation (Konikow, 2013).

Groundwater management this is sustainable involves controlling extraction, encouraging effective irrigation techniques, and placing laws into area that protect aquifers for coming generations. Another problem that needs to be resolved for sustainable water control is overexploitation. For example, groundwater substances are being depleted at an unsustainable rate in many elements of the world. Over-extraction for irrigation and concrete water deliver causes aquifers to come to be salinized and water tables to drop (Konikow, 2013). Sustainable groundwater control approach limiting extraction, promoting efficient irrigation practices, and enacting legislation that safeguards aquifers for destiny generations. Water policy is critical to making sure that water assets are controlled pretty and sustainably. Water governance is the method of setting up institutional and prison frameworks that modify the use and distribution of water. regulations should take into account the wishes of different sectors, which includes domestic consumption, enterprise, agriculture, and electricity, even as maintaining the surroundings and ensuring equitable get admission to. powerful water governance requires robust institutions, clearly described prison rights, and transparent selection-making strategies. worldwide water rules are frequently motivated by using the need to control transboundary water sources. several nations are traversed with the aid of most important rivers, consisting of the Nile, Ganges, and Mekong. Cooperation and negotiation are critical to preventing conflicts and ensuring that everyone riparian states have honest access to water (Wolf, 2007). international agreements which include the United Nations Watercourses conference offer a foundation for cooperation in shared water basins. but, setting those accords into practice is typically complicated via political disputes, uneven energy members of the family, and conflicting countrywide interests. domestic water rules also are necessary to sell water security. In many nations, get entry to to water is impacted by using social and monetary inequality. vulnerable companies, like low- earnings and marginalized communities, might also have trouble accessing easy water because of steeply-priced or inadequate infrastructure. Policymakers should supply social equality in water distribution pinnacle priority so that you can guarantee that water sources are allocated pretty and that the poorest human beings have get right of entry to to low cost, secure consuming water (Gleick, 2000) furthermore, given the increasing hazard posed by using weather change, water coverage must adapt to moving precipitation patterns and water shortage. Restoring natural water ecosystems, including wetlands, which act as boundaries towards excessive weather activities, encouraging water-efficient farming, and enhancing flood control are some methods that policies may want to include climate resilience (UN-Water, 2020).

Objectives

In a world wherein water troubles are developing more complex, it is important to take a look at the numerous elements of water sources, their management, and the technology that underpins them. the following targets spotlight key regions to cognizance on so that it will recognize and remedy these issues.

1. Recognize how climate trade influences water quality, distribution, and availability.
2. Check out the causes and effects of water contamination, accounting for chemical, industrial, and agricultural pollution.
3. Broaden sustainable water management techniques to optimize water use and defend water sources.
4. Examine the reasons, outcomes, and enduring effects of groundwater depletion.
5. Remember the ways wherein era can lessen water intake and growth water efficiency.
6. Take a look at the effects of coverage and government on the sustainability and control of water assets.
7. Deal with the worldwide problem of water scarcity with the intention to make certain long-time period water safety. and give you solutions. keep in mind the geopolitical challenges and possibilities for cooperation within the control of shared water resources.
8. Increase adaptable water management techniques that account for the effects of climate exchange.

Data And Methodology

Data

Temperature fluctuation, increase in people and urbanization are placing additional demands on water resources, making sound technological control plans, and legal frameworks essential to ensure sustainability use. The weather change is drastically affecting water availability, changing rainfall patterns and making droughts and floods more common, especially in the arid and semi-arid regions (IPCC, 2021). This is related to IWRM whose goal is to place top a green use, fair allotment and environments coverage (International Water Partnership, 2000). Additionally, if there is a need to fulfil present and future water desires water coverage and governance frameworks need to be inclusive, bendy and incorporate stakeholder engagement (Meals and Agriculture Organization [FAO], 2018). Clever irrigation, water recycling, and desalination are technological advances that could provide options to enhance performance and tackle water scarcity (Gleick, 2018). Protecting current water resources for future generations is based on those trends, strong governance, and sustainable management strategies. The technological and control strategies used to address the problems in water property consist of records collecting, modeling simulations, coverage assessment, and stakeholder participation. This method combines scientific with practical approaches for sustainable management.

Methodology

1. Records accumulating and monitoring:

Knowing how much, what's best, and how available new water is essential to making informed choices. Data property has satellite remote sensing, hydrological stations, groundwater monitoring, and water quality testing. Real-time information on temperature, precipitation, and water storage is necessary to understand how climate change is affecting water resources, and new remote sensing technology provides this information. Data on groundwater tracking wells and river flows can be used to monitor the trend of current depletion and existing water quality deterioration.

2. Hydrological and climate Modelling:

Several hydrological models like the SWAT and HEC-HMS are being used to predict future water availability due to climate change. These models predict river water flow in normal rains, floods, and droughts. Models of climate and weather will be effective for predicting the incidence of surplus or deficit of water anywhere in future.

3. Water manipulate Practices evaluation:

Sustainable manage practices, like inexperienced irrigation and wastewater recycling, are assessed through field research and pilot projects. those programs acquire records on water use usual overall performance, environmental effect, and charge-effectiveness, which allows understand remarkable practices that can be prolonged for broader use.

4. Coverage And Governance Assessment:

analysing institutional frameworks and suggestions requires searching at laws, regulations, and governance structures in precise jurisdictions. Stakeholder discussions, case research, and interviews help to make clean understanding coverage picks have an effect at the allocation and sustainability today's water sources. moreover, contrasting a success water manipulate techniques gives direction for developing adaptable guidelines for a diffusion present day occasion.

5. Stakeholder Engagement:

taking element with close by companies, government agencies, and agency ensures that the strategies and rules produced are context-unique, inclusive, and sensible for prolonged-term implementation.

Result & Discussion

Data gathering, climatic and hydrological modelling, policy analysis, stakeholder involvement, and management practice review are all components of the approach to managing water resources in a difficult environment. Each stage is thoroughly explained in the following:

1. Data Collection and Monitoring

For water resource management to be effective, precise statistics on water availability, utilization, and quality are necessary. This data comes from a variety of systems and technologies that offer both long-term trends and real-time information.

Key Data Sources:

- **Satellite Remote Sensing:** gives information on temperature, precipitation, and variations in water storage (lakes, glaciers, and reservoirs).
- **Hydrological Stations:** Gather information on water levels and river flow to gain a better understanding of the availability of surface water.
- **Groundwater Monitoring:** In order to measure groundwater depletion, wells monitor water table levels.
- **Water Quality Testing:** Regular monitoring of water quality by testing for contaminants such

nitrogen, phosphorus, and heavy metals.

Results

The information gathered by these devices aids in monitoring water resource changes, evaluating the effects of climate change, and forecasting future water surpluses or shortages.

Data Type	Source	Purpose
Precipitation Levels	Satellite, Meteorological Stations	Understand rainfall patterns and predict droughts
River Flow Data	Hydrological Stations	Track surface water availability
Groundwater Levels	Monitoring Wells	Assess depletion rates and identify over-extraction
Water Quality Indicators	Water Quality Testing	Monitor pollutants (e.g., nitrogen, phosphorus) for ecosystem health

Climate and Hydrological Modelling

Advanced hydrological fashions like SWAT and HEC-HMS are used to estimate water flows, replenish groundwater, and predict destiny water availability. these fashions use weather facts to simulate situations based totally on one of a kind greenhouse gasoline emission path, allowing for the prediction of water availability underneath a selection of destiny climate situations.

Findings:

- ➢ Projections of water scarcity or abundance for some of areas beneath climate exchange scenarios.
- ➢ figuring out the critical regions maximum at hazard for water assets

Water Management Practices evaluation

Water control Practices Sustainable technology inclusive of green irrigation (e.g., drip irrigation) and wastewater recycling are evaluated via pilot tasks that research preserves an eye fixed on: Water Use performance: the quantity of water required for each unit of industrial or agricultural production.

- ➢ Environmental impact: the effect of practices on nearby ecosystems.
- ➢ fee-Effectiveness: The viability of enforcing thoughts at scale from a monetary point of view.

Outcomes techniques that work are highlighted, and suggestions are provided for expanding these techniques in areas with limited water assets.

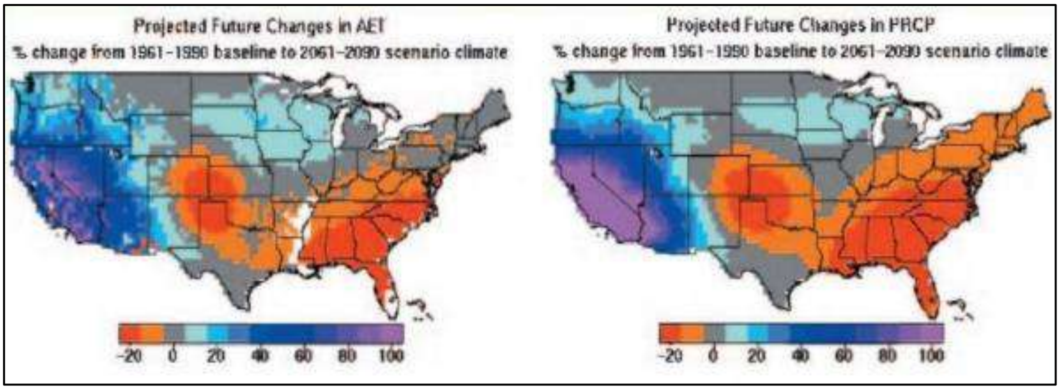
Coverage And Governance Analysis

- ➢ To find loopholes and enhance water control, an examination of laws, policies, and governance structures is essential. This comprises:
- ➢ Stakeholder Consultations: attractive with local communities, authorities groups, and industries to understand water governance demanding situations.
- ➢ Case studies: figuring out which water management strategies paintings excellent in positive areas.
- ➢ consequences: perspectives on a success governance strategies and coverage tips for environmentally pleasant water control techniques.

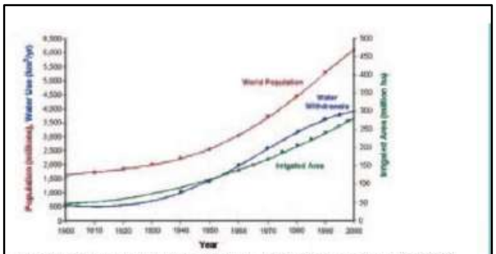
Stakeholder Engagement

For projects to achieve success and tailor-made to the local context, cooperation with nearby communities, companies, and governmental companies is vital. Stakeholder engagement includes the following:

- Public consultations and discussions to guarantee that plans for water management remember the goals and requirements of diverse agencies.
- Determining who's chargeable for what in water governance.
- **Effects:** creation of management techniques which are inclusive and flexible sufficient to fulfill nearby and nearby demands.



An ecosystem version (BIOME-BGC) that uses a destiny climate state of affairs produced from a global weather model to estimate destiny adjustments in real evapotranspiration (AET) and precipitation (percent) through the 12 months 2100. The atmosphere version adjusted the leaf location index, a measure of plant productivity, in response to versions in O^, weather, water, and nitrogen availability. in this state of affairs, atmospheric carbon dioxide (CO^) extended by means of about zero.five% year. those forecasts normally suggest that the arid West will enjoy more rainfall and plant growth, in an effort to improve AET. the primary reasons for the Southeast's expected decrease evapotranspiration are reduced rainfall and the subsequent impacts of drought on plants. See container 2 (VEMAP II effects, supplied with the aid of P. Thornton of the Numerical Terradynamic Simulation institution at the college of Montana) for further details.)



— Global data for human population, water withdrawals, and irrigated land area from 1900 to 2000. nd updated from Gleick (1998).

Discussion

The method outlined for addressing water aid management in a challenging world presents essential insights into the way to method water scarcity, pollutants, and weather trade impacts.

The records collection and tracking method plays a pivotal position inside the initial expertise of water availability, usage, and high-quality. accurate and real-time records from satellite remote sensing, hydrological stations, and groundwater monitoring permit knowledgeable decision-making and help examine the lengthy-term traits in water sources. This information permits us to expect water shortages, together with in areas going through decreased rainfall or over-extraction of groundwater (Grafton et al., 2018). as an example, the potential to display water first-rate the usage of checking out technology facilitates identify pollution early, permitting focused interventions earlier than ecosystems or human fitness are considerably impacted (chippie et al., 2018). Forecasts of destiny water deliver below specific climate scenarios are furnished with the aid of the hydrological and weather modelling section, which is essential for preparing for issues like droughts and floods. when mixed with projections of climate exchange, fashions such as SWAT and HEC-HMS resource in locating vital regions wherein water supplies are maximum at hazard. Policymakers would possibly deal with areas that need instantaneous interest by way of the usage of this information to tell mitigation efforts (IPCC, 2021) crucial hints for environmentally friendly techniques like drip irrigation and wastewater recycling are included within the exam of water management techniques. specially in agriculture, where water intake is excessive, those techniques can significantly increase water use performance. additionally, assessing the fee-effectiveness of those techniques ensures their viability and scalability for broader use in regions with limited water sources (Grafton et al., 2018).

Effective water control may be hindered via insufficient felony and governance frameworks, but a success case studies show that bendy, responsive regulations may be developed through stakeholder engagement and figuring out high-quality practices (Wolf, 2007).

Stakeholder involvement ensures that strategies are contextually relevant and actionable, fostering collaboration amongst governments, agencies, and neighborhood corporations to acquire long-time period water safety (UN-Water, 2020).

Conclusion

In conclusion, an intensive framework for addressing problems with water assets is obtainable by means of the included method that mixes facts amassing, modelling, evaluation of control techniques, policy evaluation, and stakeholder involvement. This approach improves water security, tackles the consequences of weather exchange, and guarantees green, bendy management for sustainable water resources in a converting international by using leveraging actual-time records, predictive models, sustainable practices, and inclusive governance.

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Demographic Transformation of Ralegansiddi Watershed Village Before and After Watershed Development

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Introduction

In the subject of Geography various branches are studied since ancient time, few of them are newly introduced in the subject matter of Geography. Population Geography is one of them. Population Geography is recently emerged as a separate discipline of study and research. It is concerned with the spatial and temporal analysis of population. It involves not only the magnitude of human population but also its different characteristics, growth and mobility (Ghosh, 1985) scope of this branch is too vast thus, today it is treated as an independent specialized branch. Geography is the study of distribution of physical and cultural factors over the surface of the earth. Population itself is an important cultural aspect, which varies over the surface of the earth. Distribution of population, its growth, its religious and linguistic composition, sex ratio and age composition, migration, standard of living, its economic and occupational structure etc. are some of the indicators, which are studied in population geography, and all of them directly or indirectly put an impact on the human development. Adaptation of various human groups to their respective environments in different parts of the world, and also other various aspects of population have been studied since long in this branch.

Within the past two decades, vast changes have occurred in many aspects of life in every country of the world. Perhaps the most significant is the recognition, that rapid rate of population growth influences every sector of economic and social development. Worldwide interest in the population problems evolving from rapid population growth has been promoted by two major considerations, an increasing concern about the relation between population growth and available resources and a growing awareness that unrestricted population growth tends to impose a strong constraint on the standard of living, happiness and even survival of mankind through the spiraling consumption of the fixed quantity of resources (Bhattacharjee and Shastri, 1976).

If we want to solve the water problem in rural areas and stop the mass migration of the rural people to the urban centers, watershed development is the only solution. If we plan watershed development, works well, we can save the country from water crisis in the future. For that, a village should be considered as a unit and then composite thoughts need to be given to all the watershed areas in that unit. Watershed development is a miracle which transforms the society. Watershed developments not only increase water availability of the area but also change the society. It takes social and economic transformation through various activities. Watershed development is the foundation of economic and social transformation. Watersheds developments teach earn water through hard rock, and use it for welfare of village and downtrodden community of the village to raise their social transformation. The social transformation brings the economic transformation (Anna Hajare, 2011)

Effective watershed management is also considered an appropriate approach for addressing food security and poverty alleviation. Watershed management is being seen as a major component of soil; water and vegetation cover conservation, rural communities' living standard improvement and better environmental conditions. So, watershed management is one of the important topics of this present study. For the development of a country, its natural resources must be conserved, utilized and managed properly. This can be achieved efficiently by considering watershed as a basic workable unit and it has been proved by a number of researchers (David A.Eash 1994).

Watershed management implies rational utilization of land and water resources for optimum and sustained production with the minimum of hazards to natural resources and environment. It requires collection and analysis of a great deal of information on physical relationship of vegetation-soil-water to land management which ensures economic and social progress of a region (Nagarajan. N.2012).

In India, most watershed projects are implemented with the twin objectives of soil and water conservation and enhancing the livehood of the rural poor (Sharma and Scott, 2005). For these different types of treatment activities are carried out in watershed villages like Ralegansiddi, Hiwrebajar, Darewadi, Mudgal, Shirpur, Johad etc. These model watershed villages are the best examples, and they indicate that watershed is not only tool to increase availability of water, but also watershed is the best tool of socio-economic transformation of the society. But today these villages are also facing problems of scarcity of water, so there is a dire need to acquaint people with water management.

Demographic Characteristics

Population Distribution

Table No. 1 Distribution of total population in model watershed village Ralegansiddhi.

Sr. No.	Name of Village	1991			2001			2011		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
1	Ralegansiddhi	1042	940	1982	1041	1265	2306	1217	1148	2365

Source: Computed by researcher (Census 1991-2011).

The table no. 1 shows population distribution in the Ralegansiddhi. As per the census of India 1991, total number of households and population in Ralegansiddhi. was 310 and 1982. In this census year female (940) population is less than male (1042). According to the census of India 2001 total number of households and population in Ralegansiddhi was 394 and 2306. In this census year female (1265) population is decreases as compare to the male (1041). According to the census of India 2011 total number of households and population in Ralegansiddhi. 530 and 2365. In this census year female (1148) population is decreases as compare to the male (1217).

According to the above table population of the village is increased according to increased census years.

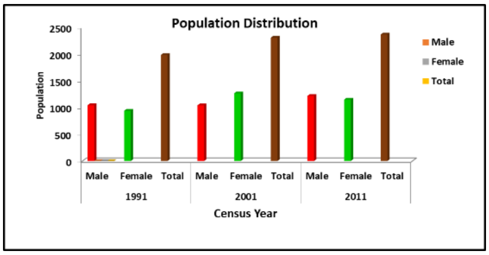

Fig. no. 1 Population Distributions in Ralegansiddhi (1991-2011)

Population Growth Rate

Table No. 2 Population growth rate of model watershed village Ralegansiddhi.

Sr. No	**Name of Village**	**Population Growth (Percentage)**		
		1991	**2001**	**2011**
1	**Ralegansiddhi**	31.43	16.90	2.07
2	**Ahmednagar District**	24.35	19.80	12.44

Source: Computed by researcher (Census 1991-2011).

Table no 2 represents population growth rate of study area. Declining trend of population growth rate is important characteristics of Indian population. This was followed by Ralegansiddhi average growth rate is declined. Population growth rate of Ralegansiddhi was decline continuously from 1991 to 2011.

Population growth rate of study area also declined continuously in Ralegansiddhi 1991 (31.43) to 2011 (2.07), and it is one of good indicator of socio-economic development due to watershed development.

In general, the village Ralegansiddhi shows rapid declining trend of population growth rate due to development in way of living, increased per capita income, educational attainment, health facility and better awareness of population explosion.

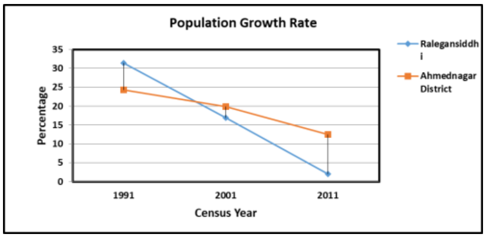

Fig. no. 2 Population Growth Rate of Ralegansiddhi (1991-2011).

Population Density

Table No. 3 Population density distribution of model watershed village Ralegoansiddhi.

Sr. No.	Name of Village	Population Density (Person /Sq. Km)		
		1991	2001	2011
1	**Ralegansiddhi**	202	236	241
2	**Ahmednagar District**	198	237	266

Source: Computed by researcher (Census 1991-2011).

Table no. 3 represents population density that is land man ratio of study area. As per the data population density of Ralegansiddhi increased rapidly in the last three decades, but if compared with district average density of Ralegansiddhi, it is less except 1991 census year where Ralegansiddhi. has exceed density above district average and in 2001 and 2011 census Ralegansiddhi is showing population density below Ahmednagar district.

It is clear from the data that proportion of population to the land is high in Ralegansiddhi and the population density is increased in the village by 39 Persons / Sq. Km. in the last three decades

It is found from the data that decadal increase in population density is less from 2001 to 2011 as compare with 1991 to 2001.

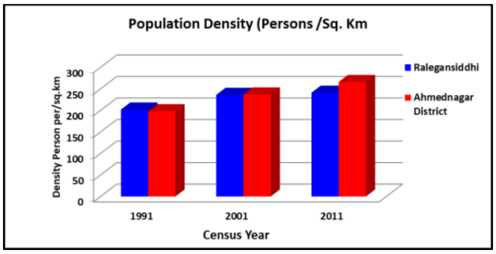

Fig. No. 3 Population density distributions of Ralegansiddhi 1991-2001.

Sex Ratio

Table No.4 Sex ratio of model watershed village Ralegansiddhi .

Sr. No.	Name of Village	Sex Ratio (Female's / '000' Male)		
		1991	**2001**	**2011**
1	**Ralegansiddhi**	903	810	943
2	**Ahmednagar District**	949	940	939

Source: Computed by researcher (Census 1991-2011).

Table no. 4 represents sex ratio of study village which is important indicator of socio-economic development in the region. From the data it is clear that in Ahmednagar district sex ratio is declined by 10 females/ 000' males. Ralegansiddhi Shows very contrast trend. Where it declined very rapidly in 1991 to 2001(92 females/ 000' males) and again it increased in 2011 (133 females/ 000' males).

In general, the increased sex ratio of the study area is a sigh of socio-economic development of the model watershed village.

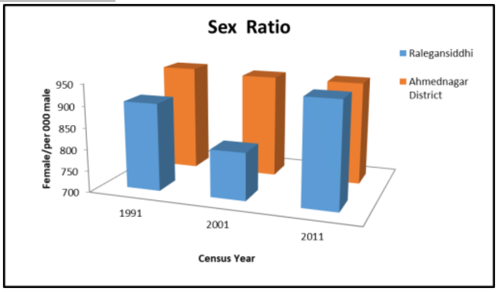

Fig. No. 4 Population Sex Ratio of Ralegansiddhi 1991-2001.

Child Sex Ratio (0 to 6 ages)

Table No.5 Child sex ratio (0 to 6) of model watershed villages.

Sr. No.	Name of Village	(Female's/ '000'/ Male)		
		1991	2001	2011
1	Ralegansiddhi	839	806	799
2	Ahmednagar District	949	885	852

Source: Computed by researcher (Census 1991-2011).

Table No. 5 shows the child sex ratio of 0-6 age. The table of child sex ratio of model village shows serious problem of very deficient child sex ratio. Child sex ratio of Ahmednagar District declined regularly in the last three decades, it is 949 females /000' male children in 1991 to 852 females /000' male children in 2011, which is 97 females /000' male children. It is very serious social problem in the study area.

Ralegansiddhi where child sex ratio decreased from 1991 to 2001 by 33 females /000' male children but in the last decade of 2001 to 2011 it declined by 07 females /000' male children.

Rapidly declining child sex ratio of model village is one of the problems of serious concern. In order to overcome this serious problem, schemes such as save girl child, ban on sex determination, sex equality etc. need to be implemented urgently.

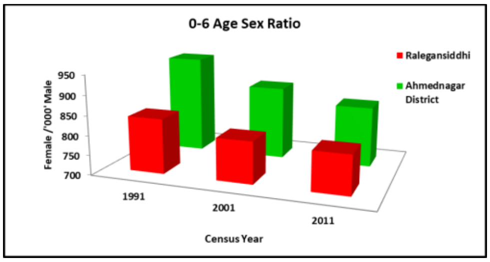

Fig. No. 5 Population 0-6 Age Sex Ratio of Ralegansiddhi 1991-2001.

Findings and Recommendations

Major Findings

1. Ralegansiddhi is situated on Decan trap region times Basalt lava flow. 70 percent area of the study region covers by Basaltic hard rock. Due to this type of topography ground water recharge capacity of the region is low.
2. In the Ralegansiddhi percentage of population increased from census 1991(1982) to 2011 (2365). Rate of population increases is less than Ahednagar District.
3. Ralegansiddhi has less population growth rate (2.07 %) as compare with the average population growth rate of Ahmednagar district (12.44 %) in 2011 census. Less population growth rate is indication of impact of watershed Management on human recourse development.
4. Population density Ralegansiddhi has is increasing continuously in all census year. Density of Ralegansiddhi has increased by 39 persons per sq.km. in that last three decades.
5. Declining sex ratio in study area is serious social and demographic problem. It is found that

Ralegansiddhi has shown declining sex ratio at the alarming rate. From 1991 to 2001 (92 females/ 000' males) (1026/000'males). In the census year 2001 to 2011 indicates drastic change in sex ratio that is sex ratio incase 133 females/ 000' males. In general, the increased sex ratio of the study area is a sigh of socio-economic development of the model watershed village.

6. Ralegansiddhi where child sex ratio decreased from 1991 to 2001 by 33 females /000' male children but in the last decade of 2001 to 2011 it declined by 07 females /000' male children. Continuity declining trend of child sex ratio is serious demographical problem in Ralegansiddhi.

Contribution to the Society

1. Awareness of demographic, social and economic problems is made in study area.
2. Peoples should know sustainable use of natural resources.
3. Socio-economic status of project beneficiaries is increased through this work
4. Environmental awareness and sustainable development of the area is possible by the present work.

Recommendations

1. Social awareness is necessary about several demographic characteristics such as declining sex ratio, increasing dependency ratio etc. which creates several social problems.
2. For the increasing working participation rate among people establishment of agro-base occupations / industries and use of modern techniques in field of agriculture are necessary.
3. Farmer must be trained for additional income generation activities along with agriculture, such as dairy farming, hatch rich and poultry farm, nursery, goat rearing etc.
4. Strong support and technical training from various government departments, such as horticulture, forestry, irrigation, animal husbandry and NGOs is needed.
5. State, Central government and NGOs should work collaborative and give demographic awareness to project beneficiaries of watershed management.

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