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Development and Assessment of a Water Quality Index (WQI) Analyzer for Palanadu District Based on IS 10500: 2012 Standards

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Abstract: Water Quality Indices (WQIs) generate a single numerical value based on different physicochemical parameters. This facilitates the interpretation of data and assists with monitoring and public health decisions. This work presents the development and validation of a Python-based Graphical User Interface (GUI) WQI Analyzer. It was coded in the PyCharm (Integrated Development Environment) based on the Tkinter library, according to Indian Standard IS 10500:2012. It is made for use in the Palanadu district of Andhra Pradesh. It computes WQI based on eleven major physicochemical parameters: pH, Hardness, Fluoride, Total Alkalinity, Total Dissolved Solids (TDS), Chloride, Sulphate (SO_4^{2-}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^-), and Iron (Fe). People can enter real-time measurements or mean values to obtain the WQI score and the corresponding water quality category. Field evaluation using 110 water samples revealed WQI values between "Excellent" to "Poor". Levels at some sites exceeded the levels for Hardness, TDS, Fluorine and Alkalinity. The analyzer is a trusted, user-friendly, and configurable tool for researchers, local government, and public health professionals to enhance drinking water quality assessment and management in rural parts of Palanadu district.
Keywords: Python, Graphical user interface, PyCharm IDE, Water quality index, Physicochemical Parameters, Drinking Water, Palanadu District.

I. INTRODUCTION

Access to safe and clean drinking water is a basic human right and key to sustainable development. Drinking water quality impacts on public health, economic productivity, and community well-being. Public water quality in rural and semi-urban areas of Palanadu district, particularly in agricultural oriented districts, is usually compromised due to contamination from many sources. The sources of pollution are natural contaminants such as surplus fluoride and iron, agricultural runoff containing nitrates and pesticides and human interventions leading to increased hardness, alkalinity, and Total Dissolved Solids (TDS). Without continuous monitoring, these issues may go undetected, increasing the potential for waterborne illness, long-term health concerns, and reduced quality of life. The Water Quality Index (WQI) is now one of the most valuable tools for condensing challenging water quality information into a single, interpretable value. By merging different physicochemical parameters into one score, WQI allows researchers, policymakers, and communities to rapidly assess water quality for drinking and other purposes. WQIs have been utilized successfully in environmental monitoring schemes worldwide, including Canada, the USA, Morocco, and Australia. The indices allow for comparisons among different regions and different periods and aid local management and long-term policy planning.

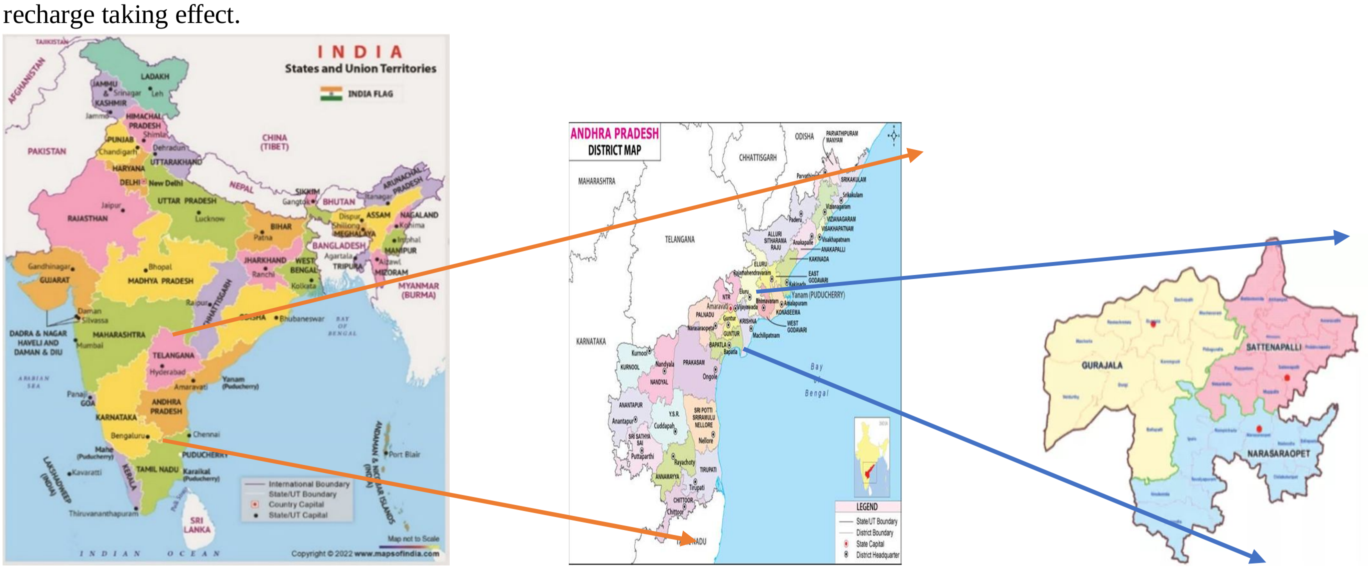
In India, the Bureau of Indian Standards (BIS) establishes drinking water quality standards in IS 10500:2012 that specifies acceptable and permissible values for different water quality parameters. Conventional calculation of WQI, although accurate, requires manual computation and proper parameter normalization. The procedure is difficult to carry out and may be time-consuming, as well as prone to calculation errors in the case of large volumes of data. Local government agencies, public health administrators, and rural development agencies require a simplified, end-user-friendly system that computes the WQI automatically based on national guidelines. Recent developments in computing power, particularly the emergence of Python-based graphical user interface (GUI) programs, provide an innovative approach to addressing this problem. GUI-based WQI calculators can minimize human errors, accelerate analyses, and simplify water quality monitoring for technical and non-technical end-users alike. A number of studies, including in Morocco, have demonstrated that incorporation of WQI methods into specialized software tools significantly enhances efficiency, consistency, and acceptability by field personal and scientists.

In this study, a Python GUI Water Quality Index Analyzer, developed with the Tkinter library in the PyCharm Integrated Development Environment (IDE), is urban and rural water monitoring requirements in the Palanadu district of Andhra Pradesh, India. The eleven most important physicochemical parameters pH, Hardness, Fluoride, Total Alkalinity, Total Dissolved Solids (TDS), Chloride, Sulphate (SO_4^{2-}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^-), and Iron (Fe^-) as per IS 10500:2012 are covered by the tool.

Groundwater sources or handpumps, offer a primary drinking water supply to most rural villages in Palanadu and are the subject of research. Sampling was done at pre-monsoon time, when the water table is usually lowest and contaminant concentrations may be highest because of reduced dilution from rainfall. Seasonal targeting provides a worst-case scenario perspective regarding safety of drinking water. The program accepts users to feed in either real-time measured values or average dataset values from laboratory analysis, calculating the WQI instantly and classifying water quality into Excellent, Good, Medium, and Poor classes. In this research, the analyzer was cross-checked with 110 pre-monsoon groundwater samples collected from handpumps in semi-urban and rural regions of Palanadu. The outcomes identify remarkable spatial differences in water quality and identify areas with parameter exceedance, particularly in relation to hardness, TDS, and alkalinity. By combining scientific complexity with practical applicability, the envisioned WQI Analyzer functions as a reliable, expandable, and user-friendly instrument for environmental observation. It has direct applications in safeguarding public health, rural development planning, and implementing environmental policy. This makes it a necessary addition to water resource management initiatives in the Palanadu district and possibly in other areas of similar concern.

II. STUDY AREA

The investigation was conducted in Palanadu District of south-central Andhra Pradesh, India. Geographically, the district lies between approximately 16.3820° N latitude and 79.8297° E longitude. With an area of approximately 7,400 sqkm of both urban and rural settlement and a semi-arid climate with hot summer heat and moderate monsoon rains during the southwest monsoon season, Palanadu District is situated. Mean annual rainfall is 700-900 mm, with most of the rainfall occurring between June and September. Groundwater is the primary source of drinking water within the district due to the lack of surface water. The lithology of the region is hard rock country and the aquifers consist primarily of fractured granites, gneisses, and weathered zones. These lithological conditions have an effect on the natural mineral composition of the groundwater. The area has experienced increased water requirements for domestic consumption due to population growth, agriculture, and industry. More specifically, there has been an issue of fluoride and nitrates contamination, which is typical in semi-arid zones with high agricultural production. For this study, pre-monsoon groundwater was collected from urban and rural locations throughout Palanadu District to document spatial variability in the quality of water. Locations were selected to represent diversified hydrogeological and land-use conditions like residential, agricultural, and peri-urban spaces. This helped in meaningful coverage of the district's drinking water quality prior to monsoonal recharge taking effect.



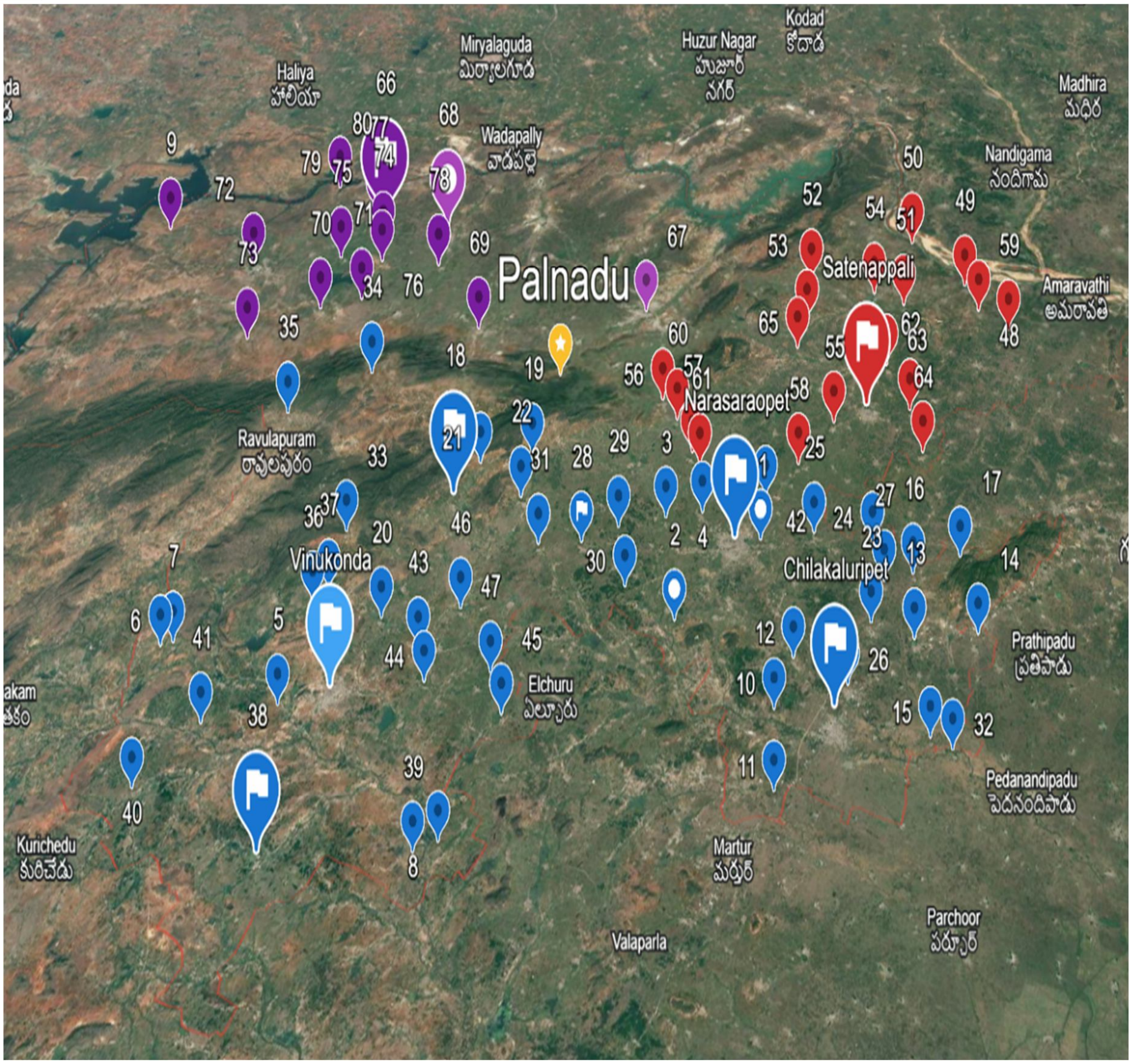


Figure 1 sampling locations of Palanadu District

III. MATERIAL AND METHODS

The groundwater drinking samples of both rural and urban regions of palanadu district were obtained as per standard grab sampling guidelines. All the samples were tested in the laboratory for physicochemical parameters as per IS 10500:2012 standards. Parameters like pH, hardness, fluoride, chloride, TDS, calcium, magnesium, sulphate, nitrate, iron, and alkalinity were obtained. Triplicate measurements were taken to minimize analytical error, and quality control standards were followed during analysis.

The construction of a water quality index entails four steps: selection of parameters, normalization of parameter values, weighting of various parameters and summation of sub-indices. The index was constructed in three steps, since there was no weighting step involved: selection of water quality parameters, normalization of parameters into sub-indices into an overall index.

The constructed index was implemented into a Python computer program with an intuitive graphical user interface (Tkinter). This software automates data entry, performs the WQI calculation, and provides the associated water quality classification. Through integration of all steps of the WQI approach, the program enables a fast and open working process from parameter measurement to ultimate classification.

Generally, if 'X' water quality parameters are analyzed in the lab of a water sample and just 'n' parameters are considered to assess water quality at this measurement point, the raw data values of these chosen parameters are normalized broken down into sub-indices and further combined into a final index that indicates the overall water quality.

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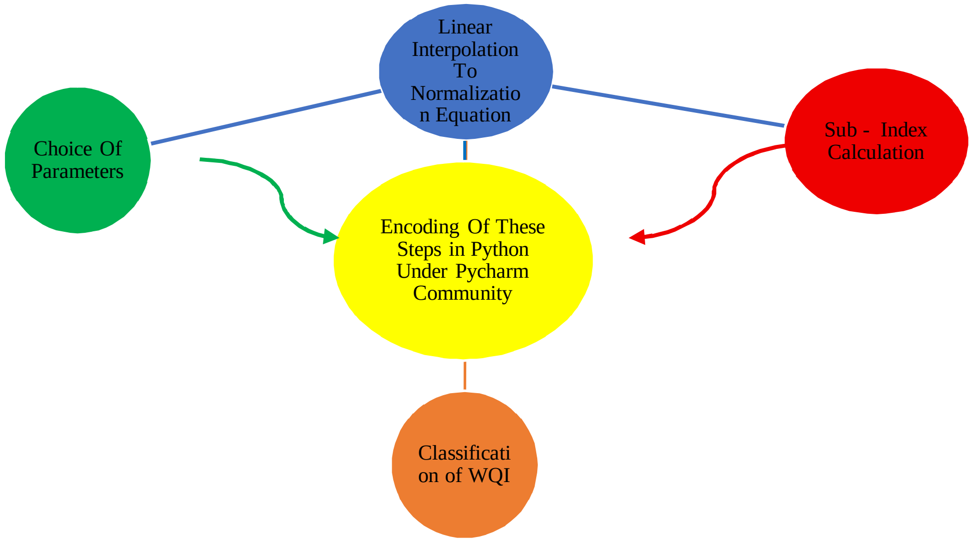

Figure 2 selection of parameters and Normalization process

A. *Selection Of Parameters*

The choice of parameters is a very important step in the development of a water quality index The eleven most important physicochemical parameters pH, Hardness, Fluoride, Total Alkalinity, Total Dissolved Solids (TDS), Chloride, Sulphate (SO_4^{2-}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^-), and Iron (Fe^-) were used in this study to calculate the Water Quality Index (WQI). In general, the water resources management bodies in a locality define this choice. The Palanadu District of Andhra Pradesh was selected as the study area owing to its semi-arid climatic conditions, which exert considerable pressure on the availability and quality of groundwater samples for drinking purposes were collected at the pre-monsoon season, when groundwater levels are generally at the lowest and dissolved constituent concentrations are highest An early-season sampling permits a conservative approximation of water quality conditions and detects zones of concern before dilution from monsoon recharge. This district depends much on groundwater as a major supply of drinking water, especially in rural areas where surface water supply is scarce. For this reason, evaluating the physicochemical quality of groundwater here becomes very important for maintaining public health and sustaining water resource management.

B. *Normalization Of Parameters*

Parameter normalization is the transformation of variables, which are in different units and dimensions, into a common scale Water quality parameters are not expressed in the same unit. In the current study conducted in Palanadu District, Andhra Pradesh, parameter normalization was used to normalize all measured variables into a single, dimensionless scale. The eleven parameters that were taken into account pH, Hardness, Fluoride, Total Alkalinity, Total Dissolved Solids (TDS), Chloride, Sulphate (SO_4^{2-}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^-), and Iron (Fe) are described in various units and orders of magnitude (for instance, mg/L for chemical species, µS/cm for Electrical Conductivity, unitless for pH). Certain parameters, like pH, in the acceptable range enhance water quality, while increased levels of Nitrate, Iron or Fluoride degrade it. This heterogeneity requires normalization such that all parameters contribute proportionally to the Water Quality Index (WQI).

To this end, pre-monsoon groundwater samples taken from the rural regions of Palanadu District were converted into sub-indices using a piecewise linear interpolation process according to the IS 10500:2012 drinking water quality standards. All measured values were then plotted on to a common scale ranging from 0 -25 (Excellent), 25 – 50 (Good), 50 – 75 (Medium), 75 – 100 (Poor).

The segmented linear interpolation equation used was

$$I_i = (x - a_i)\left(\frac{b_{i+1}-bi}{a_{i+1}-a_i}\right) + b_i \quad , \quad a_i \le x \le a_{i+1} \text{ and } b_i \le I \le b_{i+1}$$

Where I_i is the sub-index of the *i*th parameter; x is the measured value; ai and ai+1 are threshold values from standards; and bi, bi+1 is corresponding WQI scores. Normalized sub-indices were then classified into four categories: Excellent (0–25), Good (25–50), Medium (50–75), and Poor (75–100) to facilitate water quality assessment. Table 1 shows the distribution of classes with numerical values as follows:

Table 1: Classification of water based on the WQI Proposed

Description	Value
Excellent	0 – 25
Good	25 – 50
Medium	50 – 75
Poor	75 – 100

For example, Fluorine measurements that are strictly less than 0.6 mg/l are considered “Excellent” in terms of water quality description, and correspond to the range of numerical values {0 to 50}. To normalize this class, simply do:

Eq (1): $I\ (F)(0 \leq x \leq 0.6) = (x - 0)\ \{(50 - 0) / (0.6 - 0)\} + 50 = -\ 83.33x+50$

Table 2 Water quality parameters Acceptable and Permissible

S.NO	PARAMETER	ACCEPTABLE	PERMISSIBLE
1	PH	6.5-8.5	NO RELAXATION
2	HARDNESS	200 mg/L	600mg/L
3	FLUORINE	0.6 mg/L	1.5 mg/L
4	CHOLORIDE	250 mg/l	1000 mg/L
5	TDS	500 mg/L	2000 mg/L
6	CA^{+2}	75 mg/L	200 mg/L
7	MG^{+2}	30 mg/L	100 mg/L
8	SO^{4-}	200 mg/L	400 mg/L
9	NO^{3-}	45 mg/L	NO RELAXATION
10	FE^{-}	0.3 mg/L	NO RELAXATION
11	ALKALINITY	200 mg/L	600mg/L

Table 3: shows the sub-indices of the water quality parameters. For each class a linear equation was developed to quantitatively estimate water quality

S.NO	PARAMETERS	RANGE	WQI	LINEAR INTREPOLATION EQUATION
		ai - ai+1	bi+1 - bi	I = (x - ai) (b i+1 - bi/ a i+1 - ai) + bi
1	PH	0 - 6.5 6.5 - 7 7 - 8.5	0-50 50-75 75-100	I PH ($0 \leq x \leq 6.5$) = -7.6923x + 50 I PH ($6.5 \leq x \leq 7$) = -50x + 400 I PH ($7 \leq x \leq 8.5$) = -16.66x + 216
2	HARDNESS	0 - 200 200 - 400 400 - 600 >600	0 - 50 50 - 75 75 - 100 >100	I HARDNESS ($0 \leq x \leq 200$) = - 0.25x+50 I HARDNESS ($200 \leq x \leq 400$) = - 0. 125x+100 I HARDNESS ($400 \leq x \leq 600$) = - 0.125x-150 I HARDNESS (>600) = 0
3	FLUORINE	0 - 0.6 0.6 - 1.2 1.2 - 1.5	0-50 50-75 75-100	I F ($0 \leq x \leq 0.6$) = - 83.33x+50 I F ($0.6 \leq x \leq 1.2$) = - 41.66x + 99.99 I F ($1.2 \leq x \leq 1.5$) = - 83.33x + 200

4	CHOLRIDE	0 - 250 250 - 500 500 - 750 750 - 1000 >1000	0 - 25 25 - 50 50 - 75 75- 100 >100	I CL- (0≤x≤250) = - 0.1x+25 I CL- (250≤x≤500) = - 0.1x+75 I CL- (500≤x≤750) = - 0.1x+125 I CL- (750≤x≤1000) = - 0.1x+175 I CL- (>1000) = 0
5	TDS	0 - 500 500 - 1000 1000 - 1500 1500 - 2000 >2000	0 - 25 25 - 50 50 - 75 75- 100 >100	I tds- (0≤x≤500) = - 0.05x+25 I tds- (500≤x≤1000) = - 0.05x+75 I tds- (1000≤x≤1500)= - 0.05x+125 I tds- (1500≤x≤2000)= - 0.05x+175 I tds- (>2000) = 0
6	CA^{+2}	0 - 75 75 - 125 125 - 175 175 - 200	0 - 25 25 - 50 50 - 75 75- 100	I ca^{+2}- (0≤x≤75) = - 0.33x+25 I ca^{+2}- (75≤x≤125) = - 0.5x+87.5 I ca^{+2}- (125≤x≤175)= - 0.5x+137.5 I ca^{+2}- (175≤x≤200) = - x+275
7	MG^{+2}	0 - 30 30 - 55 55 - 80 80 - 100	0 - 25 25 - 50 50 - 75 75- 100	I Mg^{+2}- (0≤x≤30) = - 0.833x+25 I Mg^{+2-} (30≤x≤55) = - x+80 I Mg^{+2}- (55≤x≤80)= - x+130 I Mg^{+2}- (80≤x≤100)= - 1.25x+200
8	So^{4-}	0 - 100 100 - 200 200 - 300 300 - 400	0 - 25 25 - 50 50 - 75 75- 100	I So^{4-} (0≤x≤100) = - 0.25x+25 I So^{4-} (100≤x≤200) = - 0.25x+75 I So^{4-} (200≤x≤300)= - 0.25x+125 I SO^{4-} (300≤x≤400)= - 0.25x+175
9	No^{-3}	0 - 15 15 - 30 30 - 45 >45	0 - 25 25 - 50 50 - 75 75- 100	I No^{3-} (0≤x≤15) = - 1.66x+25 I No^{3-} (15≤x≤30) = - 1.66x+75 I No^{3-} (30≤x≤45) = - 1.66x+125 I No^{3-} (>45) = 0
10	FE (IRON)	0 - 0.1 0.1 - 0.2 0.2 - 0.3 >0.3	0 - 25 25 - 50 50 - 75 75- 100	I Fe- (0≤x≤0.1) = - 250x+25 I Fe- (0.1≤x≤0.2) = - 250x+75 I Fe- (0.2≤x≤0.3) = - 250x+125 I Fe- (>0.3) = 0
11	TOTAL ALKANITY	0 - 200 200 - 300 300 - 400 400 - 600 >600	0 - 25 25 - 50 50 - 75 75- 100	I $_{TA}$- (0≤x≤200) = - 0.125x+25 I $_{TA}$- (200≤x≤300) = - 0.25x+100 I $_{TA}$- (300≤x≤400)= - 0.25x+87.5 I $_{TA}$- (400≤x≤600)= - 0.125x+150 I $_{TA}$- (>600)=0

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C. Aggregation Of Sub-Indices

Following the conversion of all the measured water quality parameters into their respective dimensionless sub-indices, the second step was to combine them to acquire a single representative indicator called the Water Quality Index (WQI) for every sampling site. During the current research work, equal weights were assigned to all the parameters keeping in view the assumption that every parameter has an equal contribution towards the total drinking water quality. The process of aggregation was done through the arithmetic mean method, which provides an easy and clear manner of aggregating more than one sub-index. The overall WQI for any sample was calculated by applying the following equation:

$$\mathbf{WQI} = \frac{1}{n}\sum_{i=1}^{n} I_i$$

where I_{di} denotes the sub-index for the ith parameter, and n denotes the number of parameters under consideration. After achieving WQI values, they were mapped into different quality classes according to IS 10500:2012 guidelines for ease of interpretation.

D. Encoding The Index In A Computer Application

To promote efficiency, reproducibility, and accessibility, the proposed Water Quality Index (WQI) methodology was implemented using a computer-based application via the Python programming language. The software was created with a Graphical User Interface (GUI) based on the Tkinter framework, which allows for researchers and local governments to interactively analyze groundwater quality data without the need for programming knowledge. The workflow of the application replicates the process steps employed In manual calculation. The application carries out data input, normalization, aggregation, and classification automatically as per the IS 10500:2012 standards. The simple user interface includes input boxes for eleven parameters are pH, Hardness, Fluoride, Alkalinity, TDS, Chloride, Sulphate, Calcium, Magnesium, Nitrate, and Iron and functional buttons to calculate, reset, and show results. When the "Calculate WQI" button is pressed, the application carries out the following steps in sequence:

- Normalization: Transforms every input parameter into a sub-index through the segmented linear interpolation equation formulated from IS 10500:2012.
- Aggregation: Calculates the mean of all sub-indices to arrive at the overall WQI value.
- Classification: Places the result into qualitative ranges: Excellent, Good, Medium, or Poor.
- Visualization: Shows the quantitative WQI value and its associated category on the GUI screen directly.

Default mean parameter values from the Palanadu District data are imported into the interface but may be adjusted by the user for various scenarios. The application is therefore a decision-support tool, enabling quick, precise, and reproducible calculation of WQI values. Its modular structure enables future connectivity to mapping platforms or real-time water quality monitoring systems. Through embedding the index algorithm in a Python platform, the research fills the gap between field-based data fieldwork and computerized analytical computation, and it makes water quality assessment more effective and transparent.

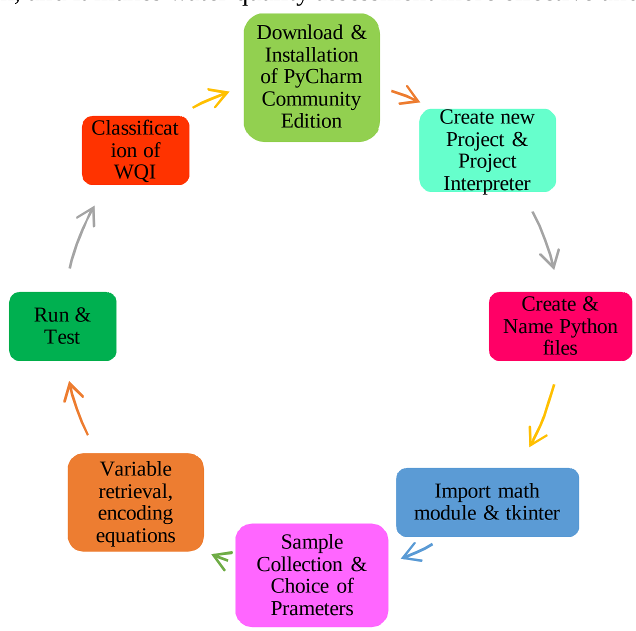

Figure 3 Process of Normalization and encoding of WQI in Python

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IV. RESULT AND DISCUSSION

The proposed Water Quality Index (WQI) Analyzer was built to compute the WQI using the physicochemical properties of water samples obtained from the study region. These parameters are pH, Hardness, Fluoride, Chloride, Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Iron (Fe), and Alkalinity. For each parameter, its numerical mean value is typed directly into the WQI calculator interface. As is evident from the WQI Calculator window, the software offers text boxes where users can enter these measured parameter values. On entering the data, when the "Calculate WQI" button is clicked, the values are automatically processed through the computation model programmed into the software to calculate the overall Water Quality Index. The interface is kept easy, interactive, and user-friendly to quickly assess water quality according to the IS 10500:2012 standards.

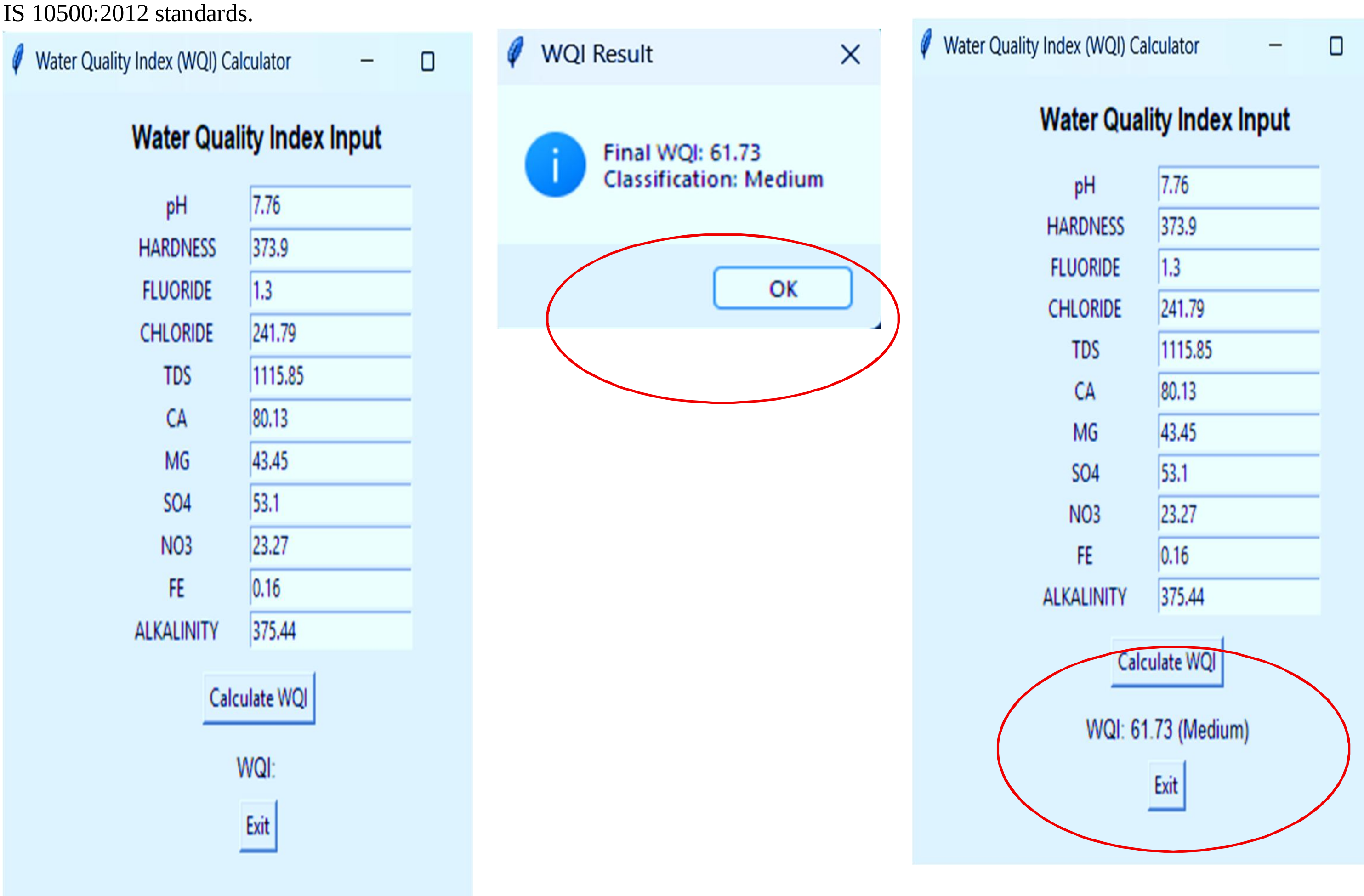

Figure 4 Interface of the developed Python based WQI Analyzer

The computed WQI values were then translated into placing the water quality in categories of excellent, good, poor, very poor, or not drinking water quality. The findings revealed that the majority of the samples ranged between "good" to "poor" quality of water. This analysis proves that the constructed WQI calculator offers a trustworthy and effective tool for assessing water quality in both urban and rural areas. It streamlines the calculation process, minimizes errors during manual calculations, and provides a simple interface for rapid decision-making in water quality monitoring and management.

A. Water Quality Index Calculation And Interpretation

For every water sample, the software calculates the WQI as the arithmetic mean of the sub-indices, giving equal weight to all parameters. If one parameter is above its acceptable limit (IS 10500:2012), the sub-index increases proportionally, thus indicating worsening in water quality. The resultant WQI value is then overlaid on the classification scale to read overall potability: *0–25: Excellent, 25–50: Good, 50–75: Medium,75–100: Poor*

For instance, the groundwater from Narasaraopet and Sattenapalli Mandals had WQI ranging approximately between 40–55, representing moderate water quality, while those of Vinukonda, Guruzala presented values more than 75, which depicted poor quality as a result of high hardness and fluoride content.

This interactive tool streamlines the analytical process, reduces human calculation errors, and facilitates quicker interpretation of water quality information. The application of Python-Tkinter GUI facilitates easier accessibility, particularly among field engineers and researchers in rural areas, to facilitate effective decision-making in groundwater management.

V. CONCLUSION

The created Python-based application effectively integrates data processing, sub-index calculation, and aggregation into one simple-to-use interface. Through direct input of the measured parameter values, the tool quickly calculates the WQI, hence simplifying the complicated manual calculations often needed in traditional methods.

The calculated WQI values indicated spatial variability in drinking water quality within the study area. All samples fell into the "good" to "poor" water quality classes, which were largely dominated by ***high hardness and total dissolved solids***. The results reflect the impact of the ***semi-arid climatic conditions*** and the ***pre-monsoon groundwater recharge*** status on water quality in the study area. In total, the WQI Analyzer developed is an effective and consistent decision-support tool for monitoring drinking water quality.

It can be expanded for real-time water quality estimation, integration with GIS mapping, and regular assessment of rural water resources. The strategy used in this research illustrates the feasibility of integrating environmental data with computational tools for sustainable water resource management in semi-arid parts of the country such as Palanadu District.

A. Future Scope

1) The current research can be extended in the following directions to enhance the accuracy, usability, and applicability of the Water Quality Index (WQI) Analyzer developed. With the incorporation of real-time monitoring sensors into the application, it would facilitate ongoing evaluation of water quality parameters and WQI calculations automatically without the need for manual data input.
2) In addition, the combination of the analyzer with Geographic Information System (GIS) platforms may allow for spatialization of WQI values, enabling decision-makers to more effectively spot key zones of contamination and prioritize water treatment efforts.
3) Machine learning algorithms like Random Forest, Support Vector Machines, or Artificial Neural Networks can be used to predict future trends in WQI based on historical trends and seasonality. It would be especially beneficial to forecast the effect of climatic and anthropogenic factors on groundwater quality.
4) Furthermore, the interface of this application can be scaled up to a web-based or mobile-compatible platform such that users from local water authorities, researchers, and rural dwellers can access, assess, and exchange water quality information with ease.
5) Through embracing these developments, the suggested WQI Analyzer can become an advanced decision-support and forecasting system, playing a vital role in sustainable water resource management and public health protection in semi-arid zones such as Palanadu District.

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