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Impact of Urbanization on Groundwater Quality: A Case of Kochi Municipal Corporation Area

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Abstract
This research delves into the intricate relationship between urbanization and groundwater quality by conducting a comprehensive analysis of literature case studies from Trichy, Bhubaneswar and Lahore. The primary objective is to elucidate the strategies employed, challenges faced, and ultimately, to formulate recommendations and guidelines for mitigating the impact of urbanization on groundwater resources. Drawing on a synthesis of existing literature, the study reveals diverse urbanization scenarios, highlighting unique challenges in each case study. The analysis identifies common threads, including the impact of population density, industrialization, and land-use changes on groundwater quality. Furthermore, it underscores the role of local geological and hydrogeological conditions in shaping city-specific challenges in Kochi municipal corporation area. Based on these insights, the research formulates recommendations and guidelines to alleviate the adverse effects of urbanization on groundwater quality of Kochi municipal corporation area. Guidelines encompass integrated urban planning, sustainable water management practices, and the implementation of effective waste disposal and sewage systems. The formulated recommendations and guidelines provide a foundation for policymakers, urban planners, and local communities to adopt proactive measures, fostering sustainable urban development and preserving groundwater resources in the face of ongoing urban expansion in Kochi municipal corporation area .

Keywords: Urbanization, Impact of urbanization, Urban sustainability, Sustainable Water Management, Community engagement, Water quality.

1. Introduction

As urban space continues to expand to accommodate growing global population, there it comes the need to quantify and qualify the impacts of development on natural processes. Every time we consider on macro level conditions where micro site conditions have huge impact. The Changes in surface water runoff, evapotranspiration, groundwater recharge sources, impermeable land cover, and municipal water demand are some of the ways that urbanization affects the availability of groundwater. A wide range of effects, including a decrease in river discharge, a drop in groundwater levels, a rise in salinity, and wetlands shrinkage, Urbanization is a global phenomenon with profound implications for the environment, including the quality of groundwater. The Kochi Municipal Corporation Area has experienced rapid urbanization in recent years, leading to increased demand for water resources and potential threats to groundwater quality

2. Literature Review

2.1.1 Urbanization

As urbanization in Kochi progresses, there is a growing concern about its impact on groundwater quality, especially in residential areas. Understanding the factors influencing groundwater contamination is crucial for ensuring the sustainability of water resources, safeguarding public health, and informing urban planning practices.

2.1.2 Urbanization trends in india

India has been experiencing rapid urbanization, with a significant shift of population from rural to urban areas. This is driven by factors such as better economic opportunities, improved infrastructure, and changing lifestyles. Major cities like Delhi, Mumbai, and Bangalore have witnessed substantial growth, leading to the development of mega-cities. This growth poses challenges related to infrastructure development, housing, and environmental sustainability.

2.1.3 Global Urban Population Growth

On a global scale, urbanization has been a prevalent trend. The majority of the world's population now resides in urban areas, and this trend is expected to continue.

2.1.4 Urbanization in kerala

A notable instance of rapid urbanization happened in Kerala. The urban sector of Kerala consists of 6 municipal corporations and 87 municipalities. The State has a population of 33,387,677 people according to 2011 Census as against the 31,838,619 of 2001. The urban populace of Kerala has registered a huge growth over the last decade as the number of towns in the State increased three times. Urbanization, as measured by the share of urban population of the State, has shown a sharp increase from 25.96 per cent in 2001 to 47.72 per cent in 2011.

2.1.5 Underground water sources

Infiltration Galleries

Infiltration galleries are also known as horizontal wells as they are horizontal or nearly horizontal tunnels that are constructed through the water-bearing strata along the banks of the river.

Infiltration Wells

Infiltration wells are a series of shallow wells constructed along the banks of a river. The wells collect the river water that seeps through their bottom. They have open joints and are made up of brick masonry. They are usually covered at the top and manholes are provided for carrying out inspections.

Springs

Spring is the natural outflow of groundwater to the surface of the earth, indicating that the water table has outcropped. Generally, when a pervious layer is crammed between two impervious layers, it eventually gives rise to springs. In certain springs, discharge of hot water is seen due to the presence of sulphur.

Gravity Springs

A gravity spring is formed when the groundwater table rises and overflows beside a natural valley or a depression.

Surface Springs

In surface springs, an impervious stratum or obstruction supporting the storage becomes inclined. As the stratum is inclined, the water level rises and the water table is exposed to the ground.

Artesian Springs

When water is flowing through a confined aquifer and the above layer is under pressure, it leads to the formation of an artesian spring

Wells

A well is a vertically excavated hole on the surface of the earth that facilitates access to groundwater by bringing it up to the surface. Open wells and tube wells are the two types of wells

Open Wells

An open well is a masonry well having a large diameter. This type of well is excavated only up to a limited depth and is suitable when the discharge is as low as 18 cubic meters per hour. The water must have a critical velocity in order to be withdrawn as higher velocities may disturb the soil grains and the **well lining.**

Depending on the type of strata available, open wells can be classified as shallow and deep wells.

Tube Wells

A tube well is a tube or long pipe that is bored or drilled deep into the ground. It intercepts one or more strata bearing water and generally has a small

2.1.6 Water properties

Physical Parameters

Temperature

Temperature affects the solubility of gases and influences the metabolic rates of aquatic organisms.
Measured in degrees Celsius (°C) or Fahrenheit (°F).

pH (Acidity or Alkalinity)

pH indicates the acidity or alkalinity of water, influencing chemical processes and the health of aquatic life.

pH is measured on a scale from 0 to 14, with 7 being neutral. Values below 7 indicate acidity, and above 7 indicate alkalinity.

Turbidity

Turbidity measures the cloudiness or haziness of water, indicating the presence of suspended particles.
Turbidity is measured in nephelometric turbidity units (NTU).

Dissolved Oxygen (DO)

DO is vital for the survival of aquatic organisms. Low DO levels can indicate poor water quality and negatively impact fish and other aquatic life.

Measured in milligrams per liter (mg/L).

Conductivity

Conductivity measures the water's ability to conduct an electric current, providing an indication of dissolved ions and salinity.

Usually reported in microsiemens per centimeter (µS/cm) or millisiemens per centimeter (mS/cm).

Chemical Parameters

Nutrients

Nutrients like nitrogen and phosphorus are essential for plant and algal growth but can lead to eutrophication and water quality issues when present in excess.

Nitrate, nitrite, ammonia, and phosphate levels are commonly measured.

Metals

Heavy metals such as lead, mercury, and cadmium can be toxic to aquatic life and pose risks to human health.

Analyzed through laboratory methods like atomic absorption spectrometry.

Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD)

Indicators of organic pollution, measuring the amount of oxygen needed for the decomposition of organic matter.

COD and BOD are expressed in milligrams per liter (mg/L).

Total Dissolved Solids (TDS)

TDS measures the concentration of dissolved substances in water and can affect taste, corrosion, and aquatic health.

TDS is expressed in milligrams per liter (mg/L) or parts per million (ppm).

Biological Parameters

<u>Total Coliforms and E. coli</u>

Indicators of microbial contamination and potential presence of harmful pathogens.

Expressed as colony-forming units (CFU) per 100 milliliters of water.

<u>Biotic Index</u>

Measures the diversity and abundance of aquatic organisms to assess overall water quality.

Calculated based on the presence and abundance of different species.

<u>Plankton and Algae</u>

The presence and abundance of plankton and algae can indicate nutrient levels and the trophic status of a water body.

2.1.7 Impact of urbanization

Surface Runoff and Pollution

Urban areas typically have large amounts of impervious surfaces such as roads, pavements, and buildings. This reduces the infiltration of rainwater into the ground, leading to increased surface runoff. This runoff can pick up pollutants such as heavy metals, oil, pesticides, and fertilizers from urban landscapes, and transport them into nearby groundwater.

Stormwater Management Systems

Urban development often involves the construction of stormwater drainage systems to manage runoff. However, these systems can act as conduits for contaminants to reach groundwater if they are not properly designed or maintained. Improper disposal of industrial or household chemicals can also contribute to groundwater pollution through stormwater systems.

Wastewater and Sewage Disposal

In urban areas, there is a higher concentration of sewage and wastewater. If not properly treated, these effluents can introduce nutrients, pathogens, and other contaminants into the groundwater. Leaking or improperly maintained sewage systems can be a source of groundwater pollution.

Landfill Leachate

Urbanization leads to increased generation of solid waste, and landfills are commonly used for waste disposal. Landfills produce leachate, a liquid that can contain various contaminants. If not properly managed, leachate can percolate through the soil and reach groundwater, impacting its quality.

Changes in Land Use

The conversion of natural landscapes to urban areas often involves changes in land use, such as the clearing of vegetation and alteration of soil characteristics. These changes can affect the natural filtration and attenuation processes that help maintain groundwater quality.

Infrastructure Development

The construction of infrastructure, including roads, buildings, and underground utilities, can introduce new materials and chemicals into the environment. For example, construction materials and activities may release pollutants that can seep into the groundwater.

Over-extraction of Groundwater

Rapid urbanization can increase the demand for water, leading to over-extraction of groundwater. This can result in the intrusion of saline water into freshwater aquifers or the lowering of groundwater tables, potentially concentrating existing contaminants.

Heat Island Effect

Urban heat islands, caused by the increased absorption and retention of heat in urban areas, can influence groundwater temperatures. Changes in temperature can affect the solubility and mobility of certain pollutants, potentially impacting groundwater quality.

2.1.8 Impact on water quality

Surface Water Pollution

Urban runoff from streets, parking lots, and industrial areas can carry pollutants such as heavy metals, oils, pesticides, and nutrients into nearby surface water bodies. This pollution can degrade water quality, harm aquatic ecosystems, and impact downstream water users.

Groundwater Contamination

Improper disposal of industrial effluents, leaking sewage systems, and the use of fertilizers and pesticides in urban areas can lead to groundwater contamination. Contaminated groundwater poses risks to both the environment and human health.

Sewage and Wastewater Disposal

Urban areas generate significant amounts of sewage and wastewater. If not properly treated, these effluents can be discharged into water bodies, contributing to nutrient enrichment, bacterial contamination, and other water quality issues.

Construction and Erosion

Construction activities associated with urban development can lead to soil erosion and increased sedimentation in rivers and streams. Sedimentation can degrade water quality by smothering aquatic habitats and transporting pollutants.

Industrial Discharges

Urban areas often host various industrial activities, and if not properly regulated, industrial discharges can introduce pollutants into water bodies, affecting both surface and groundwater quality.

Climate Change Interactions

Urbanization can interact with climate change, influencing precipitation patterns and temperatures. These changes can impact water quality through altered runoff patterns, changes in water temperatures, and shifts in the distribution of pollutants.

2.1.9 Impact on water quantity

Increased Water Demand

Urbanization leads to a higher population density, increased industrial activities, and greater water demand for various purposes, including domestic use, industrial processes, and agriculture. This heightened demand can result in over-extraction of water from both surface and groundwater sources.

Groundwater Depletion

As urban areas grow, there is often increased reliance on groundwater for water supply. Over-extraction of groundwater can lead to the depletion of aquifers, lowering the water table and reducing the availability of groundwater resources.

Altered Hydrological Cycle

The conversion of natural landscapes to impervious surfaces such as roads and buildings reduces infiltration and increases surface runoff. This alteration of the natural hydrological cycle can lead to changes in the timing and magnitude of river flows, potentially causing increased flooding during storms and decreased baseflow during dry periods.

Surface Water Modification

Urban development often involves channelizing rivers and modifying natural watercourses. These alterations can impact the natural flow patterns and contribute to changes in water quantity, affecting downstream ecosystems.

Urban Heat Island Effect

The urban heat island effect, characterized by higher temperatures in urban areas compared to surrounding rural areas, can influence evaporation rates. This effect may contribute to increased water loss through evapotranspiration, affecting the overall water balance.

Stormwater Management Challenges

Urbanization alters the natural landscape, leading to increased impervious surfaces. This can result in rapid runoff during storms, overwhelming stormwater drainage systems, and contributing to localized flooding. Effective stormwater management is crucial for maintaining water quantity balance.

3. Case Studies

	1-TRICHY -TAMILNADU - INDIA	2- BHUBANESWAR -ODISHA - INDIA	3- LAHORE - PAKISTAN
Issues	-With many industries and agricultural activities, water demand is high, therefore there are many private borewells that are used to meet the local needs. -Heavy pumping from these wells, especially for commercial use, has led to a decline in the groundwater levels.	-The fertile and hydrogeologically crucial tracts of the rivers, lakes and drains are being rapidly encroached by unorganized/ illegal housing, indiscriminate dumping of garbage, sewage, and construction wastes.	-The study used multiple remote sensing data to find the groundwater storage reduction and its link with the urban expansion in Lahore. -The overall increase in urbanization raised the temperature of the area as well.

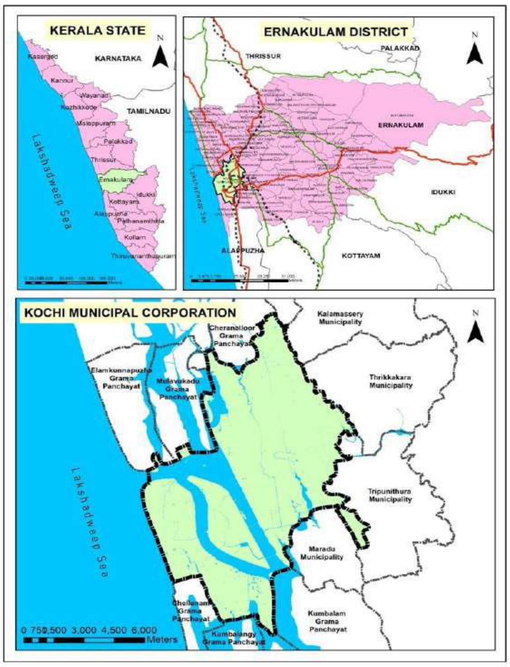
Mitigation methods	- it is necessary for the municipal wastewater treatments systems to be consistently updated to remove the pollutants, before disposing of the treated wastewater into surface water bodies. - Industries should adopt alternate technologies, where possible, by substituting -highly toxic with less toxic chemicals and reducing the use of hazardous substances -Closing the urban water cycle by recycling and reusing waste water can significantly reduce the excessive extraction of groundwater. -Artificially recharge can be adopted as a mechanism to improve the ground water table	- Overall spatial planning approach in areas along with the mapping for groundwater potential and sensitive zones is required to guide the future development. - A holistic and interdisciplinary approach for urban water sewage system needs to be mapped out. -Improving the efficiency of the sewage system of the city is important to maintain the ground water quality -Guidelines for disposal of waste water and maintenance of proper drains can be implemented	- The GRACE-based GWS results are further correlated with the groundwater monitoring stations in the study area. -The increase in temperature shows the impact of urbanization as well as groundwater consumption -Measures to decrease rate of urbanization within the study area. -Measure the preserve existing natural resources -Ground water recharge mechanisms

4. Site profile

Study area :- Kochi municipal corporation area :- 94.88 Sq .Kms

Kochi city is located in Ernakulam district, between 760 14’ and 760 21’ East longitude and 90 52’ and 100 1’ North Latitude. The district is bounded on the north by Thrissur district, on the east by Idukki district and on the south by Kottayam and Alappuzha districts.

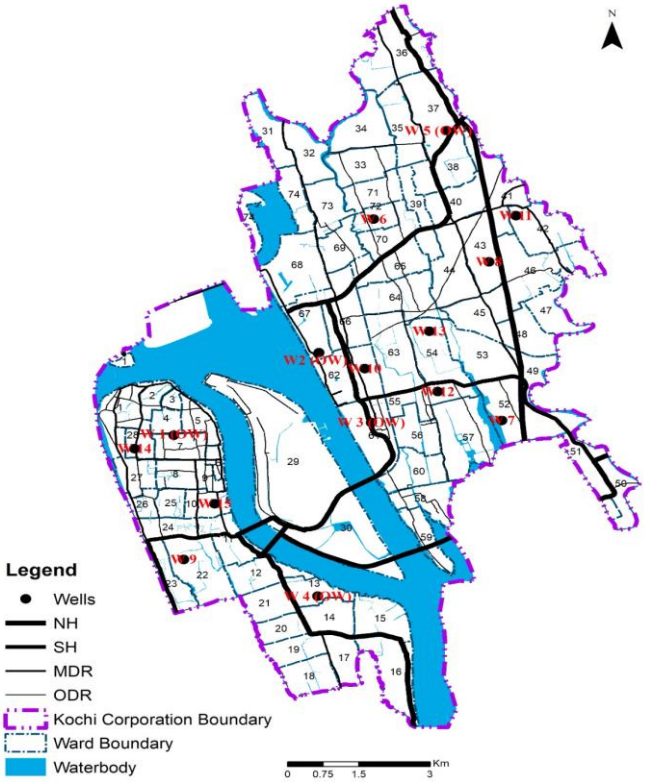
Ernakulam district consists of 2 revenue Divisions –Fort Kochi and Muvattupuzha, 7 Taluks and 124 Villages as on October 2020. The district has 98Local Self Governments (LSG’s), comprising of 1 municipal corporation, 13 municipalities and 84grama panchayats as on December 2021. The city is divided into 74 administrative divisions,



5. Water Quality Analysis

A total of 15 samples were taken from 15 different wards which includes 5 observation wells. Wards were selected on the basis of urban character and density.

OBSERVATION WELL LOCATION MAP



Source :- Impact Of Urbanization On Groundwater Quality - A Case Of Kochi Municipal Corporation Area-2024

Standards

Parameters	Drinking			Fishing	Industrial	Irrigation	Livestock
	EQBS	WHO	UN EPA				
PH	6.5 – 8.5	7.5 -8.5	6.5 -8.5	6.5 - 7.5	7	7.5	7
EC(μ-mhos/cm)	400	400	400	-	-	-	-
TDS(mg/l)	100	500	500	-	-	500 - 1000	-
ALKALINITY(mg/l)	100 - 500	500	300	-	-	50 - 250	-
TOTAL HARDNESS (mg/l)	100 - 500	500	300	400	200	500	500
Fe(mg/l)	-	0.1 -1	-	-	-	-	-
Mg (mg/l)	30 - 50	50	-	-	-	-	-
Cl (mg/l)	150 -600	250	250	600	250	600	600

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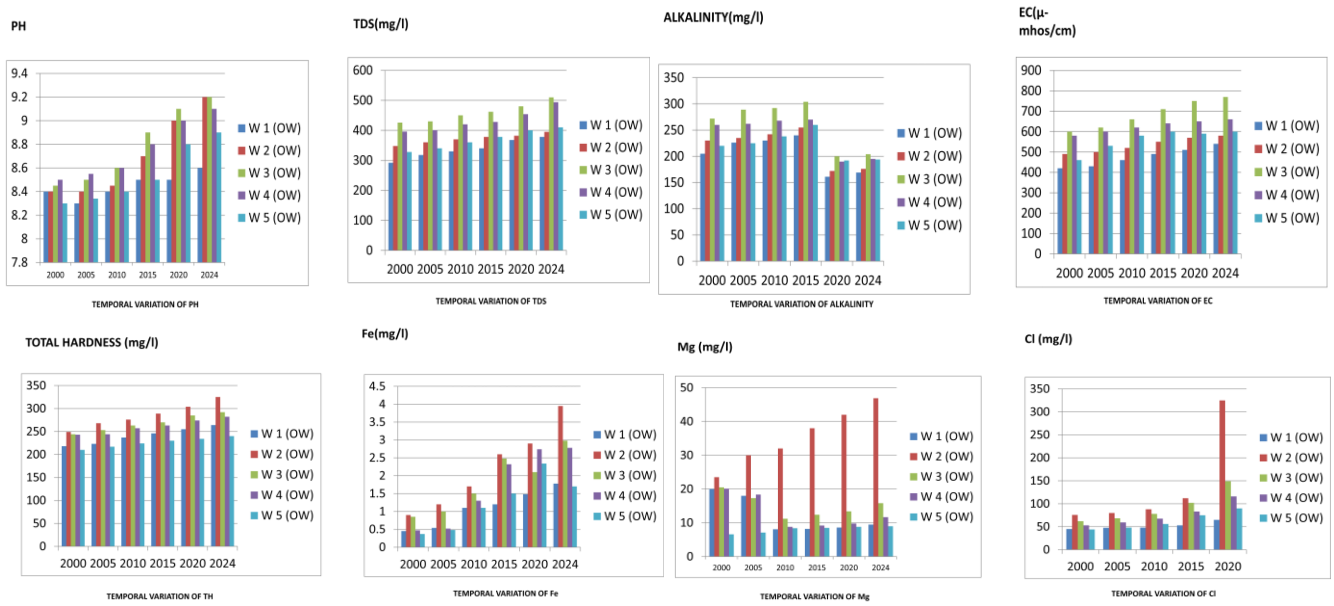
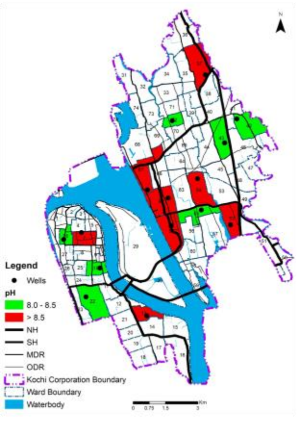


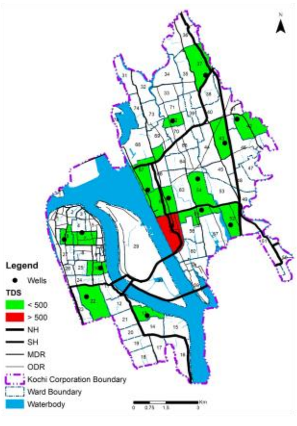
Sampling wells 2024

WELL NO	DIVISIONS	DIV NAMES
W 1 (OW)	D - 7	Cheralayi
W 2 (OW)	D - 67	Ernakulam North
W 3 (OW)	D - 61	Ravipuram
W 4 (OW)	D - 13	Kadebhagam
W 5 (OW)	D - 37	Edappalli
W 6	D - 72	Pottakkuzhi
W 7	D - 52	VytillaJanatha
W 8	D - 43	Palarivattom
W 9	D - 22	Mundamveli
W 10	D - 62	Ernakulam South
W 11	D - 42	Vennala
W 12	D - 55	Girinagar
W 13	D - 54	Elamkulam
W 14	D - 28	Amaravathy
W 15	D - 10	Karuvelippady

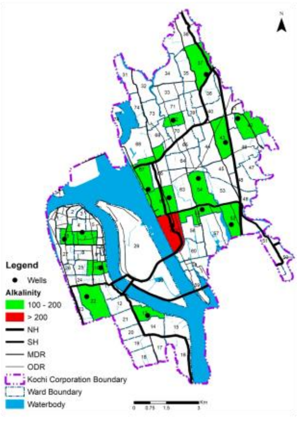
WELL NO		W 1 (OW)	W 2 (OW)	W 3 (OW)	W 4 (OW)	W 5 (OW)	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	W 15	STANDARDS
WARDS		D - 7	D - 67	D - 61	D - 13	D - 37	D - 72	D - 52	D - 43	D - 22	D - 62	D - 42	D - 55	D - 54	D - 28	D - 10	
2024	PH	8.6	9.2	9.2	9.1	8.9	8.4	8.63	8.2	8.3	8.82	8	8.3	8.56	8.32	8.1	7.5 - 8.5
	TDS	378	395	510	494	410	360	370	330	290	189	250	310	378	305	290	300
	ALKALINITY	169	176	204	195	194	169	186	130	135	190	116	132	173	140	123	200 - 500
	EC	540	580	770	660	600	310	360	320	330	530	280	370	420	330	300	400
	TH	264	325	292	282	240	210	230	235	215	345	148	218	315	223	156	100 - 500
	Fe	1.78	3.95	2.98	2.78	1.7	1.1	2.2	0.98	1	2.1	0.82	0.85	1.38	1.23	0.95	0.1 - 1
	Mg	9.48	46.89	15.8	11.66	8.99	34.2	56	28.2	32	54	17.6	33	30.2	36	26	30 - 50
	cl	65	325	149	116	90	86	92	83	87	118	66	72	85	78	69	250



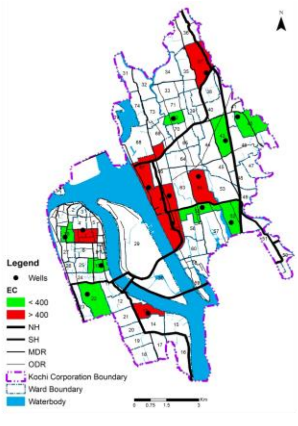
VARIATION OF PH



VARIATION OF TDS



VARIATION OF ALKALINITY



VARIATION OF EC

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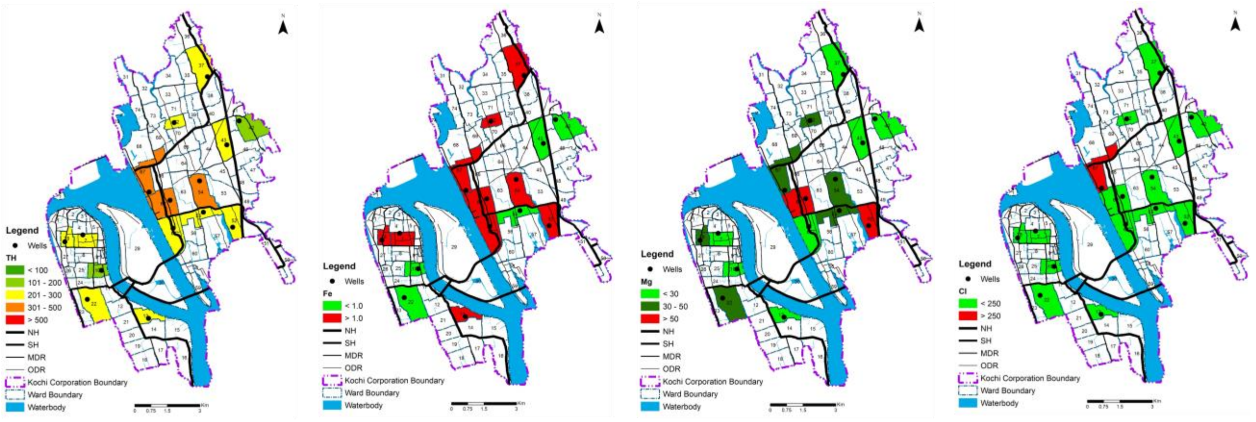

VARIATION OF TH VARIATION OF Fe VARIATION OF Mg VARIATION OF Cl

Source :- Impact Of Urbanization On Groundwater Quality - A Case Of Kochi Municipal Corporation Area-2024

PH

The ph value in the following wards 7 ,13 ,37 , 52 , 54 ,61 , 62 and 67 are comparatively higher which is a threat to the quality of water and can eventually cause health issues for the consumers

TDS

The TDS value in the wards comparatively higher in Div 61 which is a threat to the quality of water and can eventually cause health issues for the consumers

ALKALINITY

The alkalinity value is higher in the ward 61 which is a threat to the quality of water and can eventually cause health issues for the consumers

EC

The EC value is more higher in the wards 7 ,13 ,37 , 52 , 54 ,61 , 62 and 67 are which is a threat to the quality of water and can eventually cause health issues for the consumers

TH

The TH value is high in following wards 54 ,64 and 67 which shows the water nature is hard. And slightly hard in 7 , 13 ,28 ,22 ,37 ,43 ,42 , 52 ,55 and 61. it leads major health issues

Fe

The Fe iron content is increasing and higher value the wards 7 ,13 ,28 ,37 ,52 , 54 ,61 ,62 ,67 and 72 are comparatively higher which is a threat to the quality of water and can eventually cause health issues

Mg

The Mg value in the wards 52 , 62 are higher which is a threat to the quality of water and can eventually cause health issuess

Cl

The Cl value in the ward 67 higher which is a threat to the quality of water and can eventually cause health issues

5.1.1 Analyisis

The kochi corporation total of 15 samples were taken from 15 different wards which includes 5 observation wells. Wards were selected on the basis of urban character and density. In kochi major water bodies and canals are interconnected. From the analysis we concluded that pollution is due to unawareness of people like dumping solid wastes and other wastes. Due to urbanization the land area is very less and there is no safe distance between septic tanks and water bodies. Also the drainages are highly polluted and not well maintained. All this conditions are hardly effecting to the quality of water.

6. Reccomendations & guidelines

Integrated Urban Planning	Implement comprehensive urban planning strategies considering water resource management. Integrate land use, water, and environmental planning to ensure sustainable urban development.
Sustainable Water Management	Adopt sustainable practices for water extraction, storage, and distribution. Prioritize groundwater recharge through natural and artificial means to maintain water balance.
Pollution Control strategies for commercial and industrial area	Enforce stringent regulations on industrial and commercial pollutant discharges. Monitor and control the release of hazardous substances into the environment to prevent groundwater contamination.
Sanitation Improvement	Upgrade sanitation facilities in urban areas, especially in slums. Implement proper waste disposal systems to prevent contamination of groundwater sources. Safe distance between contamination source and drinking water wells in different soil types.To set guidelines for Building rules and regulations on optimum safe setback between water source and pollutants Guidelines for disposal of waste water and maintenance of proper drains can be implemented
Green Infrastructure Implementation	Promote the use of green spaces and permeable surfaces in urban development. Incorporate green roofs, rain gardens, and permeable pavements to enhance groundwater recharge.
Legislation and Enforcement	Strengthen and enforce legislation related to groundwater protection. Implement strict penalties for activities that compromise groundwater quality
Climate-Resilient Infrastructure	Design infrastructure considering the impacts of climate change on precipitation patterns. Build climate-resilient structures to minimize the effects of extreme weather events on groundwater quality.
Community Awareness and Involvement	Conduct awareness campaigns on sustainable water use and pollution prevention. Involve local communities in monitoring groundwater quality and reporting any unusual changes.

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Groundwater Recharge Strategies	Adopt land-use policies that prioritize water-sensitive practices, preventing excessive extraction in critical recharge areas and preserving natural groundwater replenishment processes. Explore and develop alternative water sources such as recycled water and desalination to reduce reliance on groundwater for non-potable uses.
Sustainable Agriculture Practices:	Promote sustainable agricultural practices, including organic farming and reduced use of chemical fertilizers and pesticides, to prevent agricultural runoff from contaminating groundwater. Foster collaboration between government agencies, NGOs, industries, and local communities to address environmental degradation collectively and share responsibility.

7. Conclusion

Urbanization significantly jeopardizes groundwater quality due to a multitude of factors. Overcrowding and mixed land use introduce diverse pollutants, while environmental degradation and industrialization contribute to contamination in cochi municipal corporation area . The depletion of natural water sources, the effects of climate change, and inadequate sanitation practices further exacerbate the situation. Additionally, transportation activities add pollutants to the groundwater. To mitigate these challenges, comprehensive urban planning, sustainable water management practices, and stringent pollution control measures are imperative in case of cochi municipality corporation. Implementing regulations on industrial discharges, adopting green infrastructure, and promoting public transportation can contribute to alleviating the impact of urbanization on groundwater quality. Community involvement, awareness campaigns, and effective waste management are crucial elements in ensuring the preservation of groundwater quality in the face of rapid urbanization of Kochi Municipal Corporation.

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