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QUANTITATIVE ASSESSMENT OF GROUNDWATER QUALITY FOR IRRIGATION USE: A CASE STUDY OF HARYANA, INDIA

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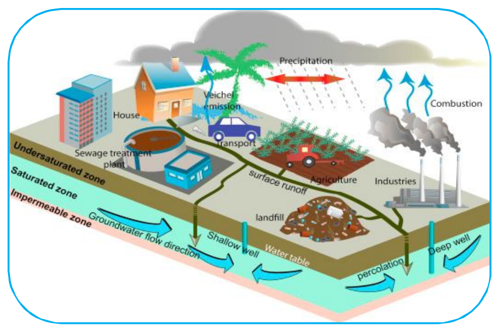
ABSTRACT :

Water quality indices serve as a valuable and comprehensible tool for managers involved in assessing the quality and potential applications of irrigation water. However, relying solely on individual quality factors to evaluate irrigation water quality can be limiting and may lead to unfavorable assessments. It is crucial to consider multiple factors in order to obtain a more comprehensive understanding of water quality. By analyzing various physio-chemical parameters such as pH, Electrical Conductivity (EC), Potassium (K), Calcium (Ca), Chloride (Cl-), Sodium (Na+), Potassium (K+), and Magnesium (Mg2+), a more accurate evaluation of water quality can be achieved. The use of specific indices such as Hydrogen Ion Activity (pH), Salinity Hazard, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Percentage Sodium, Magnesium Hazard (MH), and Kelly's Index (KI) further aids in determining the suitability of ground water for irrigation purposes. By considering these multiple factors and indices, water quality managers can make decisions and recommendations regarding irrigation practices, ensuring the optimal use of water resources while minimizing potential risks and negative impacts.



KEYWORDS *: Water Quality, Irrigation, Physio-chemical parameters, Salinity Hazard and pH.*

INTRODUCTION:

Water's importance as a vital input for agricultural development has increased with the rise of technology-intensive agriculture and the green revolution. This has led to a greater reliance on water-intensive crops and the expansion of irrigation facilities. However, the qualitative aspects of water used for irrigation are often overlooked. Understanding the chemical properties and geochemical characteristics of water is crucial for assessing its suitability for irrigation. In arid and semi-arid regions, where assured irrigation is essential for sustainability, evaluating water quality for irrigation purposes becomes even more critical. Poor water quality can have detrimental effects on crop yield, particularly for salt-sensitive crops. Agriculture plays a vital role in society, and governments prioritize the welfare of farmers. However, the path to agricultural prosperity has been challenging, with dependence on natural forces like rainfall leading to variable yields and famines.

The introduction of package technology, including high-yielding seeds and assured irrigation, revolutionized Indian agriculture during the green revolution. Assured irrigation brought qualitative and quantitative changes, boosting agricultural production and yield. Despite the importance of water quality, studies often focus solely on the expansion of irrigation without considering its impact on water quality. Water resources face increasing pressure due to growing demands for higher quality water, driven by social, political, and environmental factors. Population growth, urbanization, and changes in land use patterns contribute to the rising demand for water in agriculture, domestic use, and industries. Water pollution poses threats to human health, irrigation, and natural ecosystems, while factors like drought, salinity, and waste disposal affect surface water quality.

The availability and quality of groundwater have a significant impact on the well-being of the world's population. Groundwater supports about two-thirds of the global population, as indicated by Adimalla et al. (2018). In densely populated countries like India, approximately one billion people rely solely on groundwater for their daily needs, including fresh drinking water, household activities, and agricultural purposes, as highlighted by Kadam et al. (2019). However, India faces challenges due to the increasing reliance on groundwater resulting from the deterioration of surface water quality and inadequate availability of surface water resources, as noted by Wagh et al. (2019).

The assessment of surface water quality is of utmost importance in determining its suitability for irrigation and understanding its implications on soil characteristics, particularly in arid and semi-arid regions. The quality and quantity of irrigation water have a substantial impact on the sustainable management of soil resources and agricultural productivity. Therefore, it is crucial to prioritize the control and maintenance of water quality. Recognizing the significance of water quality and its influence on irrigation is fundamental for fostering sustainable agricultural development and promoting the well-being of farming communities. Groundwater, being a crucial resource, plays a pivotal role in supporting a substantial portion of the global population, with countries like India heavily relying on it. The escalating demands for improved water quality, driven by various factors, further emphasize the need to evaluate the suitability of surface water for irrigation and carefully consider the quality and quantity of irrigation water.

STUDY AREA:

Haryana, located in northwestern India, is the study area for this research. It spans an area of 44,212 square kilometers, accounting for 1.44 percent of the country's total geographical area. Bounded by Himachal Pradesh, Uttar Pradesh, Delhi, Punjab, Chandigarh, and Rajasthan, Haryana is characterized by its position in the Indo-Genetic plain. The state is divided into twenty-two districts and six divisions, including Gurgoan, Ambala, Rohtak, Karnal, Faridabad, and Hisar. The topography of Haryana features the Siwalik range in the north, sloping towards the south and southwest, while the Aravalli range in the south and southeast creates a slope towards the north. With an arid and semi-arid climate, Haryana experiences a scarcity of rainfall across most of its regions. Situated between the Thar Desert of Rajasthan and the moderately humid upper Ganga plain, Haryana has a population of around 25 million people, with an average density of 573 persons per square kilometer based on the 2011 census.

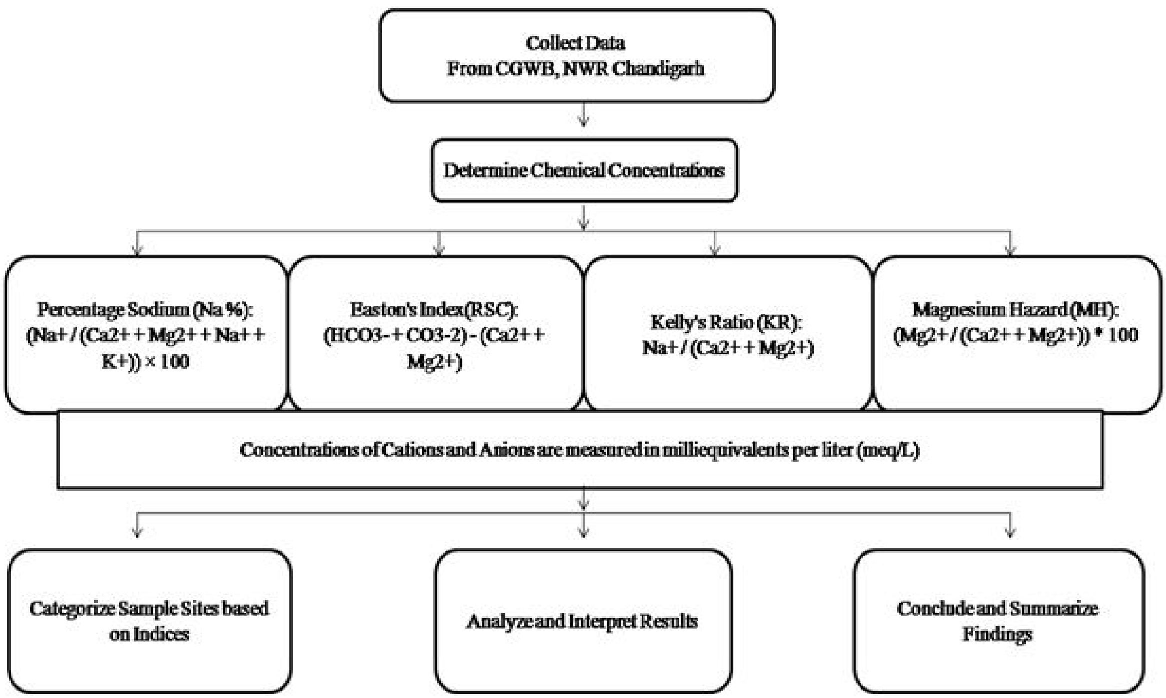
OBJECTIVE OF THE STUDY:

The objective of this study is to investigate the quality of irrigation water in the study area, particularly in the context of Haryana. Despite having favorable agricultural conditions and assured irrigation, there have been reports from field surveys, research papers, and farmers indicating that certain crops in specific areas are not responding to the provided inputs effectively. Hence, the study aims to assess the quality of irrigation water and understand the challenges faced by farmers.

SOURCE OF DATA AND METHODOLOGY:

This study relies on secondary data from the 2021 annual report of the Central Ground Water Board (CGWB), Ministry of Jal Shakti, Department of Water Resources, Government of India. The data, provided by the Central Ground Water Board North Western Region (CGWB, NWR), Chandigarh, and the Ground Water Cell of the Irrigation & Water Resource Department, Haryana, includes analysis of 463 groundwater samples collected from 22 districts across Haryana. These samples were tested for major cations (Ca, Mg, Na, K), anions (CO3, HCO3, Cl, NO3, SO4), and additional parameters such as pH, electrical conductivity (EC), fluoride (F), silica (SiO2), phosphate (PO4), and total hardness (TH as CaCO3) in the Regional Chemical Laboratory of CGWB, NWR, Chandigarh. Analytical procedures adhered to the standards set by the American Public Health Association (APHA) 23rd Edition 2017 and the Bureau of Indian Standards (BIS).

Figure 1: Methodology Flow Diagram: Water Quality Analysis and Indices Calculation



Source: Prepared by authors

The data was systematically organized and prepared for analysis, ensuring accuracy and completeness. Water quality parameters, including sodium (Na+), calcium (Ca2+), magnesium (Mg2+), bicarbonate (HCO3-), and carbonate (CO3-2), were identified and their concentrations calculated and converted to appropriate units. Specific indices, such as sodium percentage (Na%), Kelly's Ratio (KR), Magnesium Hazard (MH), and Recarbonation Soluble Cations (RSC), were computed using established formulas. The interpretation and classification of the water samples were based on predefined thresholds and criteria for each quality index. The results were summarized to assess the suitability of groundwater in Haryana for various applications. A methodology flow diagram (Figure 1) visually represents these analytical and calculation steps.

ANALYSIS AND FINDINGS:

In this study, various irrigation water quality indices were evaluated (see Table 1) to provide a comprehensive assessment of water suitability for irrigation. The Hydrogen Ion Activity (pH) measures water's acidity or alkalinity. Eaton's Index (RSC) calculates the Recarbonation Soluble Cations, indicating potential risks associated with water quality. Electrical Conductivity (EC) gauges the water's ability to conduct electrical current, reflecting its salinity. Sodium Percentage (Na %) determines the sodium content, which affects soil and crop health. Kelly's Ratio compares the concentrations of Sodium to Calcium and Magnesium, while Magnesium Hazard (MH) evaluates the risk associated with magnesium levels. Together, these indices offer valuable insights into the overall suitability of water for irrigation purposes.

Hydrogen Ion Activity (pH):

pH is a measure of the intensity of acidity or alkalinity conditions of a solution (Ramesh and Jagadeeswari , 2012). In the study area, a total of 463 water samples were analyzed for pH levels. The pH values ranged from 7.46 to 8.96 units. Out of these samples, only 143 (31%) fell within the recommended pH range of 6.5 to 8.4 units, indicating that approximately 69% of the groundwater samples were not suitable for irrigation based on pH alone. The presence of alkaline or acidic conditions in the majority of samples suggests that corrective measures may be required to adjust the pH levels and improve the suitability of the water for irrigation purposes.

Eaton's index:

According to Easton's Index (RSC in meq/L), ground waters are categorized into three classes based on their suitability for irrigation. Waters with an RSC value less than 1.25 meq/L are considered safe, comprising approximately 65.45% of the samples. The marginal category includes waters with an RSC value between 1.25 and 2.50 meq/L, accounting for around 13.30% of the samples. Lastly, waters with an RSC value exceeding 2.50 meq/L are classified as unsafe, representing approximately 21.25% of the samples. The RSC values of the ground waters in this dataset range from below zero (-18.59 meq/L) to 19.19 meq/L, indicating a wide variation in the alkali hazards present in the samples.

Table 1
Water Quality Indices and their Categorization of Selected Sample Sites in Haryana, June 2021

Indices	Range	Water type/ classification	No. of samples under different classes	Percentage of total Samples
Hydrogen Ion Activity (pH):	6.5 to 8.4	Suitable	143	31
	Above 8.4	Unsuitable	320	69
Easton's Index (RSC in meq/L) ***Eaton (1950)***	<1.25	Safe	304	65.66
	1.25-2.50	Safe Marginal	61	13.17
	>2.50	Unsafe	98	21.17
EC (S /cm)	250-750	Good	147	31.75
	750-2250	Doubtful	171	36.93
	> 2250	Unsuitable	145	31.32
Soluble Sodium Percentage (SSP) ***Wilcox (1955)***	<20	Excellent	33	7.13
	20-40	Good	110	23.76
	40-60	Permissible	147	31.75
	60-80	Doubtful	121	26.13
	>80	Unsafe	52	11.23
Kelly's Ratio ***Kelly (1940)***	< 1	Suitable	224	48.38
	>1	Unsuitable	239	51.62
Magnesium Hazard (MH) ***Raghunath, (1987)***	<50	Suitable	53	11.45
	>50	Unsuitable	410	88.55

Source: Categorized by authors using data provided by CGWB

ELECTRICAL CONDUCTIVITY:

The electrical conductivity (EC) of groundwater is an important parameter to consider when assessing its suitability for irrigation purposes. EC measures the salt concentration in the water, with higher conductivity indicating a higher salt content. In the context of irrigation, excessive salt levels can have detrimental effects on plant growth and soil quality. Based on the provided data, the EC ranges are divided into three classes: "Good," "Doubtful," and "Unsuitable." The "Good" class corresponds to an EC range of 250-750 S/cm, indicating a low salt concentration and suitable water for irrigation. This class comprises approximately 31.75% of the total samples. The "Doubtful" class represents an EC range of 750-2250 S/cm, signaling a moderate salt concentration that requires caution in its use for irrigation. This class constitutes around 36.93% of the total samples. The "Unsuitable" class, with an EC value greater than 2250 S/cm, indicates a high salt concentration that renders the water unsuitable for irrigation. This class represents approximately 31.32% of the total samples. Understanding the EC of groundwater helps in making informed decisions about its usage in irrigation practices, ensuring optimal crop productivity and preventing soil degradation due to excessive salt accumulation. Regular monitoring and management of EC levels are vital to maintain the quality and productivity of irrigated land.

SOLUBLE SODIUM PERCENTAGE (SSP):

The sodium hazard in irrigation water is an essential parameter used to assess its suitability for agricultural purposes. Sodium content can have severe adverse effects on soil quality. Table 1 represents the classification of irrigation water based on the percentage of sodium (Na%). The water samples were categorized into five classes based on their SSP values. The "Excellent" class represents water with an SSP below 20, and it accounted for 33 samples, making up 7.13% of the total samples. The "Good" class includes samples with an SSP ranging from 20 to 40, totaling 110 samples, which accounted for 23.76% of the total samples. The "Permissible" class encompasses samples with an SSP between 40 and 60, amounting to 147 samples and representing 31.75% of the total samples. The "Doubtful" class comprises samples with an SSP ranging from 60 to 80, totaling 121 samples, accounting for 26.13% of the total samples. Finally, the "Unsafe" class includes samples with an SSP above 80, amounting to 52 samples, which represented 11.23% of the total samples.

KELLY'S RATIO (KR):

Kelly's Ratio (KR) is an important parameter used to assess the quality of groundwater, specifically in relation to sodium concentration. It provides information about the suitability of water for irrigation purposes. However, SAR (Sodium Adsorption Ratio) is a more advanced method for detecting sodium content. The Kelly index is used to classify samples as suitable or unsuitable based on their Kelly's Ratio. The interpretation of Kelly's Ratio is straight forward and provides valuable information about the suitability of water for irrigation based on sodium concentration. When the Kelly's Ratio exceeds 1, it indicates that the water sample is unsuitable for irrigation due to a high concentration of sodium. On the other hand, when the Kelly's Ratio is less than 1, it signifies that the water sample is suitable for irrigation purposes. Analyzing the data, it is observed that out of the total samples, 224 samples, accounting for 48.38%, have a Kelly's Ratio below 1, making them suitable for irrigation. Conversely, 239 samples, representing 51.62% of the total samples, have a Kelly's Ratio exceeding 1, classifying them as unsuitable for irrigation.

Magnesium Hazard (MH):

Magnesium Hazard is a parameter used to assess the concentration of magnesium in water and its impact on irrigation suitability. Magnesium is an essential nutrient for plant growth, and its deficiency can lead to yellowing, reduced growth, and lower crop yields. Therefore, determining the magnesium concentration in water is crucial for evaluating its suitability for irrigation and agricultural use.

Table 1 represents the range of MH values, the corresponding water type or classification (suitable or unsuitable for irrigation), the number of samples falling into each category, and the percentage of total samples. From the given data, it can be observed that 53 samples, accounting for 11.45% of the total samples, have MH values less than 50, indicating suitability for irrigation. On the other hand, 410 samples, representing 88.55% of the total samples, have MH values greater than 50, classifying them as unsuitable for irrigation due to a higher concentration of magnesium.

CONCLUSION:

In conclusion, the groundwater quality for irrigation in the study area is significantly compromised. Key indicators such as pH levels, alkali hazards (Eaton's Index), electrical conductivity (EC), sodium percentage (Na %), and magnesium hazard (MH) reveal that the water is generally unsuitable. Many samples fall outside the ideal pH range, and there are widespread issues with alkali hazards, high salinity, elevated sodium concentrations, and excessive magnesium levels. These deficiencies pose severe challenges to agricultural practices, particularly for crops like rice and sugarcane that are prevalent in the region. Such water quality problems not only impede crop growth but also reduce the overall productivity of agricultural lands. Immediate intervention is essential to address these water quality issues through targeted management and treatment strategies. Enhancing water quality will support sustainable agriculture and improve land productivity, ultimately benefiting crop yields and agricultural viability in the region.

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