PHYSICOCHEMICAL ASSESSMENT AND GIS MAPPING OF GROUNDWATER IN RURAL AND URBAN AREA OF LUCKNOW

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CHAPTER 1
INTROUCTION

1.1 BACKGROUND

Lucknow is the capital city of the most populous state Uttar Pradesh and is one of the fastest developing urban centers of India. Lucknow district is a part of Central Ganga Plain covering an area of 2, 528 km2. and lies between North latitudes 26°30’ and 27°10’ and East longitudes 80°30’and 81°13’ with total population of 34 lakhs as per 2011. There is a requirement for regular monitoring of contamination source, water quality for the purposes of sustainable development and ground water management, parameters, hydrogeochemical assessments etc., to control the natural geological baseline chemistry. To assess the impacts of contaminants on groundwater or on an aquifer quality, it is crucial to have information of the natural baseline quality with an acceptable degree of confidence. The 5 control on water quality situation is difficult to achieve due to the low public awareness and high clean-up cost for water/ wastewater treatment. In view of this, the current study will explore the quality of ground water for drinking as well as irrigation purpose in rural, and urban areas of Lucknow (India). Surface water and Ground water are the main source of irrigation in the district. Length of canal in the district is 962 kms. Gross irrigated area is 126607 hectares out of which 28149 hectares (22.23%) is irrigated through ground water (77.77%) by means of Deep tube wells, shallow tube wells, private tube wells borings etc. About 90% of the net cultivated area in the district has assured irrigation facilities while the irrigation intensity is 144.25%. Water is the most precious indispensable natural resource and inevitability for sustaining the life as well as fundamental means for the economic growth. But unfortunately, the access of safe and potable drinking water for the individual human beings are the major concerning issue. Still the majority of rural (90%) and urban (30%) Indian population are completely hinge on the untreated ground water resources. Over the past few decades the demands of water supply have been increasing tremendously due to the rapid industrialization on one hand and exploding population on the other hand. However, unsustainable ecological practices have led to rapidly depleting levels in groundwater.

leading to wide-spread water shortage and groundwater contamination. In every 20 years, the global consumption of water is doubling, more than twice the rate of human population growth. The pollution of groundwater is of major concern, firstly because of increased utilization for human needs and secondly because of the ill effects of the increased industrial activities. The menace of water-borne diseases and epidemics still threatens the well-being of population, particularly in under-developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind. Authorities are battling to make groundwater safe for human consumption, sustainable and accessible to all. As a citizen, you can strengthen the cause in your own way.

Various factors are responsible for the complex chemistry of the groundwater and surface water interactions. A spill of a chemical contaminant on soil, located away from a surface water body, may not necessarily create point source or non-point source pollution, but nonetheless may contaminate the aquifer below. Analysis of groundwater contamination may focus on hydrology, as well as the nature of the contaminant itself. Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle. Any changes in the hydrology, especially those from the introduction of drainage, will have often-irreversible effects on the functioning of these fragile ecosystems. Contamination may involve different chemicals, excess amounts of nitrogen and phosphorous, and pathogens like bacteria and viruses. Sometimes it is impossible to clean it up to drinking water standards. This contamination not only threatens public health but also to the environment.

Classification of water pollutants / contamination

1. Organic Pollutants
   - a) Volatile organic compounds
   - b) Pesticides
   - c) Plasticizers, chlorinated solvents, benzo[a]pyrene, and dioxin.

2. Inorganic Pollutants
    a) Chloride
    b) Inorganic salts
    c) Sulfate
    d) Heavy metals
3. Suspended solids and sediments
    a) Silt
    b) Sand
    c) minerals
4. Radioactive Materials
    a) Mining & processing of ore (Uranium)
    b) Radioactive isotopes (Cs^{137}, K^{40})

Groundwater is the only resource of water that used for multi-activities [5]. The chemical composition of groundwater depends not only on natural factors such as lithology of aquifer, the quality of recharge waters and type of interactions between water and aquifer, but also on human activities which can alter fragile groundwater systems either by polluting them or by changing hydrological cycle [6]. Saltwater encroachment associated with over drafting of aquifers or natural leaching from natural occurring deposits are natural sources of groundwater pollution. Most concern over groundwater contamination has centered on pollution associated with human activities. Human groundwater contamination can be related to waste disposal (private sewage disposal systems. The occurrence of fluoride in ground water is mainly due to geogenic contamination of ground water and depends on the geological setting of an area. The fluoride content of ground water is originated from the dissolution of fluoride bearing minerals in the bedrock and thus bedrock mineralogy is, in general plays a primary factor for the variations in fluoride content of ground water. Many factors such as availability and solubility of fluorine-bearing minerals, temperature, pH, concentration of calcium, bicarbonate and sodium ions in water etc. plays important role in fluoride contamination of ground water. The excessive fluoride concentration in ground water may persist for very long time; enter into food chain, cause adverse impact on human health including dental or skeletal fluorosis etc. Therefore, it is essential to determine the causal factors of fluoride enrichment in underground water in time as space to mitigate the problem.

Table 1.1 Types of groundwater contamination sources

Place of origin	**Types of groundwater contamination sources**			
	Municipal	**Industrial**	**Agricultural**	**Individual**
At or near the land surface	• air pollution • municipal waste land spreading • salt for de-icing streets • streets & parking lots 	• air pollution • chemicals: storage & spills • fuels: storage & spills • mine tailing piles 	• air pollution • chemical spills • fertilizers • livestock waste storage facilities & land spreading • pesticides 	• air pollution • fertilizers • homes • cleaners • detergents • motor oil • paints • pesticides 
Below the land surface	• landfills • leaky sewer lines 	• pipelines • underground storage tanks 	• underground storage • tanks • wells: poorly constructed or abandoned 	• septic systems • wells: poorly • constructed or abandoned 

The data will be analyzed with reference to WHO and BIS standards. An effort will also be been made to explore the GIS mapping of selected sampling site, heavy metal contamination, essential metal ions, chemistry of major cations and anions, hydro-chemical facies, classification of ground water type. The rapid growth in population in India enhanced the groundwater salinity through excessive consumption of groundwater for agricultural, domestic and industrial purposes due to the lack in surface water sources and high demand of water. Moreover, high evaporation and low and erratic rainfall depleted the groundwater level and available groundwater quantity, especially in the coastal areas, and resulted in seawater intrusion. Consequently, several agriculture farms near to the coast are abandoned due to groundwater salinity. Further, many inland farms have also been abandoned and groundwater in most of the farms is even not supporting date palms though date palms are very tolerant to salinity. Hence, it is apparent that recent studies firmly argue the effect of natural and anthropogenic contamination sources on groundwater composition, especially in coastal aquifer, and also imply the necessity of groundwater contamination studies in coastal aquifer. In the present study, a detailed investigation was carried out to evaluate the geochemical processes regulating groundwater quality in coastal aquifers of Tuticorin region since the groundwater has been impaired by natural as well as anthropogenic activities. Anthropogenic activities can alter the relative contributions of the natural causes of variations and also introduce the effects of pollution (Whittemore et al. 1989). Distribution of fresh water resources is uneven throughout the world and the fresh water availability is becoming scarce day by day owing to population growth and diverse human activities. In the absence of fresh surface water resources, groundwater is exploited to meet the demand exerted by various sectors. Spatial variation in the quality of groundwater in response to local geologic set-up and anthropogenic factors warrants the evaluation of the quality of groundwater for any purposes including that for human consumption. Assessment of the water quality for drinking purpose involves the determination of the chemical composition of groundwater and the remedial measures for the restoration of the quality of water in case of its deterioration demand the identification of possible sources for the contamination of groundwater. This paper presents findings on the chemical composition of the groundwater and investigates the possible geogenic and anthropogenic sources for chemical solutes. Many researchers across the globe have carried out studies with spatial technologies and interpreted the quality of groundwater. Mapping the spatial distributions of major elements and their interpolation with the geology and land use/land cover maps in GIS environment have contributed for the better understanding of the chemical processes of water and the methods of their acquisition. The present study pertains to the evaluation of the physico-chemical characteristics of the groundwater in and around a defunct copper mine located in a semi-arid region wherein the people of the terrain are entirely dependent on the groundwater for their needs. The paper also provides an assessment on the suitability of the groundwater for drinking purposes. Urbanization is characterized by clustering of people in relatively small areas and is recognized as an inevitable historical process (UN, 2004). The urbanization leads to many changes which have adverse impacts on Environment, including ecology, especially hydrogeomorphology, water resources and vegetation. Rapid growth of urban areas has further affected the ground water quality due to over exploitation of resources and improper practices. The city is facing a rapid change in environmental quality. Rapid urbanization leads to many problems as it places huge demand on land, water, housing, transport, health, Education etc. The city has an alarming increase in population it increased from 0.497 million in 1951 to 2.267 million in 2001 and 2.714 million in 2006 to 3.306 in 2011 increased 4.56 times (456 per cent) during the last fifty years. The growth rate of population Lucknow (UA) was at 7.12% per annum (Lucknow Master Plan, 2010). This rising population density has major impact on natural resources of the area especially on water quality and quantity. Fresh water is most important natural resources for the life but overexploitation and unjustified use of water has led to deterioration of quality of water. In the last few decades, ground water has become an essential resource due to its use for drinking, industrial and irrigation purposes. Groundwater is being used for various purposes like drinking, washing, irrigating etc. Knowing the quality of groundwater is important to determine the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activity. Suitability of groundwater for domestic and irrigation purposes is determined by its geochemical constituents. Subsurface rock formations control the composition of soil and hence that of water and vegetation. Groundwater geochemistry explains links between the chemical composition of groundwater and the health of plant animals and people. Decrease in soil fertility and the groundwater contamination is due to use of waste water for agricultural purposes without treatment. Geographic Information System has been used to represent and understand the various geochemical elements. Correlation matrixes were prepared for the relationship between physical and chemical parameters of groundwater.

The Study for suitability of water for drinking purposes using the software ArcGIS and the results showed that the groundwater quality was unfit for drinking in some of the areas. Safe drinking water is one of the necessities in sustaining life and a satisfactory (adequate, safe, and accessible) supply of water must be available for all people. The advantage of groundwater is that it can be abstracted in many places, which makes pipe transportation unnecessary. Furthermore, water is hygienically reliable and generally it has a constant composition. Sometimes, it can be even distributed without any treatment although a simple and cheap treatment. Due to the rising demand for clean drinking water, management of groundwater quality, especially in developing countries, is very important. It has been reported that approximately one third of the world's population use groundwater for drinking. Thus, sophisticated monitoring of quality of such resources would play a key role in achieving globally sustainable development in near future. After assessing groundwater, it is important to simplify results of the study for policy makers and other stakeholders. So, nowadays, using other sciences such as geographical information system (GIS) has been increased. GIS is a management tool that has grown since the late 20th century. In the past 10 years, the number of GIS users has substantially increased. GIS technology has previously facilitated laborious procedures. During the past two decades, various researchers have reported its application in groundwater modeling and quality assessment. It demonstrated spatial variations in groundwater quality using GIS and groundwater quality information maps of the entire studied area in India. Accordingly, using 53 observation wells showed that mean water table declined 0.496 m/year. Also, most of the water samples which were used for quality analysis were not potable. Contamination of groundwater in an area of 180 km2 in India was studied and then, they analyzed major anions and cations and found that most of the locations were contaminated by high levels of EC, TDS, K and NO_3. Groundwater resources are highly essential to the survival of human beings, particularly in areas where other sources of potable water are lacking. However, many sources of contamination contribute to the impairment of this precious resource. The major sources of spot and dispersive contaminants arising from human activities on the ground and penetration of these contaminants into the ground tend to reduce the quality of the ground water. Groundwater, being a fragile and important source of drinking water, must therefore be carefully managed to maintain its purity within standard limits. Groundwater degradation occurs when its quality parameters are changed beyond their natural variations by the introduction or removal of certain substances. In regions of intense agricultural activities, the degradation results from the addition of salts by dissolution during the irrigation process, from salts added as fertilizers or soil amendments and from the concentration of salts by evapotranspiration. Because irrigation is the primary use of water in arid and semi-arid regions, irrigation return flow can be the major cause of groundwater pollution in such regions.

Fig 1.1 boring

Fig 1.2 Handpump

Ground water is a very valuable natural resource for the economic development and secure provision of potable water supply in both urban and rural environments. Nowadays groundwater pollution has become one of the most serious problems throughout the world. Urbanization, industrialization and agricultural activity affecting groundwater quantity and quality. Water pollution threats human health, economic development and social success. In recent years it has been recognized that the quality of groundwater is of nearly equal importance as the quantity. The present realization is clear about the limited resources and competing demands. This indeed has placed urgency on the observation and the protection of quality of groundwater using advanced techniques. Chemical characteristics of groundwater play an important role in assessing and classifying the quality of water. Groundwater quality depends on a number of factors such as geology, degree of chemical weathering of the various rock types, quality of recharge water, and water–rock interaction. Groundwater is an important water resource for drinking, agriculture and industrial uses in Ardabil, a city in northwest of Iran. In study area, agriculture is the most important economic activity affecting the changes in groundwater quality by anthropogenic activity. However, in this area, quality assessment of groundwater has received little attention and efforts to use hydro-chemical data to solve problems are less or nonexistent. Therefore, hydro-chemical analysis of the groundwater has become a high priority concern. Water quality remains the main factor influencing its use for drinking, agricultural and industrial purposes. The chemistry of groundwater can be modified by the geological nature of the reservoir rock and anthropogenic activities. Nevertheless, the dissolution of minerals from the sur-rounding rock in water is the predominant factor controlling the chemical composition. Several evaporate minerals including carbonates, sulphates and chlorides dissolve rapidly and alter considerably the water chemical composition. In contrast, other minerals such as silicates dissolve slowly and therefore have a lesser effect. waterways constantly receive urban and industrial discharges often loaded with toxic elements. The examination of water physicochemical properties allows not only judging the water safety towards the domestic and agricultural use but bringing complement information to the hydrogeological study.

Groundwater provides excellent drinking water sources. To our knowledge, no hydro-geochemistry research has been per-formed for the groundwater quality assessment. Hence, it seems necessary to study these water sources with respect to natural and anthropogenic effects. Such studies will help local authorities to define the suitable strategy for the protection and management of these resources. In this context, the objective of the present work is to evaluate the groundwater quality of the Turonian sheet of Becher region and to examine its suitability for drinking and agriculture purposes. There is an extreme disparity in the distribution of water resources spatially and temporally in these river basins due to unequal precipitation. The Indo-Gangetic plain is the largest alluvial plain of the world, which has been formed by deposition of terrigenous clastic sediments through the streams of Indus, Ganga and Brahmaputra river system. The Ganga plain makes the central part of this alluvial plain. The Yamuna river sub-basin makes the western part of the Ganga basin which forms an important groundwater province of India. However, in a groundwater system in an alluvium covered area, clues may not be simple

due to masking of chemical alteration trends by anthropogenic influences. Groundwater is the prime natural resource and precious national asset. It is major source of water for drinking, irrigation, and industrial uses in many arid and semiarid regions of the world. Groundwater quality has become an important water resource issue due to rapid increase of population, industrialization and urbanization, flow of pollution from upland to low land, and excessive use of fertilizers and pesticides in agriculture. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. Once undesirable constituents enter the ground, it is difficult to control their dissolution. The chemical characteristics of groundwater play an important role in classifying and assessing water quality. Many naturally occurring major, minor and trace elements in drinking water can have a significant effect on human health either through deficiency or excessive intake. Hence understanding of the process that control the water quality is needed towards the aim of water quality control and improvement. Adverse quality conditions increase the investment in irrigation and health, as well as decrease agricultural production. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of the rural Indian population still depend completely on untreated surface or groundwater resources. While access to drinking water in India has increased over the past decades, the tremendous adverse impact of unsafe water on health continues. It is estimated that about 21% of the communicable diseases in India are water borne.

Table 1.2: Rating of water quality

WQI Value	Rating of Water Quality	Grading
0-25	excellent water quality	A
26-50	good water quality	B
51-75	poor water quality	C
76-100	very poor water quality	D
Above 100	unsuitable for drinking purpose	E

Groundwater comes from rain, snow, sleet, and hail that soak into the ground. The water moves down into the ground because of gravity, passing between particles of soil, sand, gravel, or rock until it reaches a depth where the ground is filled, or saturated, with water. Thus, groundwater is water located beneath the earth's surface in soil pore spaces and in the recharge rate which eventually leads to lowering of groundwater table. The threat of deterioration of groundwater quality is more in shallow wells than deep wells but eventually the water in deep wells also gets contaminated by vertical flow mechanism. Major portion of Earth’s Fresh Water is found beneath the ground surface and is stored in aquifers. Groundwater is responsible for contributing almost 20% of the world’s water supply. These underground reservoirs like aquifers, aquiclude etc. proves to be valuable, as they provide water to rivers in absence of no rainfall. In the present time, groundwater is facing serious threat of contamination. Only 12% of population in India receives good drinking water. Use of groundwater quality index (GWQI) is considered as appropriate method for describing the water quality status in different classes which is simply represented by a score and this score gives the information of water quality of that particular area GWQI gives a clear understanding of various water quality issues by compiling data available in the form of physico-chemical parameters and generating a score that describes water quality. The main aim of the study is to determine the suitability of the groundwater for human consumption based on the GWQI values and compliance of physico-chemical data with the Indian standards values. In the present study, we successfully applied GWQI equation to determine the groundwater quality status in the study area of Unnao district. The most concerning issues to water authorities are to provide safe and potable drinking water to every individual for their good health. Due to deterioration of surface water quality and its shrinkage, and also due to the perception that the water below ground is pure, the population in different countries use groundwater in daily routine. Groundwater is considered as a primary water supply source in urban and rural regions of developing countries and its degradation is related to different types of health issues. Today, overexploitation of groundwater for various purposes (i.e., drinking and household, industrial and agricultural uses), as well as the seepage of sewages from diverse sources into the aquifers, has made significant variations in the groundwater quality. The groundwater geochemistry is complex due to diverse reasons. Various factors such as percolation of surface and rainwater, complex hydrogeology, human influence on flow systems and contamination sources determine the chemical content. The residence time of water and the primary mineralogy control the rate of reaction with parent rocks. Knowledge of groundwater quality is significant because it is an important aspect which determines its fitness for different purposes. The quality of water tells about environment, though the water circulated in the aquifer. We can never find water in its purest form; for the human metabolism, most of the elements are required in small amounts but if present in unwanted level, they show damaging effect and it turns into a disease inducing commodity. As a consequence of a geochemical change of rainwater recharging system, every groundwater system acquired a unique chemistry. The water quality index (WQI) is a productive tool to estimate the quality of water by integrating a composite set of data and generating a score which signify the overall water quality category. The effects of irrigation, excess use of fertilizer and domestic sewage could enhance the ionic composition such as NO3 −, Cl−, Na+ and K+ in groundwater. Once contaminants go into the ground below, it may remain hidden for years, depicting groundwater unfit for human intake and other purposes. In several parts of the world, groundwater NO^{3-} contamination is a challenging task from different reasons like septic tank systems, manure or agricultural organic by-products, landfill sites that are unlined, punctured sewerage lines, poultry waste and domestic/farm animal manure. Unwarranted NO^{3-} intake in drinking water has been linked with the risk of methemoglobinemia or ‘blue baby syndrome’ in humans, stomach cancer and nitrate poisoning in animals. The most devastating arsenic poisoning had been reported from Bangladesh and West Bengal (India) where more than 36 million peoples are suffering from Arsenic induced diseases 4 and millions are still consuming arsenic contaminated water. In India also number of underground water sources from different states are unfit for consumption due to elevated levels of Arsenic contamination such as West Bengal, Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh and even Uttar Pradesh5 .In Uttar Pradesh deadly Arsenic has crept its way in as many as forty five districts, some of the worst affected areas being Ballia, Ghazipur, Basti, Balrampur, Sant Kabir Nagar, Unnao, Bareilly and Lakhimpur Khiri. Groundwater quality issues are gaining recognition as the groundwater depletion worsens. Nowadays the level of contaminants such as fluoride, arsenic, pesticides and insecticides is at an elevated level. There is a general belief that groundwater is purer and safer than surface water due to the protective qualities of the soil cover. Groundwater quality has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization and flow of pollution from upland to lowland and too much use of fertilizers, pesticides in agriculture. Pollution of water is due to increased human population, industrialization, use of fertilizers in agriculture and manmade activity. The physico-chemical parameters of water play a significant role in classifying and assessing water quality. It is the fundamental duty of every individual in this world to conserve water resources. The ground water quality is normally characterized by different physic chemical characteristics. These parameters change widely due to the type of pollution, seasonal fluctuation, ground water extraction, etc. Monitoring of water quality levels is thus important to assess the levels of pollution and also to assess the potential risk to the environment. change in ground water levels with respect to mean sea elevation along the coast largely influences the extent of sea water intrusion in the fresh water. Its use in irrigation, industries and domestic usages continues to increase where perennial surface water source are absent. Climate change and sea level rise exacerbated salt water intrusion, thereby jeopardizing water use safety, especially during the dry season. Distribution of fresh water resources is uneven throughout the world and the fresh water availability is becoming scarce day by day owing to population growth and diverse human activities. In the absence of fresh surface water resources, groundwater is exploited to meet the demand exerted by various sectors. Spatial variation in the quality of groundwater in response to local geologic set-up and anthropogenic factors warrants the evaluation of the quality of groundwater for any purposes including that for human consumption. Assessment of the water quality for drinking purpose involves the determination of the chemical composition of groundwater and the remedial measures for the restoration of the quality of water in case of its deterioration demand the identification of possible sources for the contamination of groundwater. This paper presents findings on the chemical composition of the groundwater and investigates the possible geogenic and anthropogenic sources for chemical solutes. Many researchers across the globe. It is apparent that recent studies firmly argue the effect of natural and anthropogenic contamination sources on groundwater composition, especially in coastal aquifer, and also imply the necessity of groundwater contamination studies in coastal aquifer. In the present study, a detailed investigation was carried out to evaluate the geochemical processes regulating groundwater quality in coastal aquifers of Tuticorin region since the groundwater has been impaired by natural as well as anthropogenic activities. Anthropogenic activities can alter the relative contributions of the natural causes of variations and also introduce the effects of pollution. Groundwater is being used for various purposes like drinking, washing, irrigating etc. Knowing the quality of groundwater is important to determine the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. Suitability of groundwater for domestic and irrigation purposes is determined by its geochemical constituents. Subsurface rock formations control the composition of soil and hence that of water and vegetation. Groundwater geochemistry explains links between the chemical composition of groundwater and the health of plants, animals and people. Decrease in soil fertility and the groundwater contamination is due to use of waste water for agricultural purposes without treatment. Geographic Information System has been used to represent and understand the various geochemical elements in Panvel Basin, Maharashtra, India. Correlation matrixes were prepared for the relationship between physical and chemical parameters of groundwater. The suitability of water in pudunagaram, Palakkad district for irrigation was determined and they concluded that the water is suitable for drinking and irrigation use. The water quality of Ganga in Rishikesh and concluded that regular monitoring of the quality is essential. Safe drinking water is one of the necessities in sustaining life and a satisfactory (adequate, safe and accessible) supply of water must be available for all people. The advantage of groundwater is that it can be abstracted in many places, which makes pipe transportation unnecessary. Furthermore, water is hygienically reliable and generally it has a constant composition. Sometimes, it can be even distributed without any treatment although a simple and cheap treatment (e.g. disinfection) is often inevitable. Due to the rising demand for clean drinking water, management of groundwater quality, especially in developing countries, is very important. It has been reported that approximately one third of the world's population use groundwater for drinking. Thus, sophisticated monitoring of quality of such resources would play a key role in achieving globally sustainable development in near future. After assessing groundwater, it is important to simplify results of the study for policy makers and other stakeholders. So, nowadays, using other sciences such as geographical information system (GIS) has been increased. GIS is a management tool that has grown since the late 20th century. In the past 10 years, the number of GIS users has substantially increased. GIS technology has previously facilitated laborious procedures. During the past two decades, various researchers have reported its application in groundwater modeling and quality assessment. Balakrishnan et al. demonstrated spatial variations in groundwater quality using GIS and groundwater quality information maps of the entire studied area in India. Groundwater resources are highly essential to the survival of human beings, particularly in areas where other sources of potable water are lacking. However, many sources of contamination contribute to the impairment of this precious resource. The major sources of spot and dispersive contaminants arising from human activities on the ground and penetration of these contaminants into the ground tend to reduce the quality of the ground water. Therefore, preventing the ground water from contamination is essential to the management of ground water resources.

Groundwater, being a fragile and important source of drinking water, must therefore be carefully managed to maintain its purity within standard limits. Groundwater degradation occurs when its quality parameters are changed beyond their natural variations by the introduction or removal of certain substances. In regions of intense agricultural activities, the degradation results from the addition of salts by dissolution during the irrigation process, from salts added as fertilizers or soil amendments and from the concentration of salts by evapotranspiration. Because irrigation is the primary use of water in arid and semi-arid regions, irrigation return flow can be the major cause of groundwater pollution in such regions.

Groundwater can become contaminated naturally or because of numerous types of human activities; residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality. In India severe water scarcity is becoming common in several parts of the country, especially in arid and semi-arid regions. The overdependence on groundwater to meet ever-increasing demands of domestic, agriculture, and industry sectors has resulted in overexploitation of groundwater resources in several states such as Rajasthan, Punjab, Gujarat, Haryana, Uttar Pradesh, Tamil Nadu, among others. Groundwater can be optimally used and sustained only when the quantity and quality is properly assessed for any area, a ground water quality map is important to evaluate the water safeness for drinking and irrigation purposes and also as a precautionary indication of potential environmental health problems. Groundwater quality depends on the parameters of refreshed water, atmospheric precipitation, and land surface water on subsurface geochemical processes. Time-based fluctuations in the source and constitution of the recharged water, hydrologic and social factors may effect periodic changes in water quality parameters. The applications of naturally occurring physico-chemicals parameters such as Ph, Cl, HCO_3, TDS do not change health at certain stages but may affect the suitability of irrigation and drinking groundwater. Element reactions effect of rock miners, weathering, soil, rainfall, dissolution, precipitation, mining area and additional linked processes generally takes place below the surface. Groundwater has regarded as the largest natural resource in the form of groundwater and surface water. Groundwater makes up about 20% of the world's fresh water resource, which is about 0.61% of the whole world's water, with oceans and permanent snow. In addition, the non-potable water quality of groundwater may be filtering of nutrient and relief of metals. The groundwater quality values play significant role for best suitability of wells for drinking and irrigation purposes in the hard rock region. The immigration of chemicals contaminants and the monitoring techniques of groundwater quality parameters are effective if the natural baseline quality is strongminded with a suitable degree of assurance. Anthropogenic activities can change the relative helps of the natural causes of variations and also introduce the effects of pollution. In the present situation, in most of the cities in India, the daily water demand is met by groundwater utilization, as the surface water is either deficient or polluted. Groundwater is the main source that is commonly used for drinking and irrigation purposes in rural, urban and semi urban areas. Generally, the analyses of physiochemical and biological parameters lead to assess the quality of groundwater. Hydro chemical characteristics of groundwater can also be analyzed for the groundwater assessment. The present study was carried out in the Vellore district, located in the Northern part of Tamil Nadu, India in which the rivers Palar and Ponnaiar pass through. However, the major source of drinking water for the district is groundwater which is already contaminated due to industrial establishments. Vellore district receives less rainfall and the availability of ground water is major source for irrigation and drinking purposes. Hence, this study aims to assess the quality of groundwater in Gudiyattam and Vaniyambadi blocks of Vellore district. The datasets for the groundwater were compared with Bureau of Indian Standards (BIS) and World Health Organization (WHO) standards to ensure the quality of the water. In addition, the datasets were statistically analyzed with tools such as correlation matrix, box plots and multivariate analysis to reduce uncertainties associated with the parameters. The quality of groundwater depends on the composition of recharge water, the interaction between the water and the soil, the rock with which it comes in contact in the unsaturated zone, and the residence time and reactions that occur within the aquifer. Quality is also affected by various anthropogenic activities. Quality has become an important concern particularly in rural areas where the population is widely dependent on groundwater for drinking purposes. Undesirable groundwater quality reduces the economy and restrains the improvement in living conditions of rural people. Therefore, it has become necessary for systematic assessment and monitoring of groundwater quality to examine its suitability for drinking and to adopt appropriate measures for protection. The area under investigation is a rural where residents depend on groundwater for drinking and domestic purposes. The objective of this paper is to discuss the suitability of groundwater for human consumption based on compliance of physicochemical data with reference to drinking water standards and computed WQI values. These studies are the first attempts with respect to quality management of groundwater in the Bardhaman district of West Bengal

1.2. GIS based modelling for water quality

GIS is called as geographic information system (GIS) which is mainly used to capture, store, manipulate, analyze, manage, and present spatial or geographic data. For the modelling of water quality parameters, GIS will be used as a powerful tool. Various sources of information include satellite images, aerial photographs, Soil Conservation Service (SCS) and Natural Resource Conservation Service (NRCS) soil maps, United States Geological Survey (USGS) topographic maps, and survey maps can be prepared with the use of GIS. This technique will be used for estimating the output grid value at specific sampling point on different location of Lucknow (urban and rural areas). Other studies have used GIS as a database system to prepare maps of water quality according to concentration values of different chemical constituents

1.3 OBJECTIVE

The goal of this study is to establish a methodology for generating maps of groundwater contamination with field water quality data at Lucknow area. The study employs a Geographic Information System (GIS) and methods of multivariate statistics to analyze data Collected.

- Collection of Ground water samples from rural and urban areas of Lucknow.
- Analysis of collected samples for various physiochemical water quality parameters.
- Examine for major ion chemistry to understand the operating mechanism of geochemical processes for ground water quality.
- Suitability of groundwater quality for drinking and agricultural purposes.
- Studies of SAR, %Na, RSC, PI, KI, and Chloro-alkaline indices for irrigation purpose.
- GIS mapping for water quality at different sampling locations.

CHAPTER 2
LITERATURE REVIEW

2.1 OVERVIEW ON PREVIOUS GROUNDWATER STUDIES

Verma et al., evaluated the ground water quality of Lucknow by using remote sensing and geographic information systems. He reported that in the residential areas, the drinking water is highly polluted with high population density as compared to sub urban areas which are having less population density and comparatively better quality of water. The level of nitrate and nitrite pollution in the ground water of rural areas of Lucknow was studied by Verma et al., in 2014.

Rai and Singh in the year of 2014 testified the Fluoride concentration in the drinking water of Lucknow. Most of the researcher have also reported the simple physicochemical water quality parameters of Gomti river of Lucknow. The quality and quantity of water supply is of vital significance. Fresh water which is a precious and limited vital resource needs to be protected, conserved and used wisely by man. But unfortunately, such has not been the case, as the polluted lakes, rivers and streams 7 throughout the world testify. According to the scientists of National Environmental Engineering Research Institute, Nagpur, India, about 70 % of the available water in India is polluted. Happily, there has been acute realization of the need for pollution control among the public, the government and industries. Most countries have come to a stage of recognizing water pollution as a problem and laws to prevent it have been passed. In India the water (Prevention and control of pollution) act was first enacted in 1974 and has been amended from time to time to make it more and more stringent.

Singh et al., reported the water quality of Lucknow river and their impacts on human health. Singh et al., reported the hydrochemistry of wet atmospheric precipitation over an urban area in northern Indo-Gangetic plains.

Umamaheswari et al studied that Less in fixation of sulfates gave less probability of sullying through farming practices. Measurable examination in the investigation exhibits the need and its use of vast complex datasets to acquire better data on the groundwater water quality. The estimations of relationship coefficients uncovered that SO_4^{2-} , HCO_3^- , Ca^{2+} and Mg^{2+} were discovered critical dependent on the groundwater ionic creation, dominatingly Ca^{2+}, Mg^{2+} and Cl^- were high connected ($r^2>0.9$). Moreover, the multivariate examination viz., PCA and group investigation likewise had same pattern with higher commitment of anions and cations (Ca^{2+}, Mg^{2+}, Cl^- and HCO_3^-) to the groundwater.

Vignesh et al studied that the outcomes exhibit the water quality acquired from the inspected regions is defiled and destinations groundwater is Unfit for drinking. Depending on the common filtration attributes of the nearby soil, to channel the water as it permeates through the encompassing ground, is plainly lacking to give safe consumable water to the greater part of tested zones. In this way the utilization of hand siphon and bore water is disheartened. Individuals rely upon this water are frequently inclined to wellbeing perils because of dirtied water. are frequently inclined to wellbeing perils because of dirtied water. There is an earnest need to build up some type of nearby treatment to clean ground waters for individuals in the district.

Mason 2002; Raju et al. 2009; Stadler et al. 2012 stated that Unwarranted NO^{3-}intake in drinking water has been linked with the risk of methemoglobinemia or ‘blue baby syndrome’ in humans, stomach cancer and nitrate poisoning in animals.

Raju NJ 2012 In this study the effects of irrigation, excess use of fertilizer and domestic sewage could enhance the ionic composition such as NO_3^-, Cl^-, Na^+ and K^+ in groundwater. Once contaminants go into the ground below, it may remain hidden for years, depicting groundwater unfit for human intake and other purposes.

Neeraj Agnihotri 2014 aim to study to understand the hydrochemistry of underground water of Kanpur district U.P. with special reference to fluoride contamination. The presence of fluoride in ground water cannot be predicted due to its sporadic occurrence which is also observed in present study. Presence of fluoride in ground water is often recognized only when people exhibit symptoms of fluorosis. There is an intense need of developing measures to prevent and cure ground water quality through water quality analysis and study of spatial distribution to identify sources, causes, type and level of fluoride contamination.

Divya Dudeja 2011 In this study they discuss ion sources and assesses the chemical quality of groundwater of Doon Valley in Outer Himalayan region for drinking and irrigational purposes. Valley is almost filled with Doon gravels that are main aquifers supplying water to its habitants. Recharged only by meteoric water, groundwater quality in these aquifers is controlled essentially by chemical processes occurring between water and lithology and locally altered by human activities. The hydrogeochemical analysis of groundwater of Doon Valley suggests that calcium and magnesium are the most dominant cations while bicarbonate is the most dominant anion. The pH of samples is showing mildly acidic to mildly alkaline nature in both seasons with western part of valley more acidic in nature compared to that of central and eastern part.

S. Selvam 2013 In the present study has been carried out to evaluate hydro-chemical characteristics of groundwaters of the coastal aquifers in Tuticorin, Tamilnadu. GIS has been applied to visualize the spatial distribution of groundwater quality in the study area. A total of 36 groundwater samples were collected and analyzed for various physicochemical parameters. Very wide ranges and high standard deviations of hydro-chemical parameters such as TDS, EC, Cl-, K, SO4, Mg suggest the groundwater in the coastal aquifers shows seawater mixing and anthropogenic contamination. Most of the water sample exceeds the maximum permissible limit of WHO standards.

K. Balathandayutham 2015 Water is an indispensable natural resource on earth. Groundwater is the major source of drinking water in both urban and rural areas. Increasing population and its necessities have led to the deterioration of surface and subsurface water. Groundwater quality depends on the quality of recharged water, atmospheric precipitation and inland surface water. The groundwater quality is equally important as that of quantity. Assessing and monitoring the quality of groundwater is therefore, important to ensure sustainable safe use of these resources for the various purposes. This study demonstrates that the use of GIS could pro-vide useful information for groundwater quality assessment. The results obtained gave the necessity of making the public, local administrator and the government to be aware on the crisis of poor groundwater quality prevailing in the area. The study helps us to understand the quality of the water as well as to develop suitable management practices to protect the groundwater resources.

Mohammad Mosaferi in this study aimed to examine quality of drinking groundwater of rural communities. The results represented whether the water was suitable or unsuitable for drinking purposes in this area. It was also observed that villages like Iskandar and Olakandi had low quality drinking water. It is suggested to take some necessary measures for supplying desirable water to the people living in these villages. The dominant cations were in the order of $Ca_2^+ > Na^+ > Mg^{2+} > K^+$ and dominant anions are in the order of $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^{2-}$. So, hydro-chemical faces of water were dominated by $CaHCO_3$. Different multivariate statistical techniques were used to evaluate variations in groundwater quality. Cluster analysis grouped sampling sites to four clusters of similar water quality characteristics. Based on the obtained data, a future, optimal sampling strategy can be designed which could reduce the number of sampling sites and associated costs. Principle component analysis helped in identifying the factors or sources responsible for variations in water quality. The results showed arsenic contamination in most of groundwater resources in the western areas. Universally, there are two sources for arsenic contamination in groundwater, which include geogenic source that is sometimes called background or natural and anthropogenic sources. The above-mentioned information can be useful for practical management of arsenic contamination problem and can provide an appropriate perspective for decision making and treatment strategies, especially for point of entry (POE) methods. Undoubtedly, application of different treatment methods that have been well discussed in the literature should be considered an approach after pilot studies using real water samples for arsenic removal.

Arina Khan 2017 In this assessment of actual groundwater quality using the GQI maps is an interesting exercise at regional scales to provide overall contamination scenario. The study outlines a unique approach to assign water quality status to each land-use class by extracting the mean GQI value for each land-use class. This helps to link land-use, which is a spatially varying parameter, and groundwater quality, which is observed at specific points. The comparison of water quality (in the form of GQI map) and the land use was done using GIS tools, and links between the observed land-use and the underlying water quality were highlighted, on a regional scale. Groundwater quality index for both the seasons suggests good groundwater quality. The GQI values in pre-monsoon season range from 86.66 to 93.69. The pre-monsoon 2012 GQI map shows low values in the north and north-eastern part corresponding to poor groundwater quality.

This study demonstrates the use of spatial interpolation and statistical methods in mapping of groundwater quality parameters in basaltic hard rock in the Akola and Buldhana districts of Maharashtra, India. Groundwater quality exceeded limits for drinking use for most ions at certain locations. Groundwater quality of different water samples in Basaltic hard rock has been analyzed and evaluated. Therefore, the groundwater samples were collected from wells located in basin area. The groundwater quality parameters were studied to investigate the water quality for drinking and irrigation. Arc GIS software has been used for groundwater quality parameters analysis and spatial mapping of big storage of data and result making so that groundwater quality constructed studies have done successfully. The study of hydrochemistry parameters was dominated by alkali and strong acids. As per comparison with WHO and ISI standard, 80% of groundwater has potable for domestic and drinking purpose with few irregularities. The spatial difference maps in the groundwater quality parameters were observed different values in the basaltic hard rock area. The present study of groundwater quality maps can be used for irrigation and drinking purpose in the saline area. Higher TDS and EC values were observed in western-central and eastern-western part of the study area dominated by agricultural practices and industrial dominance. Higher concentration was noted in 2013 post-monsoon season following summer.

The present result presented appropriateness of groundwater for drinking and irrigation purposes. The study benefits us to understand the quality of the groundwater resources to improve proper management in area. In this area, Deccan rock weathering, geochemical weathering process and evaporation procedures are the main role in hydro-geochemical analysis impact for the concentration of main ions in groundwater quality.

J. Umamaheswari In this study, a detailed analysis of various physicochemical parameters of samples collected from 28 bore wells revealed the presence of more chlorides, electrical conductivity, TDS, TH, Ca^{2+}, Mg^{2+} and also slightly alkaline especially in Vaniyambadi (VB) study location. Less in concentration of sulphates provided less possibility of contamination through agricultural practices. Statistical analysis in the study presents the need and its application of large complex datasets to obtain better information on the groundwater water quality. The values of correlation coefficients revealed that SO_4^{2-}, HCO^{3-}, Ca^{2+} and Mg^{2+} were found significant based on the groundwater ionic composition, predominantly Ca^{2+}, Mg^{2+} and Cl^- were high correlated (r^2>0.9). Furthermore, the multivariate analysis viz., PCA and cluster analysis also possessed same trend with higher contribution of anions and cations (Ca^{2+}, Mg^{2+}, Cl^- and HCO^{3-}) to the groundwater.

Ground water contamination by the heavy metals has become a striking problem for last two decades as results of discharge of industrial effluent, untreated domestic waste and increasing the use of Agrochemicals, i.e. fertilizers and pesticides in our farming. Today, heavy metals are frequently present in our water, soil and air due to extensive use of their compounds Groundwater occurs at shallow aquifers under unconfined conditions within a depth of 37 m from the surface. Groundwater primarily flows south, southwest, and southeast directions during post-monsoon period and southeast, south-west, and south during pre-monsoon period. In this study, the computed values of WQI vary from 15.3 to 475.9 for pre-monsoon and 18.2 to 584.3 for post-monsoon season. According to the WQI values, groundwater at only three locations in pre- and post-monsoon periods were found unsuitable for drinking Asit Kumar Batabyal et al 2015.

CHAPTER 3

METHODOLOGY

3.1 Hydrogeology of The Study Area

Lucknow is the capital of Uttar Pradesh, and it is the central region of Uttar Pradesh and the capital of the biggest populated states of India. It historically known as the Awadh region and it always been a multicultural place. Lucknow city is divided in eight blocks. It is located between 26` 30` and 27` 10` in the north latitude and 80` 30` and 81` 31` east longitude. It is situated on the bank of river Gomati and it divides the city into two parts. As reported by the Census of India, the total population of Lucknow city till 2017 was about 3.382 million. Lucknow city is spread among more than 2528 square km on both side of the Gomti river with the population of 28,15,601 and recognized as metro city. Nearly 56% of total area is under active cultivation whereas 5.19% covers forest area and 2,54% occupies agricultural area. The cultivated area of Rabi crop is 102318 hectares. Kharif 76278 hectares and of Zaid is 37049 hectares. Surface water and Ground water are the main source of irrigation in the district. Length of canal in the district is 962 kms. Gross irrigated area is 126607 hectares out of which 28149 hectares (22.23%) is irrigated through ground water (77.77%) by means of Deep tube wells, shallow tube wells, private tube wells borings etc. About 90% of the net cultivated area in the district has assured irrigation facilities while the irrigation intensity is 144.25%. The urbanization leads to many changes which have adverse impacts 6 on Environment, including ecology, especially hydro-geomorphology, water resources and vegetation. Rapid growth of urban areas has further affected the ground water quality due to over exploitation of resources and improper practices. The city is facing a rapid change in environmental quality. Rapid urbanization leads to many problems as it places huge demand on land, water, housing, health, transport, education etc. Fresh water is most important natural resources for the life, but overexploitation and unjustified use of water has led to deterioration of quality of water. In the last few decades, ground water has become an essential resource due to its use for drinking, industrial and irrigation purpose. At present the water demand in the Lucknow city is 1250 MLD and it supplies only 750 MLD out of which rest is goes out due to leakage. 80% percent of shortage can be handled if these leakages are plugged.

3.2. Selection of sampling points

For groundwater analysis and assessment regarding the suitability of water for human consumption and other domestic purposes, specialized sampling and sample handling procedures are required. The site of sampling is selected randomly by considering the population, location and source in areas of Lucknow.

Plastic bottles of 1-liter capacity with stopper were used for collecting samples. Each bottle was washed with distilled water thrice. The bottles were then preserved in a clean place. All the collected samples were stored at 4℃ until analyzed. Analyses were done within 48 hrs of collection.

3.3. Water quality parameter for drinking purpose

In general, the standard methods recommended by APHA were adopted for the determination of various physico-chemical parameters of the collected groundwater samples. Temperature, pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Hardness, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Electrical Conductivity (EC), Chloride, Nitrate, Sulphate, Total Alkalinity, Calcium, Magnesium, Nickel, Copper, Cadmium, Lead, Chromium, Zinc were monitored. A brief description is given below.

3.3.1. Hydrogen ion concentration

The hydrogen ion activity (pH) was measured electrometrically with the help of calibrated portable pH meter on the spot. At some instance pH was recorded in the laboratory by using systronic pH meter model 20D, reproducible to 0.1 pH unit with a range of 0 to 14 and equipped with a temperature compensation adjustment. The instrument was calibrated with the standard buffer solution prior to analysis.

3.3.2. Electrical Conductivity (EC)

Electrical conductivity of water is dependent on the presence of ions in the salts such as NaCl, KCl, $CaCl_2$, $MgCl_2$, $CaCO_3$, $CaSO_4$, $MgSO_4$, their total concentrations, mobility, valence and relative concentration. It is a measurement of ability to carry an electric current or conductance and is reported in µmhos/cm or µS/cm. For the measurement of conductivity of water samples at 25 0C the standardization of conductivity meter was done using 0.1N solution of KCl. 745.6 mg of KCl was dissolved in conductivity water and diluted to 1000ml at 25 0C. It is the standard reference solution at 25℃ , which has conductivity of 1413 µmhos/cm.

3.3.3. Total Dissolved Solids (TDS)

Total dissolved solid is the portion of solids that passes through a filter of 2µm (or smaller) under specific conditions. This was determined by evaporation of 100 ml of well mixed sample in a weighed beaker and was dried to constant weight at 180 ±2 0C after filteration through a standard glass fiber filter (Whatman filter paper no.42). Increase in weight of beaker represents the total dissolved solids and it was calculated by using the formula:

$$\textbf{TDS (mg/l)} = \frac{[(\boldsymbol{A}-\boldsymbol{B})\times \mathbf{1000}]}{\boldsymbol{V}}$$

A= weight of dried beaker + Residue in mg

B= weight of beaker in mg

V= Volume of sample in mg

3.3.4. Total Hardness

It is the sum of concentration of all metallic cations other than cations of alkali metals, expressed as CaCO3 concentration. It is measured by complexometric (EDTA) method. The EDTA and its sodium salt form a chelate soluble complex when added to solutions of certain metal cations. If a small amount of dye such as Eriochrome Black-T is added to an aqueous solution containing Ca^{2+} or Mg^{2+} ions at pH 0f 10±.1 the solution become wine red because of metal ions-EBT complex. If

EDTA is added as an titrant, the Ca and Mg are complexed. The solution turns from wine red to blue at the end.

$$\textbf{Total hardness} = (\mathbf{A} \times \mathbf{M} \times \mathbf{100} \times \mathbf{1000}) \div \textbf{volume of sample}$$

A = Volume of EDTA consumed (ml).

M = Molarity of EDTA solution.

3.3.5. Ca- Hardness

When EDTA or its salts added to water containing both Ca and Mg, it combines first with the Ca. calcium can be determined directly with EDTA when an indicator viz. murexide is used that combines with ca only. A required amount of NaOH is also added to maintain pH. The color at the end point changes from red to violet. Ca hardness calculated by the following formula:

$$\textbf{Total hardness} = (\mathbf{A} \times \mathbf{M} \times \mathbf{100} \times \mathbf{1000}) \div \textbf{volume of sample}$$

A = Volume of EDTA consumed (ml).

M = Molarity of EDTA solution.

3.3.6. Mg-Hardness

The preferred method for determination of Mg hardness is to compute it from the results of separate determination of total and calcium hardness.

Mg-Hardness = Total Hardness – Ca Hardness

3.3.7. Alkalinity

It was determined titrimetrically with standard sulphuric acid or hydrochloric acid using phenolphthalein and methyl orange indicator and was reported in terms of equivalent $CaCO_3$. For sample having pH is more than 8.3, the titration is performed in two steps. In the first step the titration is conducted until the pH is lowered to 8.3, the point at which phenolphthalein indicator turns from pink to colorless (Phenolphthalein alkalinity). The second phase of titration is conducted until the pH is lowered to about 4.5 from 8.3 corresponding to methyl orange end point

(Methyl orange alkalinity). The sum of both phenolphthalein and methyl orange alkalinity is called total alkalinity. When the pH of a sample is less than 8.3 a simple titration is made to pH of 4.5. The choice of pH 8.3 as the end point for first step is taken because this value corresponds to the equivalence point for the conversion of carbonate ions to bicarbonate ions.

$$\textbf{phenolpthalein alkalinity} = (\mathbf{V} \times \textbf{ conc. of acid} \times \textbf{Eq. Wt. of CaCO3} \times \mathbf{1000}) \div \textbf{volume of sample}$$

$$\textbf{Methyl orange alkalinity} = (\mathbf{V} \times \textbf{Conc. of acid} \times \textbf{Eq. Wt. of CaCO3} \times \mathbf{1000}) \div \textbf{volume of sample}$$

Where,

V= Volume of the titrant

3.3.8. Sodium

Sodium is one of the most abundant elements. Their salts are highly water soluble and as such they found to be present in most natural waters. The ratio of sodium to total cations is important in irrigation water quality as well as human pathology. Sodium was measured by flame photometric method using flame photometer model FPM-125 of systronic make.

3.3.9. Potassium

Potassium is an important element present in aquatic system and play a vital role in the metabolism of fresh water environment. It also acts as an enzyme activator. It was measured using flame photometric technique.

3.3.10. Chloride

Chloride occurs in all the natural water in widely varying concentrations. The chloride concentration normally increases as the mineral content increases. Chloride was determined using Argentometric titration method or Mohr's method. In a neutral or slightly alkaline solution potassium chromate indicates the end point and used as indicator. When all chloride ions are bonded with Ag as AgCl, silver ions added in excess after the end point combine with the chromate ions to form reddish brown silver chromate. Red color formed because of the formation of silver chromate disappears slowly as the solution contains high concentration of chlorides. The chloride ions were then determined using the following formula:

$$\mathbf{chloride(ppm)} = [(\mathbf{A} - \mathbf{B}) \times \mathbf{N} \times \mathbf{35.5} \times \mathbf{1000}] \div \mathbf{volume\ of\ sample\ (ml)}$$

Where,

A = ml of titrant with sample

B = ml of titrant with blank

N = Normality of AgNO3 solution

3.3.11. Sulphate

The sulphate ions are one of the major anions found in the natural water. It is of importance in public water supply because of its laxative effect on human beings. Sulphate ions react with barium chloride solution to form insoluble barium sulphate which is kept in suspension by the conditioning reagent solution added. The absorbance of developed turbidity was measured by nephelometer at 420 nm after 15 min of adding barium chloride solution. The concentration of sulphate was calculated by standard curve.

3.3.12. Nitrate

Nitrate was measured with the help of visible spectrophotometer at 410 nm. The water sample was filtered to remove possible interference from suspended particles. One drop of sulphite urea reagent was added to 2 ml of sample. The flask of the sample was placed in a tray of cold water (10-20 0C) and then 2 ml of antimony reagent was added. After about 4 min, 1 ml chromotropic acid reagent was added in the sample and this solution was swirled. After wards it was left in cooling bath for 3 min and further concentrated sulphuric acid was added to bring the volume near the 10 ml mark. At last it was left at the room temperature for 45 mins. The amount of nitrate ions were then measured as per the following formula.

3.3.13. Dissolved Oxygen

Iodometric or Winkler's method was used for the determination of dissolved oxygen. The principle involved in the determination of D.O. is to bring about the oxidation of potassium iodide to iodine with the dissolved oxygen present in the water sample after adding MnSO4, KOH and KI. The basic manganic oxide formed acts as an oxygen carrier to enable the dissolved oxygen in the molecular form to take part in the reaction. The liberated iodine is titrated against standard sodium thiosulphate (hypo) solution using starch as indicator. In the modified Winkler's method, the interference due to certain oxidizing agents such as nitrite or reducing agents such as ferrous ions are removed by treating the sample with an excess of KMnO4 in acid medium. The dissolved oxygen contents in the sample were calculated by the following formula.

$$\textbf{dissolved oxygen} = (\mathbf{V} \times \mathbf{N} \times \mathbf{Eq.\,Wt.\,of\,O2} \times \mathbf{1000}) \div \textbf{volume of sample(ml)}$$

V = Volume of the sodium thiosulphate solution used

N = Normality of sodium thiosulphate

3.3.14. Biological Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen required for the biological oxidation of the organic matter under aerobic conditions at 20 0C and for a period of 5 days. It is directly related to the extent of pollution caused by waste water, sewage and industrial effluents. More the BOD of a sample more will be the pollution caused by it. The BOD test is based upon determination of dissolved oxygen prior to and following 5 days period at 20 0C. A known volume of sample of sewage is diluted with a known volume of dilution water (water containing nutrients for a bacterial growth).

3.4. Groundwater quality for irrigation purpose

The suitability of water for irrigation depends upon TDS (salinity) and the sodium content in relation to the amounts of calcium and magnesium or SAR. The suitability of groundwater for irrigation use was evaluated by calculating Salinity, SAR, Percent sodium, Kelly's Index (KI), Residual sodium carbonate (RSC), Chloro alkaline indices and Permeability Index (PI).

3.4.1. Salinity of irrigation water

Water salinity may result from the application of saline irrigation water, insufficient rainfall and irrigation to leach excess salts, poor drainage, upward movement of leached salt from perched water tables and/or salt water intrusion. Turf continually irrigated with high salinity water often becomes weak, eventually declining to a point of no longer being acceptable. Salts reduce turf grass health mostly by an osmotic effect on the turf grass plant. The more the salt in the root zone, the harder the plant works to take-up the water. Turf grass species have varying levels of salt tolerance. Only a few species grow well under saline conditions. Salinity also slows seed germination. High salinity makes it more difficult for the seed to imbibe water and the germination rate is reduced. Unfortunately, this problem is accentuated with light frequent irrigations that are typically utilized during turf grass establishment. Each light irrigation deposits salt in the seedbed and salinity can accumulate rapidly to levels that prohibit seed germination.

3.4.2. Measuring and classifying irrigation salinity

Salinity is determined by measuring the ability of water to conduct an electrical current. Salinity is expressed in two different ways, one as Electrical Conductivity (EC) and seems as Total Dissolved Salts (TDS). In this study most of water salinity class is medium. It is according of US Salinity Laboratory's classification of saline irrigation.

3.4.3. Percent sodium

Soils containing a large proportion of sodium with carbonate as the predominant anion are termed alkali soils; those with chloride or sulfate as the predominant anion are saline soils. The role of sodium in the classification of river water after irrigation was emphasized because of the fact that sodium reacts with soil and as a result clogging of particles takes place, thereby reducing the permeability. Percent sodium in water is a parameter computed to evaluate the suitability for irrigation. Na% can be calculated by the following equation;

$$\mathbf{Na\% = [(Na + K) \,/\, Ca + Mg + Na + K\ \ ] \times 100}$$

Where: Na, K, Ca and Mg are in meq/l.

3.4.4. Sodium Adsorption Ratio (SAR)

Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability, High Sodium concentration leads to the development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). SAR is a calculated value and an indicator of sodium hazard of water. Sodium adsorption ratio (SAR) has been calculated as follows:

$$\mathbf{SAR\ = Na\ \div \left[\frac{\sqrt{Ca} + \sqrt{Mg}}{2}\right]}$$

Where: Na, Ca and Mg are in meq/l. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. High concentrations of sodium in soils affect its physical condition and soil structure resulting in formation of crusts, water-logging, reduced soil aeration, reduced infiltration rate and reduced soil permeability; excessive concentrations of sodium in soils may also be toxic to certain types of crops. SAR gives a very reliable assessment of water quality of irrigation waters with respect to sodium hazard, since it is more closely related to exchangeable sodium percentages in the soil than the simpler sodium percentage. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is an important parameter for the determination of the suitability after irrigation water because it is responsible for the sodium hazard.

3.4.5. Permeability Index (PI)

The soil permeability is affected by long-term use of irrigation water. Sodium, calcium, magnesium and bicarbonate contents of the soil influence it. Doneen evolved a criterion for assessing the suitability of water for irrigation based on a permeability index (P.I.)

$$\mathbf{PI} = [(\mathbf{Na} + \sqrt{\mathbf{HCO3}} -) / \ \mathbf{Ca} + \mathbf{Mg} + \mathbf{Na}\ ] \times \mathbf{100}$$

where Accordingly, waters can be classified as Class I, Class II and Class III. Class I and Class II waters are categorized as good for irrigation with 50-75% or more of maximum permeability. Class III waters are unsuitable with 25% of maximum permeability.

3.4.6. Kelly's Index (KI)

Kelly's index was calculated by using the following expression

$$\mathbf{KI} \ = \mathbf{Na} \ \div (\mathbf{Ca} + \mathbf{Mg})$$

Where, concentrations are expressed in meq/l. The Kelly's ratio of unity or less than one is indicative of good quality of water for irrigation whereas above one is suggestive of unsuitability for agricultural purpose due to alkali hazards.

3.4.7. Residual Sodium Carbonate (RSC)

When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be diminished. When the excess carbonate (residual) concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material (scale) which settles out of the water. The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. This excess is denoted by 'residual sodium carbonate' (RSC) and is determined as suggested by Richards. The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black color of the soil. Further, continued usage of high residual sodium carbonate waters affects crop yields. RSC is given by the relation:

$$\mathbf{RSC = (HCO3 + CO3) - (Ca + Mg)}$$

Where, the concentrations of ions are expressed in meq/l. If RSC exceeds 2.5 meq/l, the water is generally unsuitable for irrigation. If the value of RSC is between 1.25 and 2.5 meq/l, the water is marginally suitable, while a value less than 1.25 meq/l indicates safe water quality.

3.5. Removal of Heavy metals

Atomic absorption spectrophotometer was used for determining the amounts of heavy metals in the water samples. Atomic absorption spectroscopy is one of the most widely used methods in analytical chemistry. This phenomenon can be divided into two major processes

(i) The production of free atoms from the sample

(ii) The absorption of radiation from an external source by these atoms.

The conversion of analytes in solution to free atoms in the flame is done by the flame atomizer. Here the metallic elements from its dissolved salts in the sample solution are converted into free atoms of the element, by converting the sample solution into its aerosol. This aerosol when enters the flame, solvent is evaporated leaving small particles of the dry solid which is then converted into its vapour. Finally, this dissociates to give neutral free atoms. Some of these atoms are thermally excited by the flame but most remain in the ground state. These ground state atoms can absorb radiation of a particular wavelength that is produced by a special source made from that element. The wavelength of radiation given off by the source is the same as those absorbed by the atoms in the flame. The absorption follows Beer's law i.e. the absorbance is directly proportional to the length of the light path and to the concentration of absorbing species. However, the path length may be held constant and the concentration of the analyte in the solution, which is displayed on electric read out. In the analysis a suitable and recommended matrix modifier such as magnesium nitrate, palladium nitrate, and ammonium phosphate were used. Standard conditions were applied and Flame atomic absorption spectrometer, PerkinElmer Analyst 3100 was used for the determination of heavy metals.

CHAPTER 4

RESULT AND DISCUSSION

Understanding the ground water quality is important as it is the major factor determining its suitability for drinking, domestic, agricultural and industrial purposes. The data revealed that there were considerable variations in the examined sample from different sources with respect to their chemical characteristics. Physical and chemical parameters including statistical measures such as minimum, maximum concentration are summarized in Table 4.2.

pH is the term used universally to express the intensity of the acid or alkaline condition of a solution. The pH values of ground water samples of the study area were varying from 6.5 to 8.45 with an average value of 7.7. The pH values for samples are well within the limits prescribed by WHO and BIS.

The measurement of EC is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and other mineral contamination. EC of the groundwater is varying from 332 to 1286 $\mu s/cm$. The classification of ground water on the basis of EC is given in Table 4.1. It is found that 100% of the samples are within the permissible limit, none of the samples fall in the not permissible limit and none of the sample locations can be classified as hazardous according to the WHO standard.

In natural waters, dissolved solids consist mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. To ascertain the suitability of ground water of any purposes, it is essential to classify the ground water depending upon their hydro-chemical properties based on their TDS values.

The TDS of the water samples ranges from 149 to 2,305 mg/l. According to the WHO and BIS specification, TDS up to 500 mg/l is desirable for drinking water. The study shows that only 90% of the sample is below desirable limit of TDS which can be used for drinking without any risk, 10% of the sample exceed the desirable limit of the TDS. The ground water of the study area is fresh water for 90% of the sample locations and rest of the sample represents brackish water.The classification of groundwater table 3 based on TH shows that almost all the groundwater samples fall in the very hard water category. Ground water exceeding the limit of 300 mg/l is considered to be very hard. The desirable limit of TH for drinking purpose is 600 mg/l as per BIS standard. The TH varies from 120 to 1,240 mg/l with an average value of 717.56 mg/l. About 56% groundwater samples exceed the acceptable limit of 600 mg/l. The chloride concentration varies between 30 and 1,250 mg/l with an average value of 301.86 mg/l. The chloride ion concentration in ground water of the study area exceeds the desirable limit of 250 mg/l in 24 sample locations. The limits of chloride ion have been laid down primarily from taste consideration. A limit of 250 mg/l chloride has been recommended as desirable limit for drinking water supplies. However, no adverse health effects on human have been reported from intake of water containing an even higher content of chloride.

Nitrate contamination in groundwater is one of the major issues in water quality studies. The occurrence of high levels of nitrate in ground water is a prominent problem in many parts of the country. The concentration of nitrogen in groundwater is derived from the biosphere. Nitrogen is originally fixed from the atmosphere and mineralized by soil bacteria into ammonium. The concentration of nitrate in the study area varies from 3 to 124 mg/l with an average value of 29.3 mg/l. It is found that only 12 groundwater samples exceed the desirable limit of 45 mg/l as per WHO (1993) and BIS (1991) standard. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methemoglobinaemia in children and gastric carcinomas. Nitrate produces no color or odor in water and can cause cancer in humans when consumed over a long period of time. The high concentration of nitrate is due to the intensive urbanization and industrialization.

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. The sulphate content changes significantly with time during infiltration of rainfall and ground water. The concentration of sulphate is likely to react with human organs if the value exceeds the maximum allowable limit of 400 mg/l and cause a laxative effect on human system with the excess magnesium in groundwater. However, the sulphate concentration varied between 15 and 251 mg/l with an average value of 83 mg/l and found within the maximum allowable limit in all sample locations as per WHO and BIS specification. all sample locations as per WHO and BIS specification. Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate and hydroxide compound of calcium sodium and potassium. BIS has recommended 300 mg/l as the desirable limits and 600 mg/l as the maximum permissible limit for drinking water. permissible limit. Dissolved oxygen is required to convert biodegradable organic matter from one form to another by living organisms mainly bacteria to maintain the metabolic process and produce energy for their growth and reproduction. It was found that the DO value of the groundwater samples varied from 2.7 to 9.7 mg/l. Sodium is the most abundant alkali metal. The concentration of sodium varies from 21 to 1,420 mg/l with an average value of 88.7 mg/l in this study. However, the concentration of sodium in almost all the samples was found well within the permissible limit of 200 mg/l. Such water should be treated before being used for domestic applications. Higher concentration of Na^+ may pose risk to persons suffering from cardiac, renal and circulatory diseases. The concentration of potassium varies from 1.2 to 156 mg/l with significant fluctuation. K? is an essential nutrient but if ingested in excess may behave as a laxative.

Table 4.1 Ground water classification based on electrical conductivity

Electrical Conductivity ($\mu s/\ cm$)	classification	Sample	No. of sample	Percentage of sample
<1,500	Permissible	All the sample below 1500	26	100
1,500-3,000	Not permissible	Nil	Nil	0
>3,000	Hazardous	Nil	Nil	0

Table 4.2: Summary statistics for concentrations of chemical parameters in groundwater

Parameters (units)	Maximum concentration	Minimum concentration
EC ($\mu s/\ cm$)	502	4,670
pH (mg/l)	6.5	8.5
TDS (mg/l)	149	2,305
Ca^{2+} (mg/l)	45	413
Mg^{2+} (mg/l)	14	197
TH (mg/l)	228	1,673
Na^{+} (mg/l)	19	1,420
K^{+} (mg/l)	1	156
Cl^{-} (mg/l)	30	1,250
NO_3^{-} (mg/l)	3	124
SO_4^{2-} (mg/l)	15	319
DO (mg/l)	2.7	9.7
% Na (meq/l)	4.931	81.77
SAR (meq/l)	0.3264	22.81
RSC (meq/l)	-28.598	0.8055
PI (meq/l)	10.265	85
KI (meq/l)	0.0452	4.2153
CAI-1 (meq/l)	-2.351	33.393
CAI-2 (meq/l)	-1.8711	3.0637

Table 4.3: Ground water classification based on total hardness (Sawyer and McCartly 1967)

Total Hardness as $CaCO_3$ (mg/l)	Classification	Samples name	Number 0f sample
<75	Soft	Nil	0
75–150	Moderately high	Khargapur	1
150–300	Hard	Nandpur, Khurdahi	2
>300	Very hard	Sample 1-2, sample 4-8, sample 10-19, sample 21-26	23

Table 4.4: Physico-chemical characteristics of the groundwater of the Lucknow region

Sample Name	PH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	F	SO_4^{-}
Chaupala, mal	7.9	551	551	215	36.9	28.2	28	5.13	1.15	0.1	0.66	5.87
Saraisheikh chinhat	7.7	598	598	254	73.6	18.4	16.4	4.19	33.3	0.1	0.32	2.43
Nandpur chinhat	7.8	413	413	180	31.7	24.5	12.3	5.19	3.4	0.4	0.32	5.96
Madhavkhera, Mohanlal Ganj	7.7	580	580	205	30.1	30.7	37.7	4.94	2.4	0.0	0.85	7.44
Sarojninagar	7.6	426	426	211	36.1	30	5.9	3.11	6.6	NA	0.48	2.34
Khadra, BKT	7.7	1184	1184	405	50.7	75.7	80.2	8.1	60.9	95.4	0.16	9.92
Mohanlal Ganj	7.7	559	559	209	36.2	31.8	23.2	4.33	27.4	0.1	0.72	3.79
Kanchanpur Chinhat	7.8	487	487	207	31.7	32.6	12.2	4.76	3.4	NA	0.49	4.12
Khargapur Chinhat	7.4	332	332	139	31.4	15.3	3.87	3.34	6.5	31.1	0.38	0.008
Banthra Sarojninagar	7.7	726	726	266	39.3	45.5	34.2	5.12	37.3	7.1	0.55	0.16
Kusal khera Mal	8	541	541	249	37.3	42.5	9.75	5.76	2.1	6.02	0.38	7.70
Amethi Gosainganj	7.9	538	538	257	49.5	37.5	6.62	4.82	1.8	3.9	1.04	0.75
Durgaganj Kakori	7.7	466	466	212	33.7	33.7	9.41	3.15	1.5	0.5	0.34	0.70

Tiwariganj Chinhat	7.5	1003	1003	378	88	49.2	25.2	4.44	18.4	78.1	0.10	5.47
Juggaur Chinhat	7.8	420	420	187	38.2	24.3	7,32	2.71	1.9	25.1	0.60	0.01
Gulzar colony Chinhat	7.7	665	665	263	49.4	41.9	13.1	5.31	72.3	2.9	0.27	0.32
Behata BKT	7.8	433	433	203	35,6	31.5	4.29	3.64	1.7	0.01	0.86	0.22
Madhar Mau Gosainganj	7.8	533	533	217	33.7	34.7	18.8	5.54	4.9	0.8	0.73	0.75
Gauri Sarojninagar	7.9	645	645	256	47.2	37.4	22	5.03	34.6	6.4	0.50	0.03
Khurdahi Gosainganj	7.9	366	366	178	41.6	20.2	2.67	2.09	0.86	0.2	0.28	0.52
Faizullahganj BKT	7.7	563	563	209	34.7	31	26.9	5.08	4.8	0.17	0.33	0.18
Gudamba BKT	7.9	523	523	237	51.1	31	9.69	4.59	4.6	0.01	0.47	NA
Aishbagh	8	1286	1286	532	90.1	74.7	63.7	6.5	93.8	12.4	0.38	0.67
Paikramau BKT	7.9	455	455	199	34.2	30.8	7.37	4.15	4.8	9.5	0.50	NA
Gosava Malihabad	8	484	484	222	39.6	34.5	9.2	4.92	2.09	6.8	0.89	7.71
Naibastidhanewa Malihabad	8.1	588	588	256	55.7	33.6	18	4.5	4.06	0.2	0.66	9.66

Irrigation water quality

The concentration and composition of dissolved constituents in water determine its quality for irrigation use. Several chemical constituents affect water suitability for irrigation from which the total concentration of the soluble salts and the relative proportion of sodium to calcium and magnesium. The suitability of ground water for agricultural purposes depends on the effect of mineral constituent of water on both plants and soil. Effects of salts on soil causing changes in soil structure, permeability and aeration in directly affect plant growth.

Percent sodium (%Na)

Irrigation water containing large amounts of sodium is of special concern due to sodium’s effects on soil and poses a sodium hazard. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability. Hence, the assessment of sodium percentage is necessary while considering the suitability for irrigation.

$$\mathbf{Na\ \%} = \frac{\mathbf{Na + K}}{\mathbf{(Ca + Mg + Na + K)}} \times \mathbf{100}$$

where all the ion concentrations are expressed in meq/l. The classification of ground water based on percentage sodium and found most of the samples are excellent for irrigation.

Sodium adsorption ratio

Sodium hazard is also expressed in terms of the sodium adsorption ratio (SAR). SAR is calculated from the ratio of sodium to calcium and magnesium. The latter two ions are important since they are tending to counter the effect of sodium. Continued use of water having a high SAR leads to breakdown in the physical structure of the soil. Sodium is adsorbed and becomes attached to soil particles. The soil then becomes hard and compact when dry and impervious to water penetration. The degree to which irrigation water tends to enter into cation exchange reactions in soil can be indicated by the sodium adsorption ratio. Sodium replacing adsorb calcium and magnesium is a hazard as it causes damage to the soil structure. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium Hazards. SAR has become calculated as follows:

$$\mathbf{SAR} = \frac{\mathbf{Na}}{\sqrt{\mathbf{(Ca + Mg)}}/\mathbf{2}}$$

where all the concentrations are expressed in meq/l. This water will be suitable for plants having good salts tolerance and it restricts suitability for irrigation, especially in soils with restricted drainage. This water will be suitable for all plants but natural drainage should be good.

Residual sodium carbonate

When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be diminished. When the excess carbonate (residual) concentration becomes too high, the carbonate combines with calcium and magnesium to form a solid material (scale) which settles out of the water. The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonates and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. RSC is given by the relation:

$$\mathbf{RSC = (CO_3^{2-} + HCO_3^{-}) + (Ca^{+} + Mg^{2+})}$$

where all the concentrations are expressed in meq/l. An RSC value less than (1.25 meq/l) is safe for irrigation, a value between 1.25 and 25 meq/l is of marginal quality and a value more than (25 meq/l) is unsuitable for irrigation. All the samples have RSC values much less than 1.25 meq/l which indicate that all samples are of safe quality categories for irrigation. Further the value of RSC is negative at all sampling sites, indicating that there is no complete precipitation of calcium and magnesium.

Permeability index

The soil permeability is affected by long term use of irrigation water. Sodium, calcium, magnesium and bicarbonate content of the soil influence it. Permeability index is defined by the following equation.

$$\mathbf{PI} = \frac{\mathbf{Na} + \sqrt{\mathbf{HCO}}}{(\mathbf{Ca} + \mathbf{Mg} + \mathbf{Na})} \times \mathbf{100}$$

where all the ions are expressed in meq/l. The PI values indicate excellent quality of water for irrigation. If the PI values are between 25% and 75%, they indicate good quality of water for irrigation. However; if the PI values are less than 25%, they reflect unsuitable nature of water for irrigation. According to PI values, ground water in the study area can be designated that shows majority of the ground water in the study area is good for irrigation purposes.

Kelly’s index

Based on Kelly’s index (KI) waters are classified for irrigation. Sodium measured against calcium and magnesium to calculate this parameter. A Kelly’s index of more than one indicates an excess level of sodium in waters. Therefore, water with a Kelly’s index less than one are suitable for irrigation, while those with a ratio more than one are unsuitable. Kelly’s index was calculated by using the following expression:

$$\mathbf{KI} = \frac{\mathbf{Na}}{(\mathbf{Ca} + \mathbf{Mg})}$$

where all the concentrations are expressed in meq/l. It is observed from the samples from the study area are good for irrigation regarding alkali hazards.

Table 4.1: Water Parameter Indices

Sample Name	pH	EC	SAR
Chaupala, Mal	7.9	551	11.8
Sarai sheikh, chinhat	7.7	598	5.5
Nandpur chinhat	7.8	413	6.2
Madhavkhera, Mohanlal Ganj	7.7	580	15.5
Sarojninagar	7.6	426	3.1
Khadra, BKT	7.7	1184	18.9
Mohanlal Ganj	7.7	559	9.7
Kanchanpur Chinhat	7.8	487	6.0
Khargapur Chinhat	7.4	332	3.1
Banthra Sarojninagar	7.7	726	12.8
Kusal khera, Mal	8	541	4.5
Amethi, Gosainganj	7.9	538	3.2
Durgaganj Kakori	7.7	466	4.9
Tiwari Ganj Chinhat	7.5	1003	7.4
Juggaur Chinhat	7.8	420	4.2
Gulzar colony Chinhat	7.7	665	5.6
Behata BKT	7.8	433	3.2
Madhar Mau Gosainganj	7.8	533	8.6
Gauri Sarojninagar	7.9	645	8.6
Khurdahi Gosainganj	7.9	366	2.4
Faizullahganj BKT	7.7	563	11.8
Gudamba BKT	7.9	523	4.7
Aishbagh	8	1286	12.6
Paikramau BKT	7.9	455	4.7
Gosava Malihabad	8	484	4.8
Naibasti dhanewa Malihabad	8.1	588	7.1

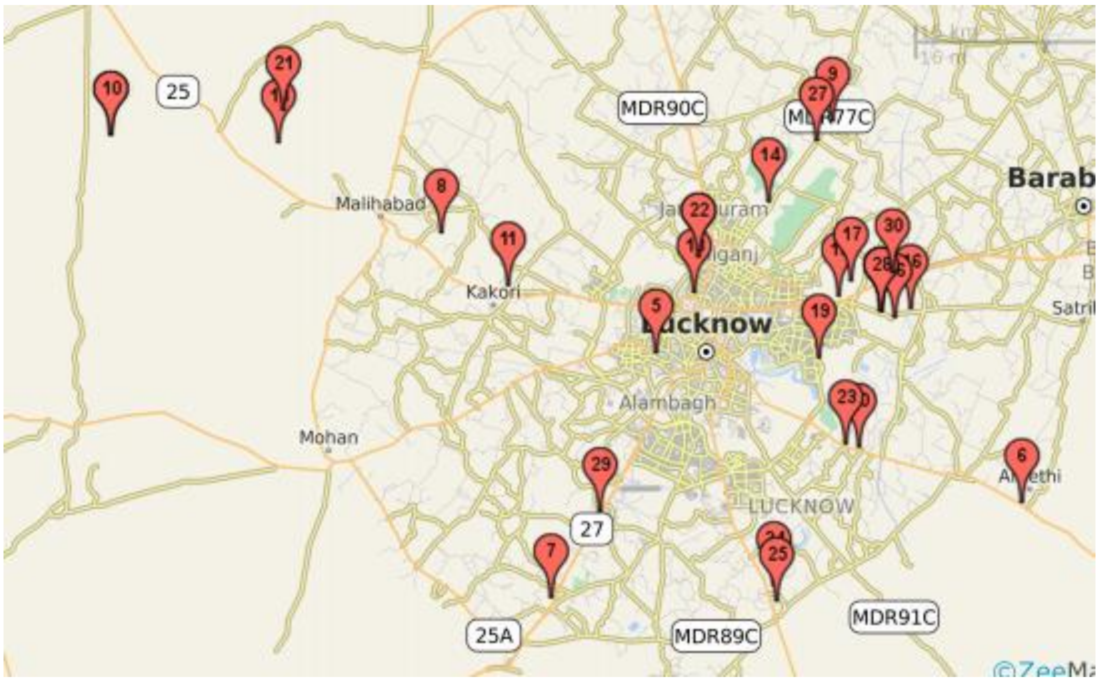
Table 4.5: limits of some parameter indices for rating irrigation water quality (After Eaton, 1950)

Category	EC ($\mu s/\ cm$)	SAR
Excellent	<250	<10
Good	250-750	10-18
Doubtful	750-2250	18-26
Poor	>2250	>26

Table 4.6: Quality of Irrigation Water in Relation to EC (After Richards, 1954)

S/N	EC ($\mu s/\ cm$)	Water Type	Suitability for Irrigation
1	<250	Low saline water	Entirely safe
2	250-750	Moderately saline	Safe under practically all conditions
3	750-2250	Medium to high salinity	Safe with only permeable soil and moderate leaching
4	2250-4000	High salinity	Unfair for irrigation
5	4000-6000	Very high salinity	Unfair for irrigation
6	>6000	Excessive salinity	Unfair for irrigation

In the below all the location of the study area is plotted in this map and chemical analysis report of groundwater is also attached with it. That show all the groundwater quality of sample area from where sample were collected.



5. AISHBAGH

PH: 8

EC: 1286

TDS: 1286

DO: 8.15

F: 0.3821

Cl: 93.8119

NO2: 0.5637

Br: 0.0954

NO3: 112.4322

PO4: 9.5708

SO4: 0.6795

Li: 0.0218

Na: 142.6085

NH4: N.A

K: 11.2198

Mg: N.A

6. AMETHI,GOSAINGANJ

PH: 7.9

EC: 538

TDS: 538

DO: 8.22

F: 1.0448

Cl: 1.883

NO2: 0.042

Br: 0.0119

NO3: 3.9989

PO4: 0.0247

SO4: 0.7525

Li: 0.0105

Na: 26.2975

NH4: N.A

K: 8.6115

Mg: 32.8415

7. BANTHRA

PH: 7.7

EC: 726

TDS: 726

DO: 8.3

F: 0.556

Cl: 37.3921

NO2: 0.3697

Br: 0.2492

NO3: 7.1483

PO4: 3.3092

SO4: 0.1604

Li: 0.026

Na: 99.8545

NH4: N.A

K: 9.1076

Mg: 40.3642

Ca: 40.34

8. BANTHRA, SAROJNINAGAR

PH: 8.1

EC: 588

TDS: 588

DO: 8.14

F: 0.6643

Cl: 4.0684

NO2: 0.0725

Br: N.A

NO3: 0.275

PO4: 13.1715

SO4: 9.6643

Li: 0.0163

Na: 58.984

NH4: N.A

K: 8.0112

Mg: 29.5082

Ca: 54.0371

9. BEHTA, BKT

PH: 7.8

EC: 433

TDS: 433

DO: 8.19

F: 0.865

Cl: 1.7796

NO2: 0.0711

Br: 0.0468

NO3: 0.0187

PO4: 0.7422

SO4: 0.2226

Li: 0.0149

Na: 23.0246

NH4: N.A

K: 6.4176

Mg: 28.1562

Ca: 35.2055

10. CHAUPALA, MAL`

PH: 7.9

EC: 551

TDS: 551

DO: 8.25

F: 0.6618

Cl: 1.1577

NO2: N.A

Br: 0.0302

NO3: 0.1074

PO4: 34.0394

SO4: 5.8703

Li: 0.0088

Na: 82.2822

NH4: N.A

K: 9.749

Mg: 29.5058

Ca: 37.7522

11. DURGAGANJ,KAKORI

PH: 7.7

EC: 466

TDS: 466

DO: 8.2

F: 0.3464

Cl: 1.5444

NO2: 0.0508

Br: 0.0302

NO3: 0.5772

PO4: 3.6984

SO4: 0.7026

Li: 0.0153

Na: 35.2882

NH4: N.A

K: 5.9875

Mg: 30.1739

Ca: 35.5461

12. FAIZULLAHGANJ,BKT

PH: 7.7

EC: 563

TDS: 563

DO: 8.12

F: 0.3301

Cl: 4.8044

NO2: 0.0935

Br: 0.0645

NO3: 0.1744

PO4: 1.9142

SO4: 0.1889

Li: 0.0147

Na: 84.5925

NH4: N.A

K: 9.477

Mg: 28.7998

Ca: 36.7126

13. GOSWA GAON,MALIHABAD

PH: 8

EC: 484

TDS: 484

DO: 8.13

F: 0.8987

Cl: 2.0992

NO2: 0.136

Br: 0.0536

NO3: 6.8439

PO4: 1.5087

SO4: 7.714

Li: 0.0127

Na: 36.0219

NH4: N.A

K: 8.5245

Mg: 29.6103

Ca: 40.155

14. GUDAMBA,BKT

PH: 7.9

EC: 523

TDS: 523

DO: 8.14

F: 0.4723

Cl: 4.6535

NO2: 0.0737

Br: N.A

NO3: 0.0179

PO4: 1.0974

SO4: N.A

Li: 0.0191

Na: 37.7116

NH4: N.A

K: 8.0728

Mg: 28.122

Ca: 48.6673

15. GULZAR COLONY,CHINHAT

PH: 7.7

EC: 665

TDS: 665

DO: 8.19

F: 0.2754

Cl: 72.3537

NO2: 0.4058

Br: 0.0922

NO3: 2.9056

PO4: 4.4519

SO4: 0.3226

Li: 0.018

Na: 45.4088

NH4: N.A

K: 9.2075

Mg: 36.3477

Ca: 45.8169

16. JUGGAUR

PH: 7.8

EC: 420

TDS: 420

DO: 8.17

F: 0.6038

Cl: 1.9204

NO2: N.A

Br: N.A

NO3: 25.1694

PO4: 3.6425

SO4: 0.0177

Li: 0.0155

Na: 29.715

NH4: N.A

K: 5.1749

Mg: 22.2968

Ca: 38.3899

17. KANCHANPUR,CHINHAT

PH: 7.8

EC: 487

TDS: 487

DO: 8.3

F: 0.4961

Cl: 3.4342

NO2: 0.1112

Br: 0.0374

NO3: N.A

PO4: 0.0005

SO4: 4.1224

Li: 0.0158

Na: 42.668

NH4: N.A

K: 8.5782

Mg: 29.9401

Ca: 33.9197

18. KHADRA, BKT

PH: 7.7

EC: 1184

TDS: 1184

DO: 8.31

F: 0.1634

Cl: 60.9483

NO2: N.A

Br: 0.1612

NO3: 95.4695

PO4: 14.8202

SO4: 9.9275

Li: 0.0189

Na: 176.8863

NH4: N.A

K: 14.0057

Mg: 66.5291

Ca: 53.7053

19. KHARGAPUR,CHINHAT

PH: 7.4

EC: 332

TDS: 332

DO: 8.29

F: 0.3838

Cl: 6.5087

NO2: 0.1123

Br: 0.0136

NO3: 31.1396

PO4: 1.9427

SO4: 0.0086

Li: 0.0094

Na: 20.0357

NH4: N.A

K: 6.3655

Mg: 14.4355

Ca: 31.9739

20. KHURDAHI,GOSAINGANJ

PH: 7.9

EC: 366

TDS: 366

DO: 8.14

F: 0.2835

Cl: 0.8632

NO2: 0.0176

Br: N.A

NO3: 0.2612

PO4: 1.7127

SO4: 0.5236

Li: 0.0067

Na: 17.5328

NH4: N.A

K: 3.8671

Mg: 18.5773

Ca: 40.8006

21. KUSAL KHERA,MAL

PH: 8

EC: 541

TDS: 541

DO: 8.24

F: 0.3852

Cl: 2.1991

NO2: 0.0417

Br: N.A

NO3: 6.0218

PO4: 0.0278

SO4: 7.7056

Li: 0.0139

Na: 34.8977

NH4: N.A

K: 10.2771

Mg: 36.952

Ca: 39.0752

23. MADHAR MAU

PH: 7.8

EC: 533

TDS: 533

DO: 8.18

F: 0.7312

Cl: 4.9437

NO2: 0.0877

Br: 0.0572

NO3: 0.8001

PO4: 1.5305

SO4: 0.7585

Li: 0.034

Na: 61.6186

NH4: N.A

K: 10.1459

Mg: 31.3126

Ca: 35.5466

24. MADHAV KHERA,MOHANLALGANJ

PH: 7.7

EC: 580

TDS: 580

DO: 8.22

F: 0.8583

Cl: 2.4123

NO2: 0.0486

Br: N.A

NO3: 0.014

PO4: 5.3072

SO4: 7.4466

Li: 0.0312

Na: 106.0893

NH4: N.A

K: 8.9248

Mg: 31.078

Ca: 31.233

25. MOHANLALGANJ

PH: 7.7

EC: 559

TDS: 559

DO: 8.32

F: 0.7286

Cl: 27.413

NO2: 0.2126

Br: 0.1693

NO3: 0.1081

PO4: 0.0042

SO4: 3.7963

Li: 0.0239

Na: 69.6456

NH4: N.A

K: 7.957

Mg: 28.3342

Ca: 37.2667

26. NANDPUR, CHINHAT

PH: 7.8

EC: 413

TDS: 413

DO: 8.26

F: 0.3198

Cl: 3.4987

NO2: 0.0972

Br: 0.0619

NO3: 0.4483

PO4: 11.2975

SO4: 5.9627

Li: 0.0125

Na: 41.2895

NH4: N.A

K: 9.1182

Mg: 24.2289

Ca: 32.2367

27. PAIKRAMAU,BKT

PH: 7.9

EC: 455

TDS: 455

DO: 8.14

F: 0.5034

Cl: 4.844

NO2: N.A

Br: N.A

NO3: 9.5205

PO4: 1.1917

SO4: N.A

Li: 0.0324

Na: 33.0971

NH4: N.A

K: 7.3827

Mg: 26.8628

Ca: 35.6571

28. SARAISHEIKH,CHINHAT

PH: 7.7

EC: 598

TDS: 598

DO: 8.19

F: 0.3229

Cl: 33.3957

NO2: 0.2899

Br: 0.5239

NO3: 0.1183

PO4: 0.025

SO4: 2.4306

Li: 0.0141

Na: 49.7681

NH4: N.A

K: 7.9522

Mg: 19.0238

Ca: 70.6614

29. SAROJNINAGAR

PH: 7.6

EC: 426

TDS: 426

DO: 8.3

F: 0.4881

Cl: 6.6875

NO2: N.A

Br: 0.0195

NO3: N.A

PO4: 0.7522

SO4: 2.341

Li: 0.0121

Na: 22.8907

NH4: N.A

K: 5.6058

Mg: 29.1441

Ca: 36.8007

ZeeMaps

30. TIWARIGANJ,CHINHAT

PH: 7.5

EC: 1003

TDS: 1003

DO: 8.18

F: 0.1015

Cl: 118.4064

NO2: 1.0612

Br: 16.4309

NO3: 78.1357

PO4: 8.2491

SO4: 5.4757

Li: 0.0433

Na: 75.271

NH4: N.A

K: 7.9229

Mg: 42.1701

Ca: 82.0143

CHAPTER 5
CONCLUSION

The rural– urban movement of population in the Lucknow City increments urban extension that has prompted natural water quality issues. The groundwaters in the examination region are marginally basic in nature. All in all, the quality evaluation of groundwater demonstrates that water is appropriate for residential use with couple of special cases that needs therapeutic measures. The investigation gives noteworthy data on the advancement of ground water quality in Lucknow. GIS has been applied to visualize the spatial distribution of groundwater quality in the study area. In many locations source of groundwater is so far from each other, like in Mohanlal Ganj, gosainganj mal area handpumps are found far from sample locations. These area need more groundwater sources for drinking and irrigation purpose The real particle science information uncovered that the ground water in the examination region is hard in nature and the physico-chemical investigations and the determination of water quality lists of groundwater from handpumps, tube wells, exhausting demonstrate that the groundwater is for the most part reasonable for domestic and irrigation purposes. The chemical data indicate that most of the groundwater samples have total hardness beyond the safe limits. The groundwater usage for domestic purposes has been limited due to the excessive desirable limit of TDS, NO_3^-, Cl^-, Fe, and TH in the study area. Richards' classification based on EC reveals that all the samples are of good to medium salinity hazard, and their SAR values indicate that all the waters are good and excellent.

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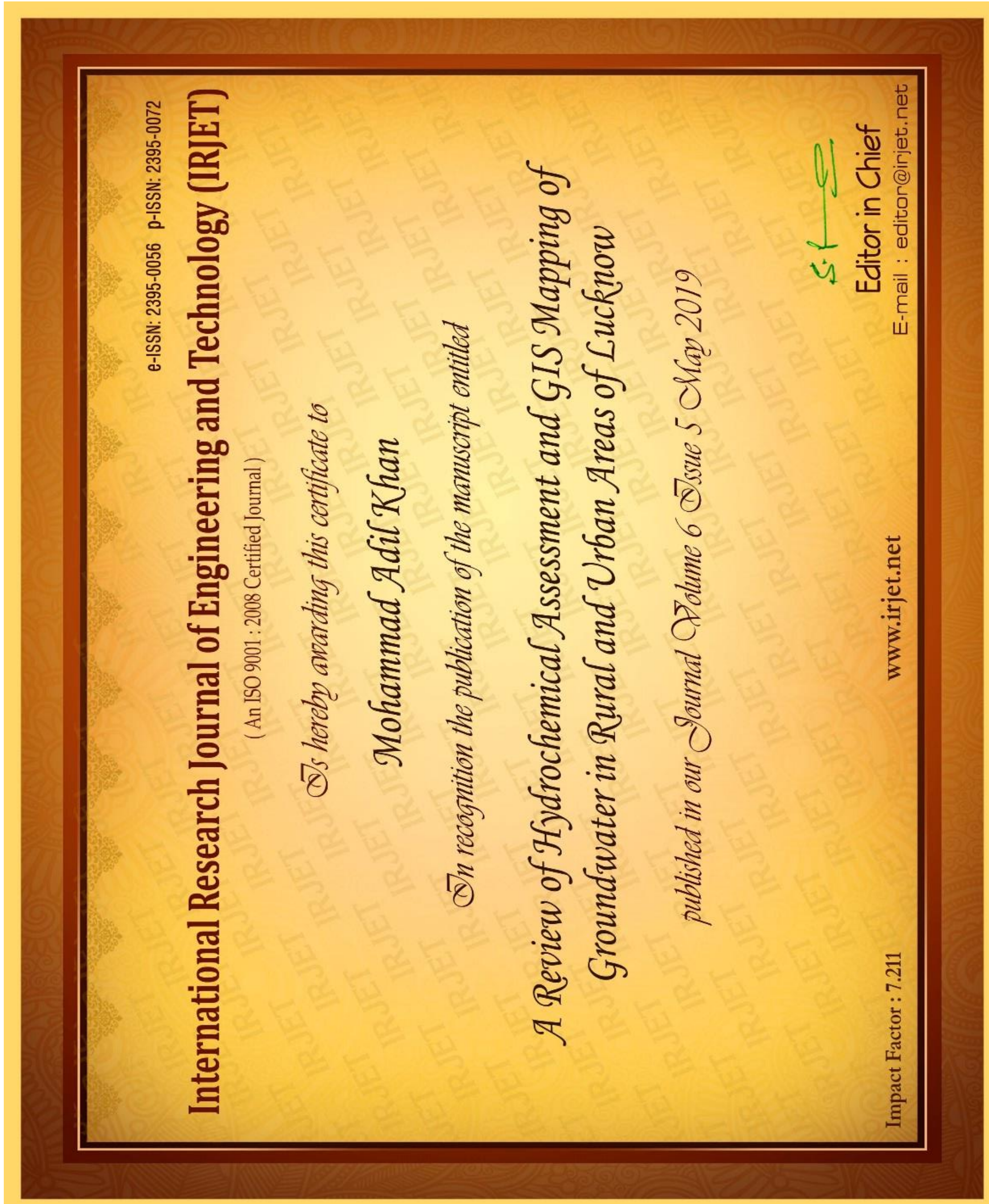
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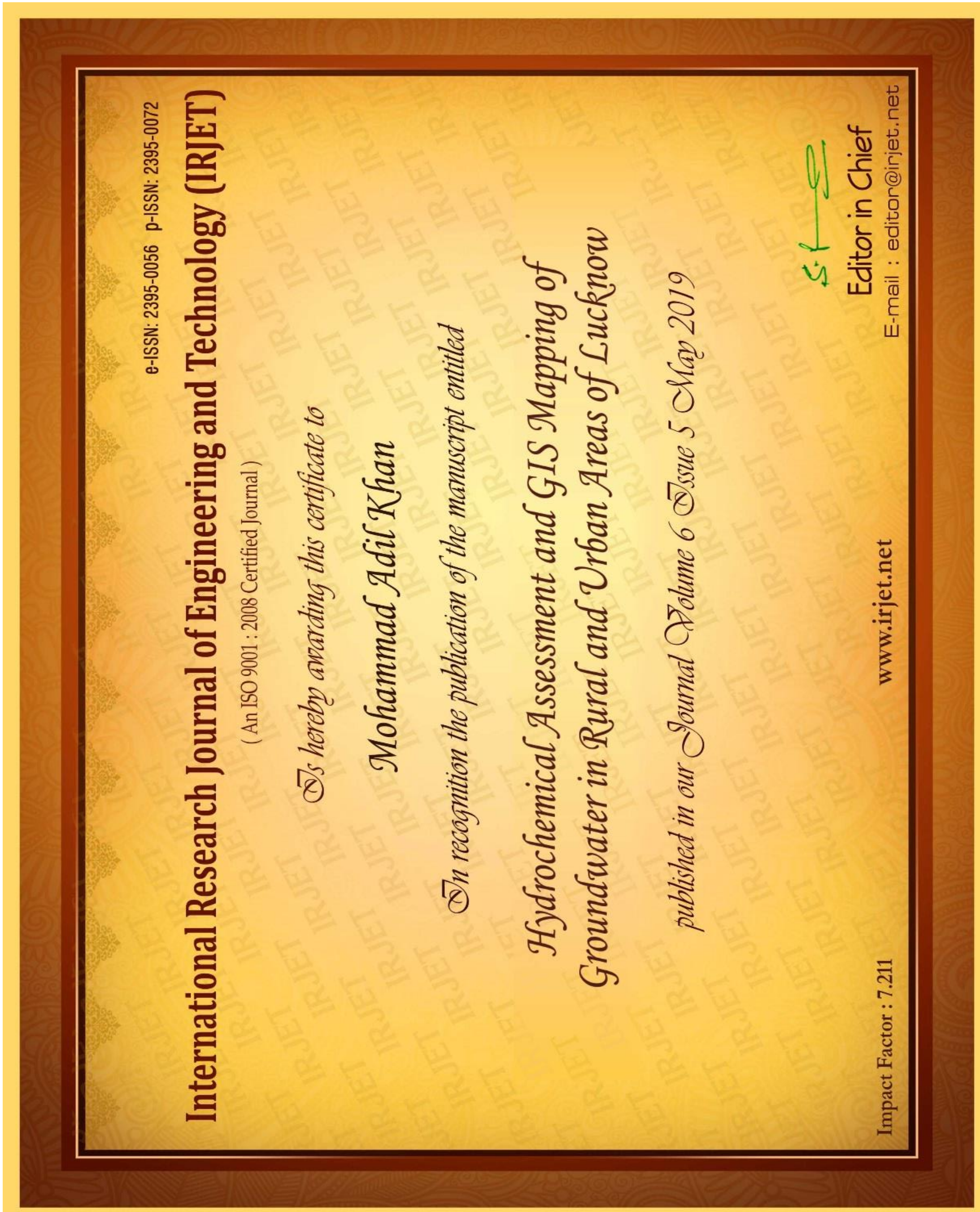
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