Reinventing the Lost Trilogy of Ponds, Natural Drains, and Groundwater with Focus on Shekha Jheel: A Case Study of Aligarh

PRANAV VARSHNEY
Student,
School of Planning and Architecture, New Delhi

MEENAKSHI DHOTE
Student,
School of Planning and Architecture (SPA), New Delhi

BIDISHA CHATTOPADHYAY
Student,
School of Planning and Architecture (SPA), New Delhi

NIKITA MADAN
Senior Environment Specialist,
National Institute of Urban Affairs (NIUA), New Delhi

Abstract
Water is essential for all life forms on Earth but never has our planet's water been under such pressure as today. Climate changes, loss of biodiversity, and pollution are some of the most common and interconnected challenges that concern water and its ecosystems. Different forms of water which includes water bodies (ponds, drains) and groundwater, form a hydrological cycle which offer critical opportunities to reduce the stresses from anthropogenic activities. In the present study on Aligarh, a city located in the Ganga-Yamuna Doab, an area historically rich in water resources but now home to degraded water resources; ponds and drains in urban Aligarh and Shekha Jheel wetland have been inventoried and assessed. Disruption in the trilogy of ponds, drains, and groundwater and its manifestations were studied. A methodology to prioritize ponds has also been suggested. Findings reveal that the interconnectedness between ponds, drains, and groundwater has been completely disrupted that has resulted in environmental degradation, taking the city away from resilience and sustainability. Recommendations encompassing regional level strategies, master plan interventions, Nature-based Solutions, people's involvement etc were suggested.

Keywords: Aligarh, Waterbody, Pond, Groundwater, Drain, Interconnectedness, Trilogy

Introduction

Globally, two billion (26%) people lack access to safe drinking water and 3.6 billion (46%) do not have access to safe sanitation. Furthermore, the global urban population facing water scarcity is expected to double from 930 million in 2016 to 1.7-2.4 billion people in 2050 (United Nations, 2023). Water scarcity, primarily of clean freshwater, and the associated vulnerabilities are further exacerbated by climate change with an increase in incidences of extreme events, heat waves, droughts, and floods (United Nations, n.d.). The Dublin Conference on Water and Environment, 1992, Rio conference, Millenium Development Goals 2015, and at present, the Sustainable Development Goals 2030, have paved the way for revisiting water related policies and practices.

In this context, the significance of holistic approaches such as the integrated approach, systems approach, ecosystem approach, and cybernetics in the conservation of sources of water viz. waterbodies, rivers, and groundwater, has increased manifold. In the global discourse, blue-green infrastructure and the provision for ecosystem services has evolved as key elements in urban adaptation strategies to enhance resilience to climate changes and disasters. While knowledge regarding the linkage between waterbodies, rivers, and groundwater has existed for a long time, it has emerged as critical in the present journey towards climate resilience and reduction in disaster risks. The trilogy as described in the present paper is based on the systems approach and focuses on the linkages between the sources of water and its association with human settlements and their activities. The need to view water as a part of the larger natural and anthropogenic ecosystem has been reiterated in this paper and was studied in the context of Aligarh, a city sitting amidst aplenty yet experiencing water stress.

Aligarh city with a population of 8.74 lakh (Census of India, 2011), lies 130 km South of the National Capital Territory of Delhi in the Ganga-Yamuna Doab. It is the district headquarter of Aligarh district which has the famous Aligarh Muslim University (AMU), established in 1875 by Sir Syed Ahmed. It is believed that Aligarh was chosen for setting up AMU due to good *'aab-o-hawa'* (roughly translated to water and air) in the area (Khalil, 2021). The city is also famous for Aligarh locks. It lies in the humid sub-tropical climatic zone (Koppen's Classification). The average annual rainfall is 754mm with 80 percent of it concentrated in the four months of June, July, August, and September.

Aligarh and its immediate surrounding areas are characterized by high groundwater table, gentle slope, fertile soil, good connectivity, and being rich in water resources. The city lies in the command area of the Upper Ganga Canal with Shekha Bird Sanctuary, an important bird area that abuts the canal. Aligarh is home to more than a hundred waterbodies of various sizes, but most of them are in dismal conditions and the city falls under the overexploited category[1] of groundwater (CGWB, Block wise Categorization, 2022), with an extraction rate of around 343% observed in the 2017 assessment (Sinha, 2021). A few of these waterbodies like Achal taal not

[1]*As per CPCB, 'Over-exploited' areas, where there should be intensive monitoring and evaluation and future ground development should be linked with water conservation measures.*

only have local cultural and religious significance but are also visited by people from nearby areas. The Comprehensive Environmental Pollution Index (CEPI) has identified Talanagari and Chherat Industrial area as severely polluted areas. The water resources of the city are under extreme stress due to anthropogenic activities and need to be judiciously managed and protected at the earliest.

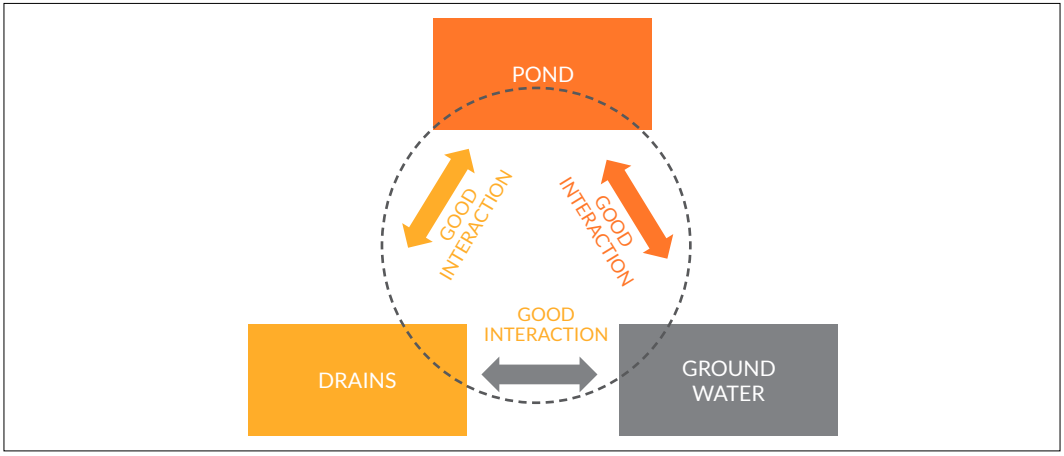
The authors argue that the disruption in the interconnectedness between the waterbodies, drains, and groundwater is one of the key factors of environmental degradation in the city and the solution to reclaiming the lost *"aab-o-hawa"* lies in re-establishing the interconnectedness. The present research is focused on studying the disruption in the trilogy of ponds, natural drains, and groundwater in Aligarh city, and the causes, processes, and manifestations thereof. A methodology for prioritization of waterbodies and stretches of drains has also been evolved to select the waterbodies and drains for rejuvenation. This shall assist the service provisioning agencies in sustainable management and conservation of aquifers and surface waterbodies within Aligarh and in other similar cities. At present, efforts by city authorities are underway in the city for conservation of select ponds but in an isolated manner.

Trilogy of Ponds, Natural Drains, and Groundwater: A Holistic Approach

The Concept of Interconnectedness

The concept of the trilogy was based on the idea of a series of three musical compositions that are closely related and are part of a single theme. The authors argue that ponds, drains, and groundwater management, each forms a part of this trilogy, thus leading up to a broader theme of water resource management. So, all three elements need to be considered in a holistic manner. While studies (Thomas C. Winter, 1998), (Cherepansky M.M), (Gelt, 1994), and (Geiger, 2018) in the past have discussed this interconnectedness theoretically, very few have been able to explain its working on the ground.

Figure 1: Representation of Trilogy



Source: Author, 2022

The interconnection between surface water and groundwater in areas with different natural conditions determines the regime and dynamics of water exchanges between them (Cherepansky M.M) and (Gelt, 1994), (Geiger, 2018). While natural processes impact surface-water/ groundwater interactions; anthropogenic actions like water pumping and untreated waste water discharge also have a direct impact on this process. Complex factors like natural geology, local aquifer conditions, and human activities related to land use also affect the quality of groundwater which further affects its connection with the surface water. Thus, in human settlements, efforts to rejuvenate waterbodies or drains need to adopt a systems approach and consider all natural and anthropogenic causes.

Approaches and Initiatives for Waterbody Rejuvenation and Groundwater Management in Urban Areas

Water Management has taken centre-stage in the global resource management discourse that is propelled by increasing water stress, exacerbated by climate changes in different regions of the world. Globally and in India, various approaches towards judicious and efficient water resource management are Integrated Water Resource Management (IWRM), Integrated Urban Water Management (IUWM), Water Sensitive Nature Based Solution Approaches such as Sustainable Urban Drainage System (SuDS), sponge cities, and water sensitive urban design and planning are also being adopted in cities. In India, some of these have translated directly or indirectly into water and sanitation programmes and schemes.

Several of the central and state programmes and schemes related to water and sanitation are being implemented in Aligarh. Rejuvenation of two waterbodies in the city has been undertaken under the Smart City Mission. Recently, five urban ponds were identified by the municipal corporation under the Amrit Sarovar Scheme. Polluted water from the drains is being treated under a pilot scheme using Phyto-remediation technology under the Namami Gange Programme. The water supply and sanitation are being improved under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and AMRUT 2.0 and the Swachh Bharat Mission.

Methods

The study was conducted as part of the Master's thesis program from November 2021–June 2022. The urban water bodies in Aligarh city and the Shekha Jheel wetland in the rural hinterland were the two major parts of the study. There were three core objectives of the study–first, to study the interconnectedness between the ponds, drains, and groundwater in urban Aligarh; second, to evolve a methodology for prioritization of ponds and drains in a holistic manner; and third, to study the Shekha Jheel in context of Aligarh.

There was a clear need to prepare an inventory of the water bodies in Aligarh due to the absence of any comprehensive study on it. The secondary data was collected from published and unpublished sources which included gazetteers, reports, statistical records, and other resources that were available in the public domain. The primary data for the waterbodies and Shekha Jheel was collected through site visits. People's perception was captured through surveys and stakeholder interviews. Maps and inventories were prepared by visiting the accessible ponds/drains and

referring to the maps that were available in the public domain; land use and activities within a 100m buffer of the waterbody were recorded. Stakeholder consultations were conducted with district level officers, municipal level officers, local NGOs, institutions, and environmentalists. Surface water and groundwater samples were collected and the water quality assessment was done from a NABET (National Accreditation Board for Education and Training) accredited lab. Ponds and waterbodies have been used interchangeably in the paper.

Software like Microsoft Excel, ArcGIS 10.8, and Google maps were used for quantitative and spatial assessment, respectively. Google Earth was used to compare the areas and development around the waterbodies from 2003 to 2022, during the post-monsoon period.

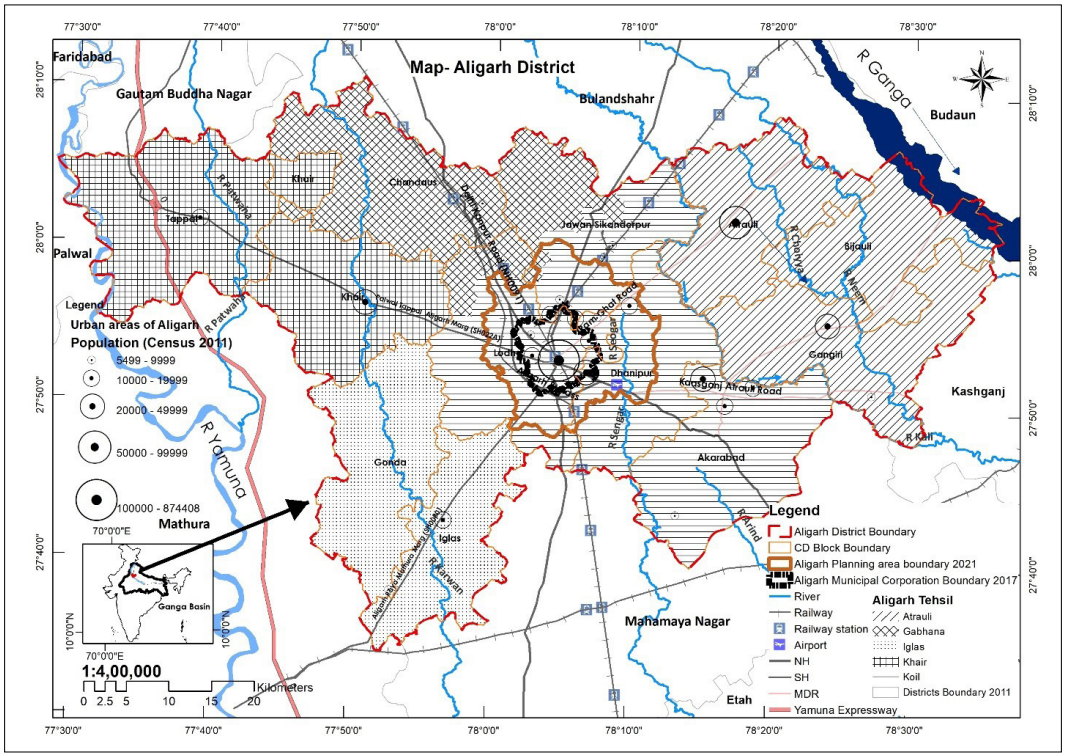
The Lost Trilogy: A Case of Aligarh City

Regional Context

Aligarh city is located in Koil tehsil and is almost the geographical centre of Aligarh district and nearly equidistant from River Ganga and River Yamuna in the Ganga-Yamuna Doab. The district has a population of nearly 37 lakh and 33 percent of the population resides in urban areas (Census of India, 2011). The city is well connected to the National Capital Region (NCR) and other cities of India through National Highway-91, National Highway-93, State Highway-22A and State Highway-80. The district is bounded by the Ganga River on the north-eastern side and Yamuna River on the north-western side. The district is drained by Rivers Kali, Sengar, Karwan, Patwaha, and Neem among others. The Upper Ganga Canal and its various distributaries pass through the district. Shekha Bird Sanctuary, an Important Bird Area (IBA) of Uttar Pradesh adjoins the Upper Ganga Canal near Aligarh city.

A little more than 900 wetlands have been identified within the district, out of which Koil tehsil has nearly one-third of the wetlands (Hussain, Ilyas, & Imam, 2022). River Kali flowing in the eastern part of the district carries sewage, chemical laced agricultural runoff, and industrial effluents from the upstream areas which contribute to the toxic waste of the environment (Ajmal et.al, 1988, CPCB, 2013, Sirohi et. al 2014). Recent studies have suggested that River Kali has contaminated the groundwater with heavy metals along the river (Khan & Khan, 2019). Though, overall, the stage of groundwater extraction is 78 percent (CGWB, Dynamic Ground Water Resources of India 2022, 2022) in the district, Aligarh city has been categorised as over-exploited.

Map 1: Aligarh District and Other Various Features



Source: Survey of India's 14 Toposheets (H43X8, H43X12, H43X16, H44S4, H44S8, H44S12, G43F9, G43F13, G44A1, G44A5, G44A9, G43F14, G44A2, G44A6), Census of India (2011), Aligarh Municipal Corporation's GIS webpage

A Brief History of Aligarh

Historically, Aligarh has been known as Allygurh, Coel, Kol, Koil (Hutchinson, 1856) and also as Muhammadgarh, Sabitgarh, and Ramgarh. (Siddiqi, 1981) In 1342, Koil was described by Ibn Battuta in his memoir Rihla, as "a lovely town surrounded by mango groves." Owing to the green environment, the area also acquired the name of Sabzabad (District Administration NIC, 2022). The area was once covered by forest, thickets, and groves. There are villages which are named after the *jungle* trees for example *Jau*, *Dhak*, *Mahua*, and *Imli* etc. (Siddiqi, 1981). The area had several ponds including rain-fed, temporary, and stagnant. Inns were constructed around Bain/ Baolies where travellers could rest. It was a custom that villagers (Aligarh city to Shekha Jheel) would construct ponds to collect rainwater. Some of the places bear resemblance to local names for ponds viz. *pokhar*, *kunda*, *dig*, *dabha*, *daha*, *nimna*, *dariya*, *tal*, *kachhar*, and *jal* (Final Report on the Revision of Settlement in the District of Aligarh, 1982).

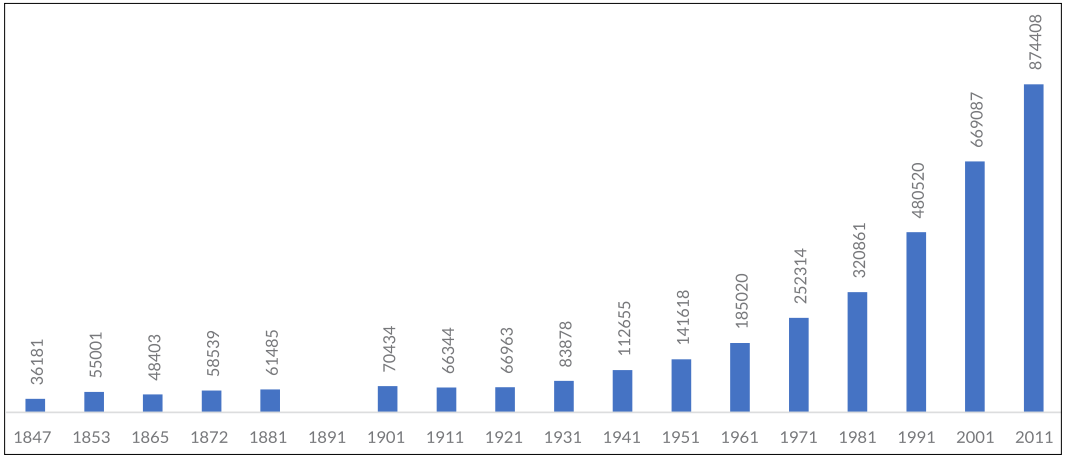
Around 1724-28, the Upper kot *Jama Masjid* was built on an elevated ground since the surrounding area was prone to waterlogging. The city also had tanks such as Sabit Khan's tank which acted as water reservoirs for the summer months. Waterbodies such as Adhawan *jheels* close to River Sengar's source, as well as moderately large *jheels* at Gopi, Bhawan Grahi, Shaikha, Ikri, and Gursikaran were present here. The area had plenty of black bucks/antelopes. The Upper Ganga Canal was built in 1852 (Atkinson, 1875). It changed the hydrological character of the area which resulted in a rise in the groundwater level along the canal and led to waterlogging conditions in the adjoining areas. Shekha Jheel was formed around this time (Kalpavriksh, 2009).

Earlier, there were areas in the north-eastern part of the city which were poorly drained that also gave rise to the growth of deep morass, resolved through excavation of the Aligarh drain. The main source of irrigation were the wells and rivers along with ponds, lakes, and water reservoirs. (Siddiqi, 1981). During 1875, Sir Syed selected Aligarh as the site for AMU stating that Aligarh's *"aab-o-hawa"* was "perfectly suitable" for the intellectual and physical well-being of an individual. (Khalil, 2021). From 1800 onwards, increase in village population and growing value of agricultural land led to a sharp decline of the groves and forest area (Siddiqi, 1981, Mann, 1995).

Aligarh City Profile

In 2021, the Aligarh city area was 63.82 sq km and the estimated population was 13,21,579 (AMC, 2021). It is a highly dense urban settlement with 22,545 persons per sq km, a typical characteristic of urban centres in the fertile Ganga plains (Census of India, 2011). The city is divided into two distinct halves on either side of the railway line. The western side houses the old city and is densely populated while the eastern side has relatively new development. The most prevalent settlement typologies in the city include planned development, unplanned development, old city area, and privately owned developed colonies. There has been a sharp increase in the slum population between 2001 to 2011 (Census of India, 2001, 2011) from 1,74,300 (26%) to 3,67,134 (44%).

Figure 2: Urban Population Growth in Aligarh

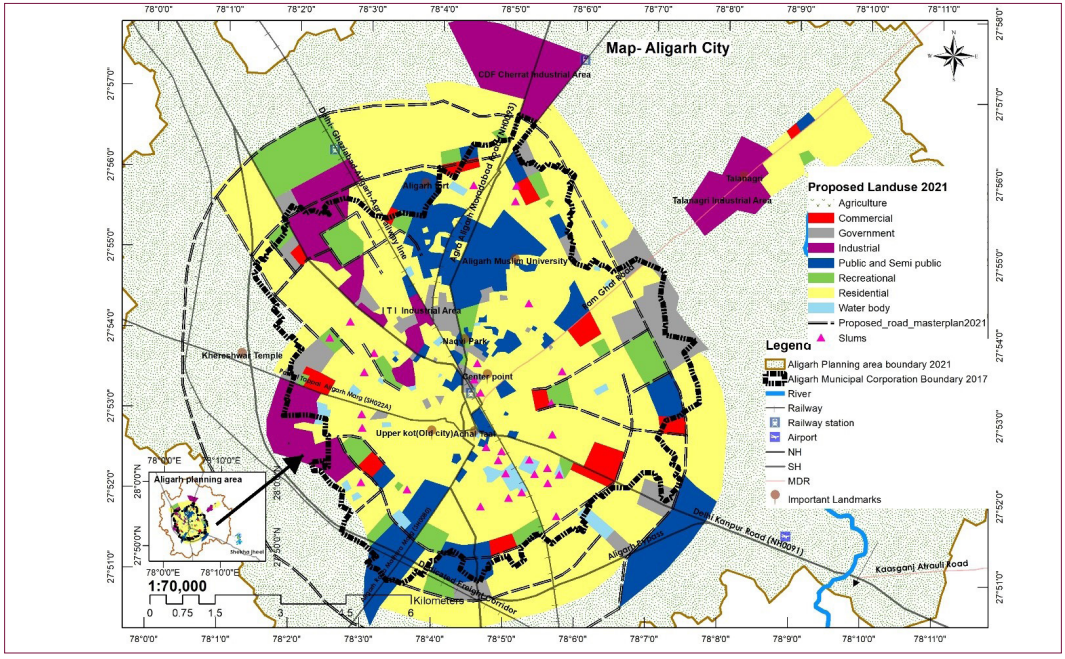


Source: Hutchinson, 1856; NEVILL, 1909; and Census of India, 2011

The built-up area in Aligarh municipal limits and the surrounding areas increased by 16 percent, from 61 sq km in 2005-2006 to 71 sq km in 2015-16 (NRSC, n.d.). In 1975, Aligarh was declared as Aligarh Regulated Area which comprised Aligarh Municipality and 110 villages. This was done to control the unplanned and uncontrolled development in Aligarh city and to speed up the planned development (Aligarh Development Authority, 2003). Aligarh has had two Master Plans, 2001 and 2021, the third (2031) is in the draft stage. The delineated planning area for 2021 is 11,470 ha that is proposed to increase to 20,986 ha in the Master Plan 2031 (Draft). Shekha Jheel has been included in the latter plan. Aligarh has only 0.37 sq m per capita of open space, much below the recommended 10-12 sq m per capita (URDPFI guidelines, 2014). As per Master Plan 2021, water bodies/Nallahs/Ponds comprise 1.33 percent of the total area (152.85 ha), while parks and open spaces comprise 9.67 percent (1109.3 ha).

According to Master Plan 2021, no other land use is allowed on the water bodies other than the 'water bodies and ponds', as listed in the Master Plan. The Master Plan also mentions that any 'layout plan above 20 acres should have 5 percent of the land reserved for ponds and water bodies, which has a minimum area of 1-acre and 6-m depth', and any 'layout plan less than 20 acres should have a recharge well'. Additionally, Percolation Pits for groundwater recharge from rain is mandatory in all plots of 1000 sq m and above area. This is not only mandatory for plots but is also applicable for all existing and new government buildings. Also, 15m around the main nallahs should be left for green areas.

Map 2: Proposed Land Use Plan 2021 and Location of Slums in Aligarh



Source: Aligarh Master Plan 2021, Municipal Corporation GIS webpage (https://gis.nnaligarh.in/GIS/Home/GISPortal), and City Sanitation Plan 2014

Aligarh has three industrial areas, ITI Industrial Area, UPSIDC Industrial Area sectors I and II (Tala Nagri), and Chherat Industrial area; the latter two are outside the municipal limits but are part of the planning area. There are 4673 small scale units and 11 large scale units, employing nearly 24,000 and 1900 workers, respectively (Personal Interview, March 2022). Many of these industries viz. locks, brassware, zinc dye, metal-based steel fabrication are Red industries (CPCB, Final Document on revised classification of Industrial Sectors under Red, Orange, Green and White Categories, 2016) with high pollution potential.

As per the Central Pollution Control Board (CPCB), Aligarh is also a Severely Polluted Area (SPA) and its CEPI[2] (Comprehensive Environmental Pollution Index) score has risen sharply from 48 to 61.88 (neutral to critical), in the water category from the year 2009 to 2018. The Shakti Nagar area in the city is a probable contaminated site[3] for lead contamination. There is no CETP but ETPs are installed in all the water polluting industries in the cluster (UPPCB, 2022). Aligarh drain and Cherrat drain receive effluents from the industrial areas (UPPCB, n.d.).

Since 1975, the city has been served by a piped water supply system from groundwater sources. To make matters worse, the water supply of the city is well below the Service Level Benchmarks (erstwhile MoUD, 2011), with water supply connections being present in only 82,326 households (31.1%). The demand for water is 205 million litres per day (MLD) however, the supply is only 120 MLD, and the per capita per day supply is only 90 litres compared to the recommended 135 LPCD (Open data Platform: India smart cities, 2019) implying that most of the households are dependent on individual private borewells in their premises. There are about 18 locations in AMU and a few government buildings in Aligarh where Rain Water Harvesting Systems (RWH) have been installed (AMU, n.d and Amar Ujala, 2021).

The city received ODF++[4] (Open Defecation Free) certification in 2020. Only 3.10 percent of the city's area and almost 20 percent of the city's population is connected to the sewerage network while the rest are dependent on on-site sanitation systems like septic tanks (Open data Platform: India smart cities, 2019). A MLD Sewage Treatment Plant is insufficient in capacity, as the sewage generation is much higher at 79.08 MLD as of May 2022. The faecal sludge treatment plant (32 MLD) is in place however it was not in a working state when visited by the author in February 2022. There are no monitoring stations for checking the quality of the surface water in the city (2022).

[2]*CEPI is the Comprehensive Environmental Pollution Index. CPCB developed CEPI to find an Index value to characterize the quality of the environment in the industrial cluster. CEPI scores of 70 and above are identified as Critically Polluted Areas (CPAs) and CEPI scores between 60 and below 70 are categorized as Severely Polluted Areas (SPAs).*

[3]*Contaminated sites are delineated areas in which the constituents and characteristics of the toxic and hazardous substances, caused by humans, exist at different levels and in conditions which pose existing or imminent threats to human health and/or the environment.*

[4] *The Swachh Bharat Mission-Urban aims to fulfil the objective of 100 percent Open Defecation Free (ODF) status in all Urban Local Bodies (ULBs) in the country by 2019. This will entail providing access to clean and usable toilet facilities for the citizens. In larger prospects, ODF flagship is taken ahead by ODF+ and ODF++.*

The official statistics for solid waste management indicate that the city (3star GFC[5] certified) is performing well as the rank has gone up from 173 in 2018 to 34 in 2022, but in reality, there is still a lot of scope for improvement. Nearly 545 Tonnes Per Day (TPD) is generated and only 435 TPD (79.8%) is collected. (Solid Waste Management City Profile : Aligarh India, 2018). Out of 80 wards, door to door collection is practiced partially in 70 wards, and as of May 2022 (Amar Ujala, n.d.) 10 wards have 100 percent door to door collection facility. The rest of the solid waste is dumped either into the open areas, roadsides, or into the water bodies.

Various urban local agencies are working in siloes for the conservation of water resources in Aligarh. The Aligarh Municipal Corporation is responsible for water supply, rejuvenation of ponds, upgradation of new infrastructure, and implementation of policies. The Irrigation department is responsible for the cleaning of drains, Upper Ganga Canal, minor canals, and ensuring availability of water, while the Forest Department is responsible for plantation of trees, and management of the Shekha Jheel. The Aligarh Development Authority (ADA) is responsible for preparation and implementation of the Master Plan. Responsibilities of rejuvenation of rural ponds and AMRIT Sarovar are in the hands of the Block Development Officers. Uttar Pradesh Pollution Control Board (UPPCB) is responsible for abating and monitoring pollution, while groundwater is managed by the Central Ground Water Board (CGWB).

Degraded Water Systems: Ponds, Natural Drains, and Groundwater

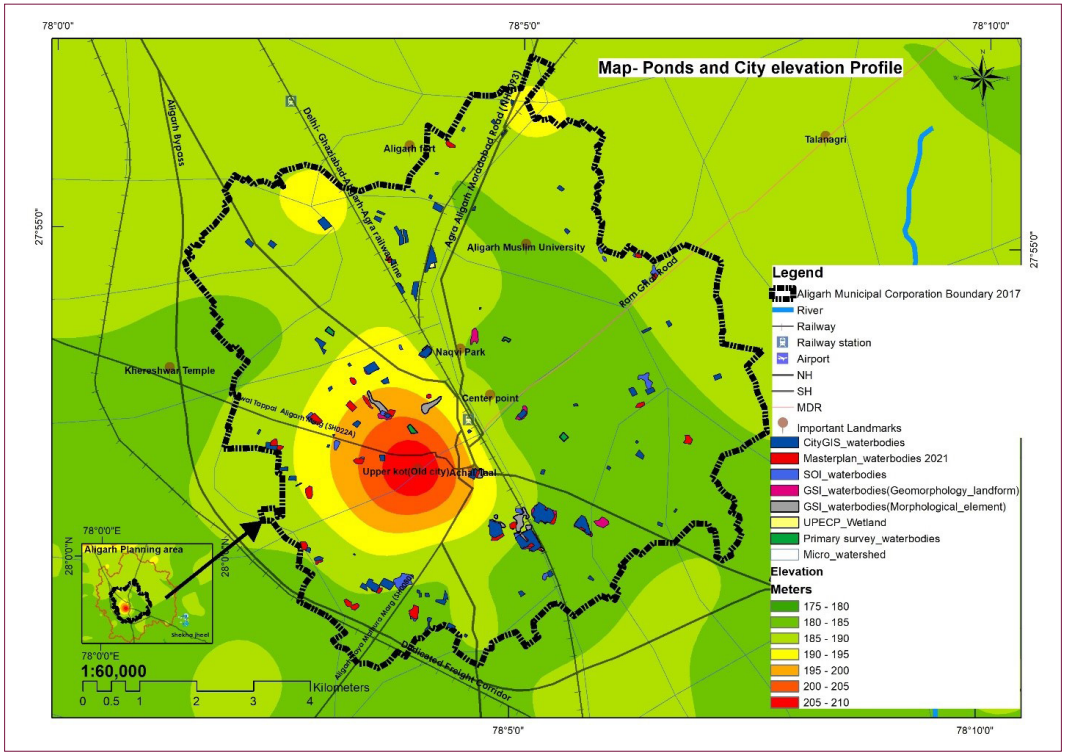
As history suggests, while the city of Aligarh was selected as a seat of learning by Sir Syed Ahmed for its conducive *'aab-o-hawa'*; the population growth in the past decades, unplanned development, and inadequate infrastructure has led to the degradation of the city's water resources.

Ponds

Multiple agencies have been involved in the preparation of an inventory of waterbodies or ponds in Aligarh city. The city GIS information displays 74 ponds while 28 ponds are listed in the proposed land use plan 2021. There are 22 ponds, marked in the Survey of India Toposheet (2005), most of which are dry in nature. The Uttar Pradesh Environmental Compliance Portal of UPPCB lists 6 wetlands, and the District Environmental Plan 2021 lists 27 ponds. The Municipal Corporation officials stated that there are around 30 ponds within the city (Personal interview, 2022).

[5]*The Ministry of Housing and Urban Affairs (MOHUA) has launched the Protocol for Star Rating of Garbage Free cities. The star rating conditions have been designed in a way to enable cities to gradually evolve into a model (7-star) city, with progressive improvements in their overall cleanliness.*

Map 3: Location of Waterbodies from Various Sources in Aligarh



Source: Prepared by author from SLUSI website (slusi.dacnet.nic.in/dmwai/UTTAR_PRADESH/District/ALIGARH.html accessed on 12, *February 2022*), *Municipal Corporation GIS page, SOI Toposheets*

Consultation with officials of Municipal Corporation (personal interview, 2022b) revealed that the distinction between ponds/waterbodies and water-logged areas is not clearly defined. In India, some of the definitions have been given by the Haryana Pond and Wastewater Management Authority (HPWWMA, 2018), Urban River Management Plan (NMCG and NIUA 2020) and Uttar Pradesh Pond Development, Protection and Conservation Authority Bill 2017 (Third Draft).

On the basis of primary survey 2022, four ponds/waterlogged areas were identified in addition to the waterbodies that were already enumerated for the city. A union approach (set operations) was used to combine the information obtained from multiple sources. Accordingly, a total of 106 ponds were marked within the municipal area.

Table 1: Number of Ponds/Waterbodies/Waterlogged Areas (According to Various Sources) in Aligarh

Sources	Year of Publication/ Reference	Scale	Map Availability in Public Domain	Total Number of Waterbodies/Ponds Observed	Total Number after Union
City GIS Portal (gis.nnaligarh.in/GIS/Home/GISPortal)	2019	-	Yes	74	106
Survey of India (14 Toposheets)	2005	1:50,000	Yes	22	
Master Plan 2021	2003	-	Yes	28	
GSI (Geomorphology)	2020/21	1:50,000	Yes	10	
GSI (Geology)	2016/17	1:50,000	Yes	8	
Uttar Pradesh Environmental Compliance Portal (UPECP) (https://upecp.in/)	2020	-	Only Geo coordinates	6	
Municipal Corporation	2022	-	No	30 (Approx.)	
District Environmental Plan	2021	-	No	27	
Primary Survey	2022	-	-	4 (Total number of waterbodies observed by author)	

Source: Author, 2022

Out of 74 ponds that are listed in the city GIS, 57 are exclusively in the city GIS while the remaining 17 ponds are also mapped in other sources. Similarly, out of 28 ponds mapped in the Master Plan, 14 are exclusively in the Master Plan while 14 ponds are also marked in other sources. Similarly, out of the 22 ponds mapped in the SoI toposheet, 7 are exclusively in the mentioned source. Interestingly, there are only six ponds that are mapped in more than 4 sources and two ponds are mapped in more than 6 sources.

Out of the identified 106 ponds, the author could visit only 80 ponds during the study. Out of the 80 ponds, 16 ponds have been encroached and converted into built-up, open plots, Sewage Treatment Plants, SWM Facilities, agriculture, and plantation. As a result, it was possible to prepare a detailed inventory of only 64 ponds.

Table 2: Classification of Ponds by Size in Aligarh

Size (Ha)	Total No. of Ponds	Total No. of Ponds Inventoried
Less than 0.5	31 (29)	18 (28)
0.5 to 1	28 (26)	16 (25)
1 to 2	25 (24)	18 (28)
2 to 5	18 (17)	9 (14)
Above 5 ha	4 (4)	3 (5)
Total	106 (100)	64 (100)

Note: Percentage in parentheses

Source: Author, 2022 prepared from above listed sources in Table 2

Of these, 64 waterbodies were inventoried and the characteristics of each of them were noted. 17 (26.5%) waterbodies had only residential land use in the demarcated 100m buffer while 12 (18.7%) waterbodies had some space at the edge and 52 (81.2%) waterbodies were found to be partially encroached upon. Connectivity of 53 (82.8%) waterbodies was through pucca roads, the rest were connected by *kuchha* roads. All the waterbodies were observed to have water hyacinth, but 95.3 percent did not have any fish while birds were spotted in 90.6 percent of the waterbodies. Probable sources of pollution in 46.8 percent of the waterbodies were domestic wastewater, solid waste, and cattle wading.

Figure 3: Ponds in Aligarh City

Pond near Gandhi Eye Hospital
Solid waste around the water body

Kali Deh Pond
Solid waste around the water body

Pond near Surendra Nagar
Roaming of animals

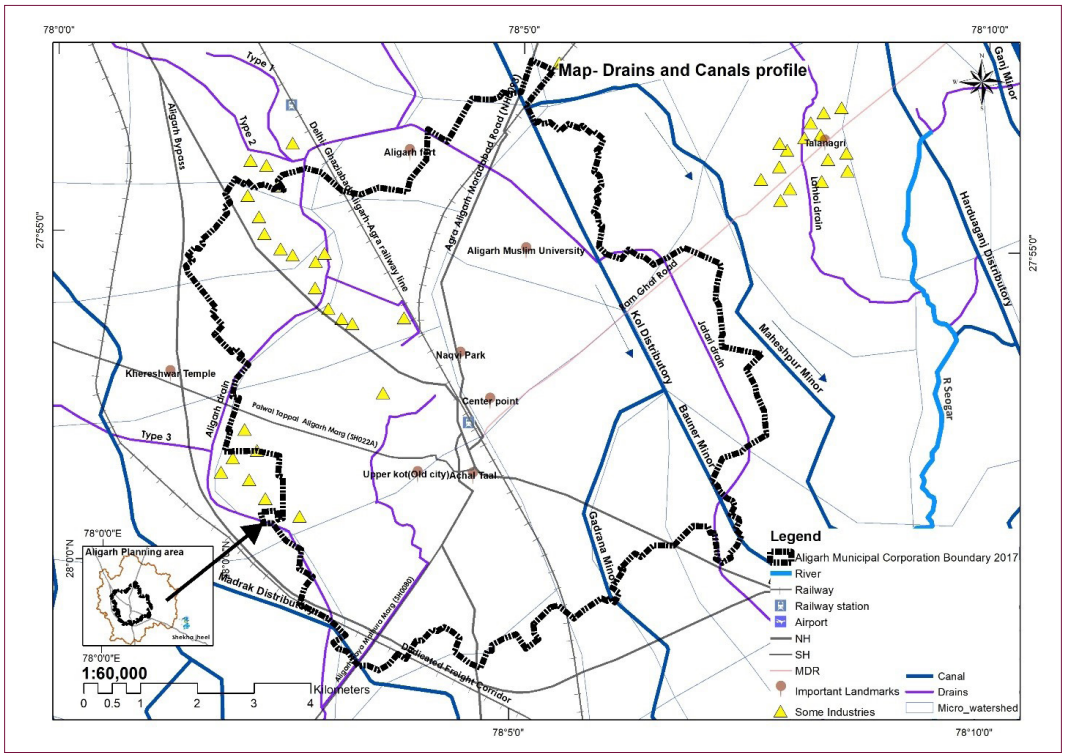
Pond near Pratibha Colony, Exhibition Ground
Solid waste around the water body

Source: Author, 2022

Natural Drains

The quality of water flowing in the minors and distributaries has deteriorated over the years and now, these serve as wastewater drains in the urban area. At present, the Gadrana minor, Boner minor, and Koil distributary are in a degraded condition in the city (*Aligarh khand ganga nahar roaster*, 2020-21). Aligarh drain and Jafri drain were studied in detail under this research.

Map 4: Drains in Aligarh



Source: Prepared by author based on SLUSI website https://slusi.dacnet.nic.in/dmwai/UTTAR_PRADESH/District/ALIGARH.html accessed on 12 February 2022), and SOI's 14 Toposheets

Only unlined drains were inventoried because there is very little interaction between concrete stormwater drains and groundwater. There are 26 industries in Aligarh which are discharging their treated effluent in the Aligarh drain (UPPCB, n.d.). The polluted waters of the Aligarh drain and Jafri drain are being treated under a pilot scheme using Phyto-remediation technology (Treatment of Polluted water, 2021). There is no sewerage network in the vicinity of both the drains. After passing through a nallah, the ITI industrial area's wastewater is discharged into the Aligarh drain. Majority of the slum areas are prone to flooding during rains. The sanitation situation is worse particularly in the outskirts of the city (City Sanitation Plan, 2014), and these outskirts became a part of the city after the 2017 expansion of city boundaries. Eight slaughter houses and 11 other industries were located near the drain which were discharging 6.37 MLD

treated effluent and the drain also carried 96.50 MLD untreated sewage, thereby emerging as a cause of concern for groundwater contamination through infiltration (UPPCB, n.d.).

Table 3: Detail of Aligarh and Jafri Drains, 2019

Drain	Flow (MLD)	Width (m)	Pollution load (mg/l)	Permissible Limit (mg/l) (If water is used for organised outdoor bathing)
Aligarh	118	18*	220	Below 3 mg/l
Jafri	55	9*	Below 250	Below 3 mg/l

Source: Author, 2022; UPPCB, n.d.*

The Aligarh drain and Jafri drain, and three canals namely Koil distributary, Boner minor, and Gadrana minor were studied in detail for this study. The latter were originally irrigation canals but on being engulfed by the city, they have been converted into wastewater drains.

Table 4: Predominant Land Use in the Surrounding Areas of the Drains in Aligarh

Drain names	No of Identified Stretches	Land-use			
		Residential	Mixed	Industrial with other uses	Agricultural
Aligarh	7	-	2	3	2
Jafri	2	-	1	-	1
Koil	1	-	1	-	-
Gadrana	1	-	-	-	-
Boner	1	1	-	-	-

Source: Author, 2022

Figure 4: Drains/Nallahs of Aligarh

A lined drain in the middle of the city | **Aligarh drain near Sarsol area** | **Koil distributary near Sarsol**

Source: Author, 2022

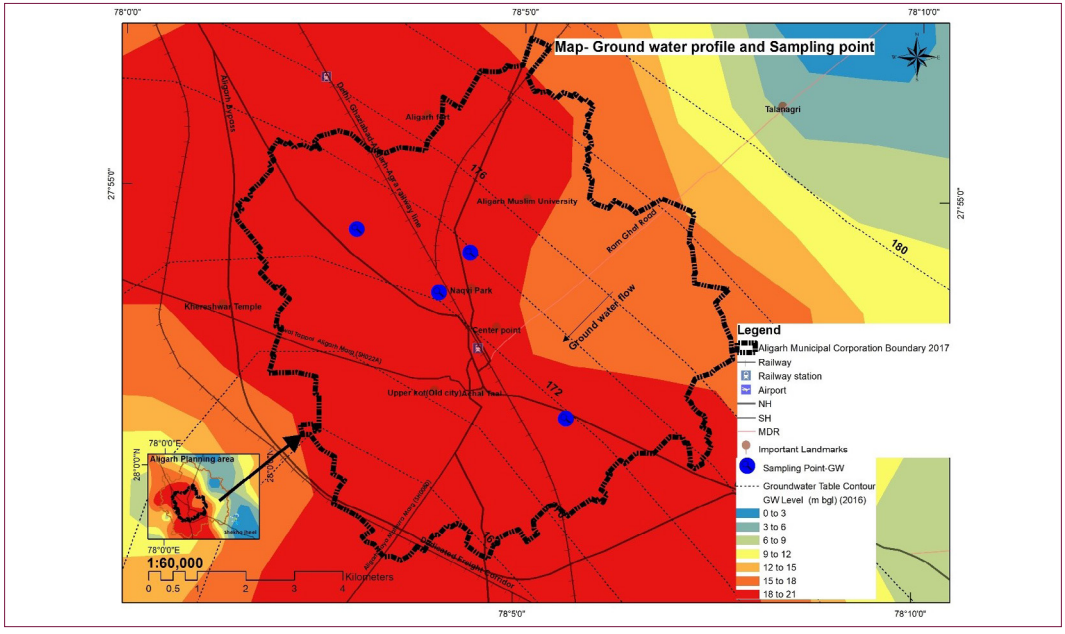
The Aligarh drain was found to be highly polluted. The BOD, which was already very poor (55 mg/l) before entering the city trebled (140 mg/l) after exiting the city. It was a similar case for COD, which increased from 147 mg/l to 316 mg/l (Primary survey, 2022).

Groundwater

Groundwater assumes a special significance for Aligarh as the city is completely dependent on it for all its uses. Due to excessive removal from shallow tubewells, the upper aquifer (9-66m mbgl) is under stress (Khurshid & Kulshrestha, 2008). The flow of groundwater is from the north-west to the south-east. The gradient of the water-table varies from 0.16 to 4.0 m/km. The post monsoon groundwater level has dropped from 8.84 (2011) to 14.42 mbgl (2021) (Jal Jeewan Mission, 2022). The deepest water level i.e., 26.63 mbgl has been observed at Jawahar Park in the Aligarh City area (Khan S. , 2017).

The region's upper aquifer is extremely susceptible to microbiological and chemical pollution (Umar et al, 2001). Groundwater samples from New Basti Colony and Naqvi Park had higher than acceptable limits (BIS standards) of TDS and total hardness. Among these, New Basti Colony had the highest nitrate (28 mg/l), though within the permissible limits (Author, 2022). Past studies also suggest poor quality of water in many places of the city (Anwar and Aggarwal, 2014, Ayub et.al 2011), along with the presence of trace elements (Khan T. A., 2011). More than 80 percent of the city, particularly to the west of the railway line have been found vulnerable to groundwater contamination (Rahman, 2008).

Map 5: Groundwater Flow and Depth in Aligarh



Source: Author 2022, prepared from SOI, SLUSI, CityGIS, CGWB 2014

Disruptions in Interconnectedness

The city has deviated from Sir Syed Ahmad's *'Aab-o-hawa'*. Ponds and drains are polluted while groundwater is also contaminated at many places in the city. The disruption in the interconnectedness has manifested in the form of health issues, loss of biodiversity, and loss of ecosystem services.

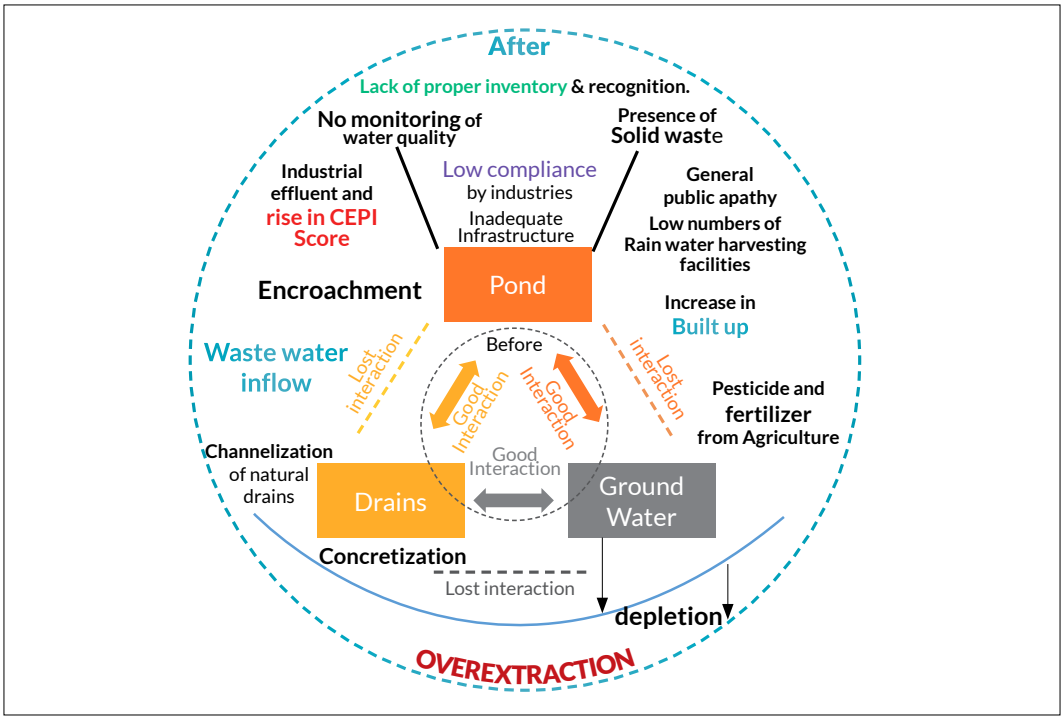
Vector borne diseases like malaria are prevalent in the city and it has been attributed to lack of natural drainage which results in the collection of waste water in depressions (Singh & Rahman , 2001). In 2022, the Health Department declared 39 areas within the city as prone to malaria and dengue (Amar Ujala, 2022c). Aligarh also has a campaign to check vector borne diseases in the post-monsoon phase (Hindustan Times, 2023), but has also been identified as a poor performer for controlling the spread of dengue (Saigal, 2023). Many ponds and drains do not have fish which is an important bio-indicator of the health of the waterbodies.

Pollution in waterbodies is one of the key stressors for the ecosystem services (Wang et.al, 2021, Grizetti et.al, 2016). While many of the provisioning ecosystem services such as fish, drinking water were absent, some of the ponds were being used for cattle wading (livelihood). Among the regulating services, groundwater recharge and discharge has been heavily compromised in terms of the quality of water. Cultural services are prominent for a few waterbodies such as Achal taal, but non-existent for others. Among the supporting services, it was highlighted by environmentalists that the variety of birds spotted near the waterbodies in the city has declined over the years.

Public apathy has also played a role in the current state of affairs. Being prone to waterlogging, the city and the adjoining areas have several waterbodies or depressions that are filled with water, particularly during the monsoons. These are also viewed as a nuisance by many residents as they become breeding grounds for mosquitos and a hub for anti-social activities. In a google survey conducted across the city by the authors, it was found that half the respondents had never visited a waterbody in the city. The presence of odour, absence of seating places and walking tracks, and presence of stray animals near the waterbodies were some of the issues highlighted during the people's perception survey. Few waterbodies, such as Achal taal, that are of religious and cultural significance have been taken over for restoration but with focus on beautification and not rejuvenation.

The trilogy of ponds, drains, and groundwater is undergoing a systemic destruction wherein though the link between the three exist, the exchange of clean water has been taken over by polluted water. The poor state of infrastructure, low compliance by industries, non-existent monitoring of water quality by authorities, and public apathy has destroyed the natural balance between the three components of the trilogy thus leading to the present dismal state.

Figure 5: Destruction in the Trilogy

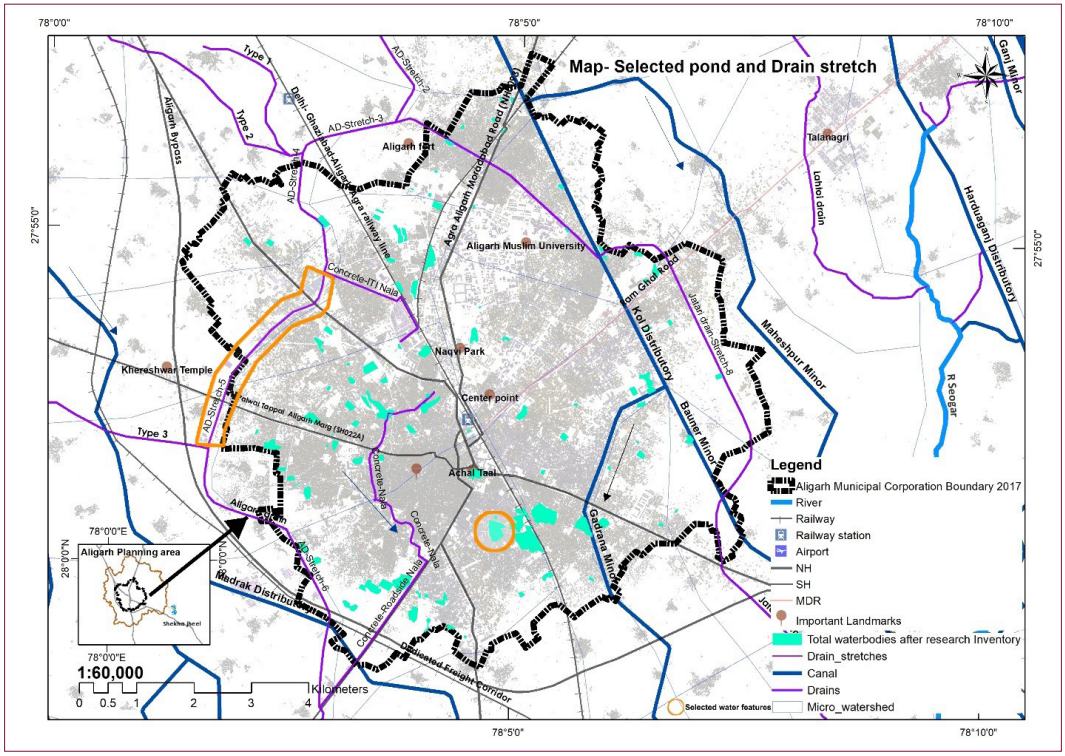


Source: Author, 2022

Prioritization Process

As part of the study, prioritization of waterbodies for rejuvenation was also undertaken. The thought behind the need for prioritization was that rejuvenation of the selected waterbodies should have the highest benefits and co-benefits and to make it financially feasible, the project should be able to access funds under the relevant government of India schemes. This will also assist the administration in holistically selecting the city's waterbodies for rejuvenation. A *"Manual on urban water body diagnostic tool"* prepared by the National Institute of Urban Affairs (NIUA) and UNESCO in April 2022 was also referred for this process.

Map 6: Selected Stretch and Pond for Intervention in Aligarh



Source: Mapped by the author from Survey of India toposheets, 2005

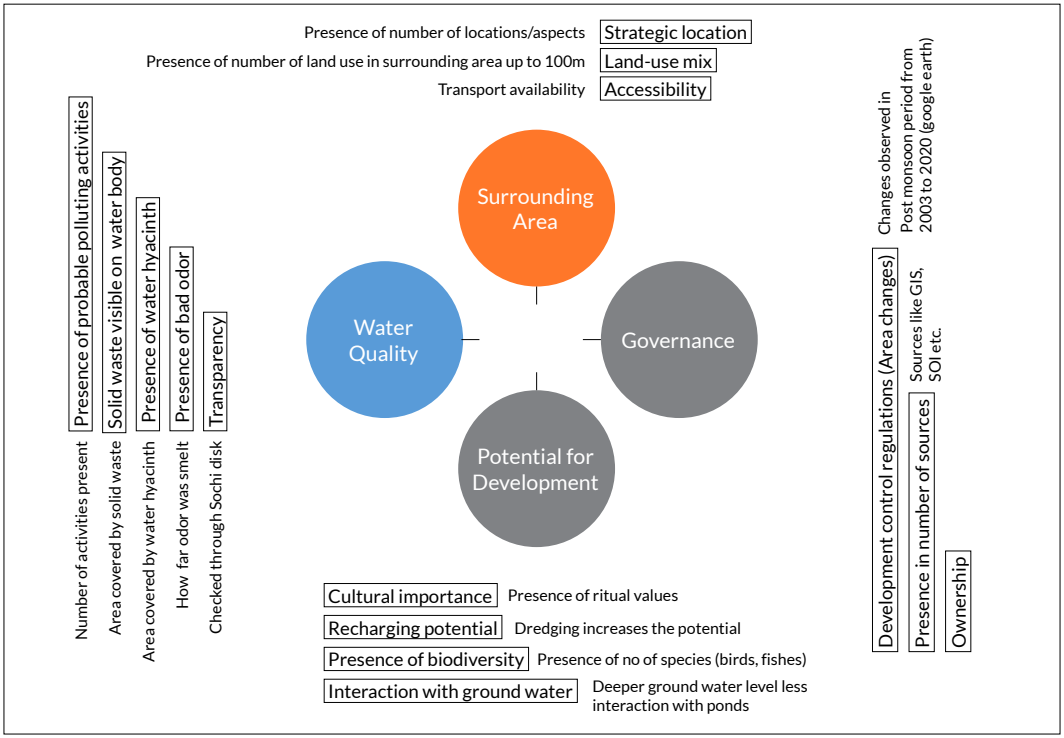
Ponds

Two levels of prioritization process were involved in the selection of ponds. The first level included 'ponds with area above 2ha', wherein 22 out of 106 ponds were selected. The rationale behind the selection of ponds with area of more than 2ha is that they are eligible for inclusion under the Repair, Renovation, and Restoration of waterbodies under PMKSY (Pradhan Mantri Krishi Sinchayee Yojana) scheme, 2017 and thus will be eligible for funds for rejuvenation.

The second level of prioritization was based on 15 sub criteria which were grouped together to form four major criteria. All the sub criteria were given equal weightage. Each sub criteria was given values from 1 to 5 where 1 was the lowest. Based on equal weightage among the sub criteria, after the addition of values, the pond with the highest value was chosen for rejuvenation.

The four criteria were water quality, buffer area/effective micro/watershed characteristics, governance, and potential for development.

Figure 6: Criteria for Ponds



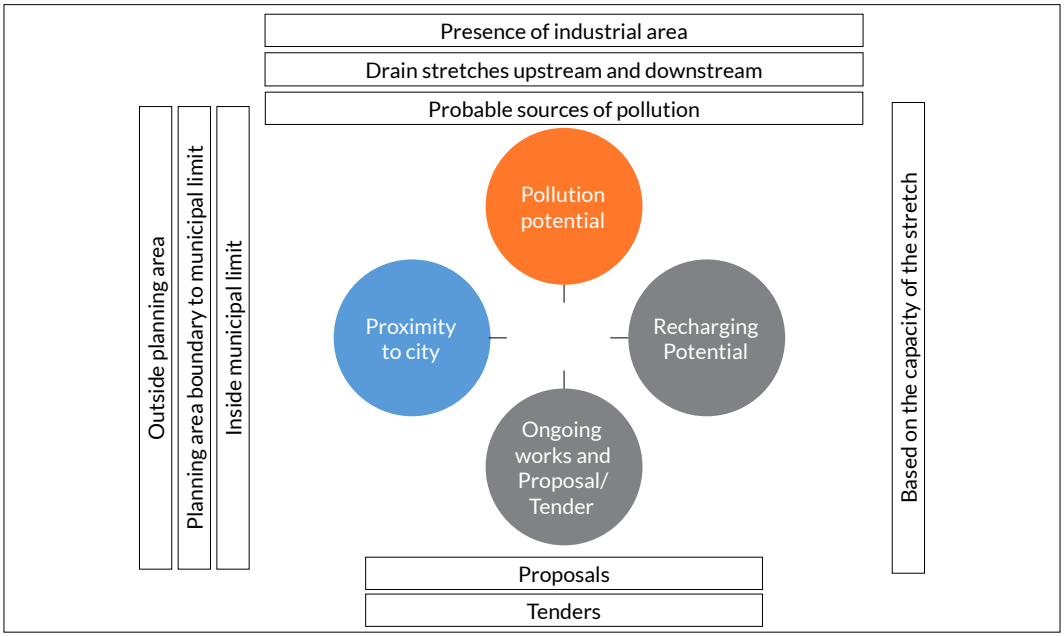
Source: Author, 2022

Out of 22, five ponds were not visited, and the remaining 17 ponds were given a score based on the prioritization process. Out of a maximum score of 75, Kali Deh Pond and New Basti pond scored the highest of 63 and 50, respectively; nine ponds scored in the range of 25 to 50 and six ponds scored less than 25.

Drains

Total 12 drain stretches were identified, which were based on the meeting points of major drains/ nallahs, and the length within the city's planning and municipal boundaries. The four criteria were assessed on a scale of 1 to 3, where 1 stood for the lowest value. The stretch with the highest calculated value will be chosen for rejuvenation, after addition of the values for each sub criteria.

Figure 7: Criteria for Drains



Source: Author, 2022

Out of the seven stretches that were identified for Aligarh drain, three stretches viz. type 1-2 drain meeting point to ITI nallah point, ITI nallah point to type-3 drain meeting point, and type-3 drain meeting point to Chhahari drain meeting point scored the highest (ten). The other four stretches viz. Origin to planning area entry point, from planning area entry point to diversion point, from diversion to type 1-2 drain meeting point, and Chhahari drain meeting point to River Yamuna (Outside Jurisdiction of Aligarh District) scored marginally lower in the range of 7-9. Two stretches of Jafri drain, from diversion till last municipal limit and municipal limit to end point (River Sengur) scored seven and four, respectively. Koil distributary, Gadrana minor, and Boner minor scored below 8.

Three stretches were found to have the same score. To select one, further criteria of length of the stretch and presence within Aligarh city was applied. Thus, stretch 6 was selected as it was the longest and it also flowed through Aligarh city for the longest distance.

Shekha Jheel: The Wetland Perspective

Shekha Jheel is a bird sanctuary and an Important Bird Area (IN-UP-21) near the village of Shekha and Bhavan Kheda, 17 km East of Aligarh city. It is a wetland that is identified under the former National Wetlands Conservation Programme (NWCP). The notified area is 40ha and its depth ranges from 0.91m to 1.22m. However, the area of the wetland is 25ha. It is a natural

perennial (inland) wetland. The area is bounded by the Upper Ganga Canal (UGC), Harduaganj and Sikandrarao distributaries, Bhavan Kheda minor, escapes and Bijaigarh drain (which probably carries wastewater from the Bhavan Khera village into the jheel). The main source of water is the UGC and rainwater. The UGC divides this area into two parts. With time, it became a popular destination for migratory and resident birds for nesting and breeding. However, before 1970, it was a shooting ground for the nearby population. Conservation efforts led by local people and beautification works by the administration started in 2012.

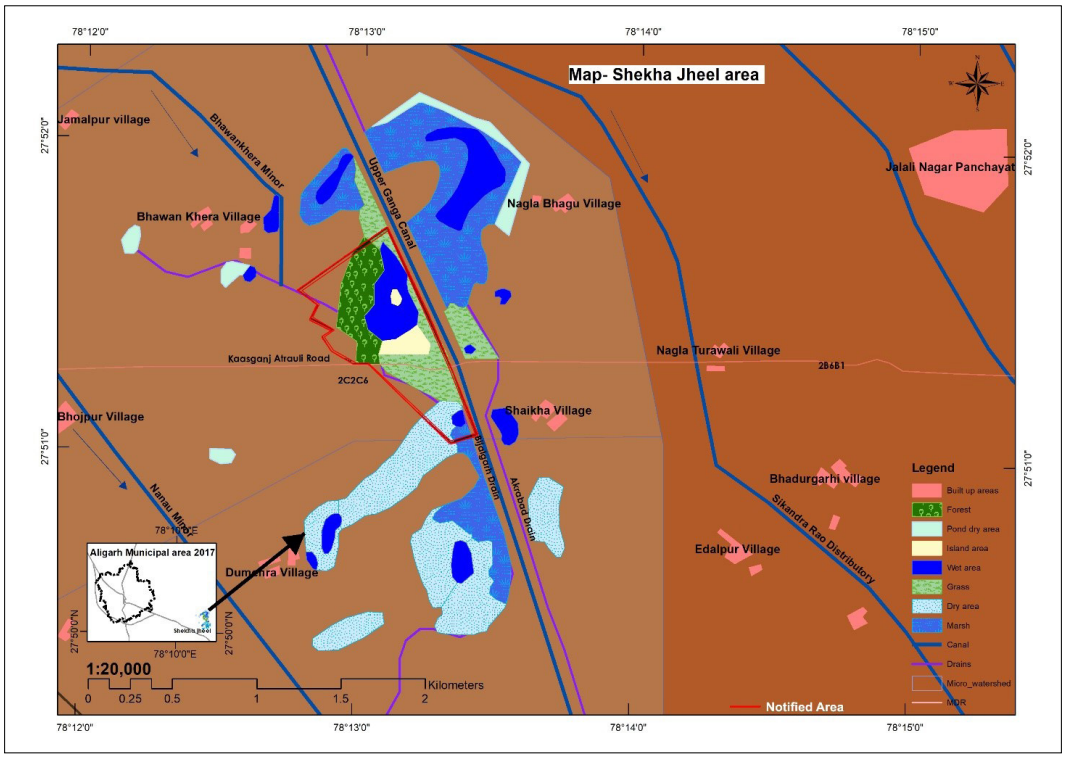
Figure 8: Shekha Jheel in Aligarh

Wetland Area | **Pathway to the Jheel** | **North-western part of the Wetland**

Source: Author, 2022

Grey Lag Goose, Black Buck, Sarus Crane, Greater Spotted Eagle, along with 166 other species which include residents and migratory birds were observed in the area (Bird life International, 2022). Black-necked stork and Wooly-necked stork are the major attractions of Shekha Jheel. The migratory birds follow the Central Asian Flyway route and arrive at this jheel every year. The density of Nilgais (Blue buck/Boselaphus tragocamelus) was maximum in and around the Shekha Jheel i.e., 132 individuals per sq km (Khan and Khan, 2016). The jheel is also recognized in the Wildlife and Eco Tourism Circuit (Western ornithology/Wetland circuit), as per the UP-Tourism policy of 2018. Rejuvenating Aligarh waterbodies of 2C2C6 watershed, will facilitate the rejuvenation of the jheel.

Map 7: Shekha Jheel and its Surroundings in Aligarh



Source: Author, 2022, Prepared from SOI, Primary survey 2022

The notified area of the jheel is almost one-third of the total area under the wetland (Primary survey, 2022). This is demarcated with a red boundary in Map 7. An integrated management plan has been prepared, which was not available in the public domain at the time of the study.

Threats to the wetland arise from grazing and firewood collection from the nearby villages of Shekha and Bhavan Kheda, from invasive alien species like Eichhornia Crassipes (aquatic plant) (Wetlands of India Portal, 2022), Lantana camara, Sida, Parthenium hysterophorus, and Cassia tora (Kalpavriksha, 2009) and agriculture practices during the dry season.

Besides provisioning, regulating, and supporting services for the residents of Shekha and Bhavan Kheda, the cultural ecosystem services rendered by the jheel for the residents of Aligarh is invaluable. It provides a space for residents to escape from the squalor of Aligarh. The findings of the tourist (42 No.) surveys indicated that 89 percent of the tourists were from the city of Aligarh. The reasons for their visit included bird watching for 19 (44%) tourists, picnic for 12 (27%) tourists, and leisure with friends for 17 (39%). Of these, 32 (72%) had a good experience. As per tourists, 24 (54%) felt that they can visit and enjoy the environment of Shekha Bird Sanctuary without much disturbance, as it is not crowded. Total 21 (51%) tourists found it to be a safe place. Only 3 percent visit the jheel regularly and 54 percent intend to visit again.

Strategies and Way Forward

Reclamation of the trilogy is a key element in achieving a resilient Aligarh and getting back the once famed *'aab-o-hawa'*. Authors suggest an integrated and multi-pronged approach that comprises regional level strategies, interventions at the Master Plan level, possible methods for rejuvenation of ponds and drains, finance options, and involvement of residents.

Regional Level Strategies and Benefit Sharing Solutions

Aligarh's water issues cannot be viewed in silo, rather they are embedded in the water region. It is critical to introduce policy and planning interventions for protection of water resources in the regional watershed of the Aligarh drain and other nallahs that pass through the city. While the central government laws, and Wetland (Conservation and Management) Rules, 2017, are applicable for the protection of Shekha Jheel, there is an absence of a potent law for protection of the urban waterbody in Uttar Pradesh. "Uttar Pradesh Pond Development, Protection and Conservation Authority Bill 2017 (Third Draft)" is yet to be enacted.

Authors suggest that the sizes of the ponds to be protected under this bill should be reduced from 0.5 hectare to 1000sqm. This will be more relevant in the urban context where smaller ponds are common and will allow more ponds to be taken up for rejuvenation. A portal (like the Wetland Portal of India) should be launched for the entire state to identify waterbodies/ponds. On such identification, they should be assigned a Unique Identification (UID) Number and steps should be taken for their restoration. Efforts should be made to bring land ownership of ponds under one agency. All the departments need to access the portal and they will need to provide a list along with details of the waterbodies apart from the listed ones on the portal.

Indian Easement Act, 1882 gives all rights to landowners to extract groundwater. Since water is a public trust, it is important to amend the said Act and enact the Indian Easements (amendment) Act, 2019, in which the use of water shall be regulated by the concerned Gram Sabha or the urban local body. The implementation of UP Ground Water (Management and Regulation) Act, 2019 should be strict and it should not allow any exemption for new developments in the state.

Spatial Interventions at Master Plan, Zonal, and Local Area Levels

If water features are included in a Master Plan (a statutory document), the area and the resources will be valued as an asset. It is important that the Master plan, zonal, and local area plans should have a water resource centric vision. Land use planning must consider the natural groundwater recharge areas. Since urban waterbodies receive not only the surface runoff from the immediate surroundings but many a times also through stormwater drains from far off areas. Thus, the completely modified catchment of the waterbody should be delineated and considered for the purpose of rejuvenation rather than just focusing on beautification of the waterbody.

Integration of blue-green infrastructure in the master planning process can enhance their utility and benefits, the way it has been done for Rotterdam, Amsterdam, Kochi, Madurai, etc. Strategies for rejuvenation of waterbodies should also be specific to the land use and the activities that they are located in.

Nature-based Practices for Urban Ponds, Drains, and Groundwater Recharge Enhancement

Nature-based Solutions (NbS) have several benefits and co-benefits and are fast gaining traction in the urban context, thus contributing substantially to circularity. A synergy is needed between the existing grey infrastructure and NbS for optimum results (Tsatsou, 2023). In the context of Aligarh, NbS can be introduced at all scales. For forests and wetlands at the regional scale, while for constructed wetlands, bioswales, rain gardens, floating wetlands etc at the urban scale. These would be instrumental in tackling the critical local issues of floods, polluted water etc.

All ponds should be properly managed, which includes regular removal of water hyacinths and breeding of non-invasive fish species that consume the mosquito larvae. Control of soil erosion through planting native vegetation may also be tried. Urban forests can be generated in suitable areas with natural depressions. Experiences can be drawn from case studies of Hauz Khas and Neela Hauz, Delhi, and the water plaza project at Rotterdam among others. Already, there is partial acceptance of these methods as one of the drains is currently undergoing phyto-remediation, but efforts need to be amplified.

Institutional and Regulatory

The definition of a pond needs to be decided and all agencies should follow that to avoid confusion. There is a need for a GIS-based waterbody mapping and inventory of ponds and drains. The UPPCB has to make sure that all ponds, waterbodies, and groundwater in various areas of the city are regularly monitored for water quality. For better management, capacity building exercises in the district administration, Municipal Corporation, the Forest department, and Irrigation department should be conducted on a regular basis. Land ownership for ponds and waterbodies ought to be centralised under one organization. Strict implementation of the UP GW (Management and Regulation) Act 2019 should be encouraged. Economic instruments such as volumetric pricing of domestic water and incentives for RWH could also be explored. UP Building Byelaws should be modified to facilitate dual piping systems for reuse of grey water and, also to work on the safe reuse of treated wastewater.

Financing Solutions

Water being a state subject, the restoration and rejuvenation of waterbodies is primarily the responsibility of the state government. Finance is available under various programmes and schemes such as the Mantri Krishi Sinchayee Yojana (PMKSY), Har Khet Ko Pani (HKKP), Jal Shakti Abhiyan: Catch The Rain, AMRUT 2.0, and Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGA).

Corporate Social Responsibility (CSR) is also a viable option for bringing funds. Besides, the CSR funds being utilised in a stand-alone manner, convergence with Mission Amrit Sarovar is also permitted.

Cultural/People Connect

People in Aligarh city need to be encouraged to think about drains as a component of a bigger river system rather than merely a place to dispose of garbage. Designing inclusive and secure green areas around waterbodies is important to change people's perceptions. Organizing *mohalla* meetings

and *Pani Sanrakhshan Samvaad* (Water conservation interactions) may be effective engagement strategies. Educational and various related institutions should be involved via adoption of a waterbody, while Corporate Social Responsibility (CSR) activities should be encouraged among the industries of Aligarh. Citizen science and '*Jan bhagidari*' (People participation) can also play a key role.

Acknowledgment

The authors sincerely acknowledge the valuable inputs received from the team of NIUA, NMCG, and reviews for critical comments during the study at multiple levels of the research work.

Funding

This research is funded and is a part of the sponsorship received under the National Student Thesis Competition (STC) Season-2 in 2022 by NIUA and NMCG.

Conflict of Interest

The authors declare no conflict of interest.

Bibliography

Amar Ujala (n.d.). सत्ता का संग्राम: उत्तर प्रदेश के प्रतापगढ़ में जनता के मुद्दों पर क्या बोले नेता? देखें राजनीतिक दलों से चर्चा, Retrieved from Amar Ujala: https://www.amarujala.com/uttar-pradesh/aligarh on May 3, 2023.

Kalpavriksh Environmental Action Group (2009). Sheikha Jheel- Case Study (2009), Retrieved May 8, 2022, from: https://kalpavriksh.org/sheikha-jheel/ on May 3, 2023.

Government of Uttar Pradesh (2022 , July 2). District of Aligarh- History, Retrieved from https://aligarh.nic.in/history/ on May 3, 2023.

Government of Uttar Pradesh (2022). Jal Jeevan Mission-Uttar Pradesh, Retrieved from https://jjm.up.gov.in/ on May 3, 2023.

Ministry of Environment, Forest and Climate Change (2022). Wetlands of India Portal, Retrieved from Wetlands of India Portal: https://indianwetlands.in/view-wetland/?profile=MTEz on May 3, 2023.

BirdLife International (2022). Sheikha Jheel , Retrieved from Bird life International: https://datazone.birdlife.org/site/factsheet/sheikha-jheel-iba-india/text on May 3, 2023.

Aligarh Development Authority (2003). Master Plan 2021, Government of Uttar Pradesh, Aligarh.

Amar Ujala (2022, May 30). गंदगी की भरमार, डेंगू-मलेरिया से जूझने को रहें तैयार. Amar Ujala. Retrieved from https://www.amarujala.com/uttar-pradesh/aligarh/aligarh-plenty-of-dirt-be-ready-to-fight-dengue-malaria-aligarh-news-ali292698328 on May 3, 2023.

Amar Ujala. (2021, June 27). फरमान हवा-हवाई, अलीगढ़ में सरकारी कार्यालयें में भी नहीं हैं रेन वाटर हार्वेस्टिंग . Retrieved from https://www.jagran.com/uttar-pradesh/aligarh-city-there-is-no-rain-water-harvesting-even-in-government-offices-in-hawa-hawai-aligarh-21760991.html on May3, 2023.

Anwar, K., & Aggarwal, V. (2014). Analysis of Groundwater Quality of Aligarh City, (India): Using Water Quality Index. Current World Environment. doi:http://dx.doi.org/10.12944/CWE.9.3.36 on May 3, 2023.

Atkinson, E. T. (1875). Statistical Descriptive and Historical Account of the Aligarh District, Allahabad.

Ayub, S., Husain, A., & Abad, K. (2020). A Study of Bacteriological Contamination of Drinking Water in Aligarh City, U. P., India. International Journal of Civil Engineering Research and Development (IJCERD), 1. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3513275 on May 3, 2023.

Building Department. (2022, December). Aims and Objectives, Retrieved from AMU: https://www.amu.ac.in/miscellaneous/building-department/home-page on May 3, 2023.

Office of the Registrar General and Census Commissioner of India (2011). Census of India- 2011, Ministry of Home Affairs, Government of India.

Central Ground Water Board (CGWB) (Ed.). (2022). Ground Water Resource Assessment, Ministry of Jal Shakti, Retrieved 2023, from Ground Water Resource Assessment: https://www.cgwb.gov.in/ground-water-resource-assessment-0 onn May 3, 2023.

CGWB. (2022). Dynamic Ground Water Resources of India 2022, Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Faridabad.

Cherepansky M.M, V. V. (n.d.). Types and Properties of Water (Vol. I). UNESCO-Encyclopedia Life Support Systems (UNESCO-EOLSS). Retrieved from https://www.eolss.net/ebooklib/bookinfo/types-properties-water.aspx on December 8, 2022,

Administrative staff college of India (2014). City Sanitation Plan Aligarh, Centre for Energy, Environment, Urban Governance & Infrastructure Development.

Commissioner, A. M. (2022). Personal Communication. (Pranav Interviewer) Aligarh.

CPCB. (2013). Pollution assessment: River Ganga. CPCB. Retrieved from http://www.cpcb.nic.in/

CPCB. (2016). Final Document on revised classification of Industrial Sectors under Red, Orange, Green and White Categories. Delhi: Central Pollution Control Board. Retrieved from https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTE4X0ZpbmFsX0RpcmVjdGlvbnMucGRm on May 3, 2023.

Press Information Bureau- Delhi (2021,). Treatment of polluted water. Retrieved from https://pib.gov.in/PressReleasePage.aspx?PRID=1782290#:~:text=As%20informed%20by%20Aligarh%20Nagar,Jal%20Nigam%20in%20the%20town on May 3, 2023.

Government of Uttar Pradesh (1982). Final Report on the Revision of Settlement in the District of Aligarh, Retrieved from Indian Culture: https://www.indianculture.gov.in/ebooks/final-report-revision-settlement-district-aligarh on May3, 2023.

Geiger, B. (2018, December 6). Explainer: Earth's water is all connected in one vast cycle. Retrieved from Science News Explores.

Gelt, J. (1994). Managing the Interconnecting Waters: The Groundwater-Surface Water Dilemma. Arroyo, Water Resources Research Center, Tucson, AZ, USA.

Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A., & Cardoso, A. (2016, July). Assessing water ecosystem services for water resource management. Environmental Science & Policy, 61.

Government of Haryana (2018). Haryana Pond and Waste Water Management Authority Act, Retrieved from https://hpwwma.org.in/impdoc/ACT%20LegislativeSupplementPartI.pdf on May 3, 2023.

Hindustan Times. (2023, October 29). 17 U.P. districts identified as underperforming in 'case-based activity' for dengue. Retrieved from https://www.hindustantimes.com/cities/lucknow-news/17-u-p-districts-identified-as-underperforming-in-case-based-activity-for-dengue-101698520541214.html on October 30, 2023.

Hussain, M. M., Ilyas, O., & Imam, E. (2022). Wetland Inventory of Aligarh District. In O. I. Khan, Case Studies of Wildlife Ecology and Conservation in India (p. 318). London: Routledge. doi:https://doi.org/10.4324/9781003321422

Hutchinson, J. R. (1856). Allygurh statistics. Thomason college press Roorkee. Retrieved from https://books.google.co.in/books?id=WHoNAAAAQAAJ&pg=PA1&lpg=PA1&dq=Allygurh&source=bl&ots=R-2VBCRRIH&sig=ACfU3U3icpGb-QGErRw9HApdcPDjxxENeQ&hl=en&sa=X&ved=2ahUKEwi9n6ejs5z6-AhVaAIgKHT35A3cQ6AF6BAhdEAM#v=snippet&q=water&f=false on May 3, 2023.

Khalil, H. (2021). The Allure of Aligarh: A Poetic Journey into the University City. Hay House.

Khan, H. H., & Khan, A. (2019). Groundwater-surface water interaction along river Kali, near Aligarh, India. HydroResearch, 2, 119-128. Retrieved from https://doi.org/10.1016/j.hydres.2019.12.001

Khan, S. (2017). Aquifer Mapping and Ground water Management Plan. Central Ground Water Board.

Khan, T. A. (2011). Trace Elements in the Drinking Water and Their Possible Health Effects in Aligarh City, India. Journal of Water Resource and Protection. doi:10.4236/jwarp.2011.37062.

Khurshid, S., & Kulshrestha, P. (2008). Groundwater resource and development potential in parts of Central Ganga-Basin, Aligarh (U.P.), India. Bulletin of Pure & Applied Sciences-Geology.

Manager (DIC), A. (March, 2022). Personal Communication. (Interviewer: Pranav)

Mann, M. (1995). Ecological Change in North India: Deforestation and Agrarian Distress In The Ganga-Jamna Doab

1800-1850. Environment and History, Vol. 1, No. 2 (June 1995), pp. 201-220.

Ministry of Culture (1982). Final Report on the Revision of Settlement in the District of Aligarh. Government Press, Allahabad. Retrieved from https://www.indianculture.gov.in/ebooks/final-report-revision-settlement-district-aligarh on May 3, 2023.

Mohammad Ajmal, R. U. (1988). Heavy metals in water, sediments, plants and fish of Kali Nadi U.P. (India). Environment International, 14(6). doi:https://doi.org/10.1016/0160-4120(88)90413-8

Nevill, H. R. (1909). Aligarh: A Gazetteer of the District Gazetteers of United Provinces of Agra and Oudh. Allahabad: F. Lukar, Superintendent, Government Press, United Provinces.

Rahman, A. (2008, January). A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. *Applied Geography.* Volume 28, Issue 1, January 2008, Pages 32-53, doi:10.1016/j.apgeog.2007.07.008

Saigal, G. (2023, October 29). 17 U.P. districts identified as underperforming in 'case-based activity' for dengue. Hindustan Times. Retrieved from https://www.hindustantimes.com/cities/lucknow-news/17-u-p-districts-identified-as-underperforming-in-case-based-activity-for-dengue-101698520541214.html on May 3, 2023.

Siddiqi, J. M. (1981). Aligarh District: A historical survey (From ancient times to 1803 AD). Munshilal Manoharlal Publishers Pvt. Ltd.

Singh, A., & Rahman, A. (2001). Malaria and related environmental issues in India: a case study of Aligarh city. GeoJournal, Volume 53, pages 89–99, doi:https://doi.org/10.1023/A:1015818318396

Sinha, R. S. (2021). State of Groundwater in Uttar Pradesh- A Situation Analysis with Critical Overview and Sustainable Solutions. Retrieved from https://cdn.cseindia.org/gic/state-of-ground-water-20210927.pdf on May 3, 2023.

Solid waste management city profile: Aligarh India. (2018). Climate and Clean Air Coalition Municipal Solid Waste Initiative. Retrieved from http://waste.ccacoalition.org/

Thomas C. Winter, J. W. (1998). Ground water and surface water: A single resource. U.S. Geological Survey. doi:10.3133/cir1139

Press Information Bureau (2021, December 16). Treatment Of Polluted Water, Retrieved from https://pib.gov.in/PressReleasePage.aspx?PRID=1782290#:~:text=As%20informed%20by%20Aligarh%20Nagar,Jal%20Nigam%20in%20the%20town on May 3, 2023.

Tsatsou, A., Frantzeskaki, N., & Malamis, S. (2023, March 25). Nature-based solutions for circular urban water systems: A scoping literature review and a proposal for urban design and planning. Journal of Cleaner Production. Volume 394, 25 March 2023, doi:https://doi.org/10.1016/j.jclepro.2023.136325

United Nations. (2023). Imminent risk of a global water crisis, warns the UN World Water Development Report 2023. UNESCO. Retrieved February 10, 2024, from https://www.unesco.org/en/articles/imminent-risk-global-water-crisis-warns-un-world-water-development-report-2023.

United Nations. (n.d.). Water – at the center of the climate crisis. Retrieved from https://www.un.org/en/climatechange/science/climate-issues/water#:~:text=Climate%20change%20is%20exacerbating%20both,world's%20water%20in%20complex%20ways, on May 3, 2023.

Uttar Pradesh Pollution Control Borad (UPPCB) (2022). Environmental Management Plan of Aligarh, Government of Uttar Pradesh.

UPPCB. (n.d.). Action plan for restoration of polluted stretch of river Yamuna. Retrieved from http://www.uppcb.com/pdf/RIVER-YAMUNA.pdf on May 03, 2023.

NMCG and NIUA (2020). Urban River Management Plan (URMP). Retrieved from https://nmcg.nic.in/writereaddata/fileupload/48_Urban%20River%20Management%20Plan%20framework.pdf on May 3, 2023.

Wang, J., Lautz, L. S., Nolte, T. M., Posthuma, L., Koopman, K. R., Leuven, R. S., & Hendriks, A. J. (2021). Towards a systematic method for assessing the impact of chemical pollution on ecosystem services of water systems. Journal of Environmental Management, Volume 281, 1 March 2021, doi:https://doi.org/10.1016/j.jenvman.2020.111873.s