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REVIEW ARTICLE

Groundwater quality analysis with the help of python programming- a review

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Abstract

Groundwater is the most important source as per human beings' demand for drinking purposes, cleaning, etc. Due to accelerated urbanization and economic growth of industrial development or computerization status or the quality of groundwater getting severe gradually which is very unpleasant for the growth of the population and the growth of animals. This gradual increase in aquatic pollution is also affecting the health of human beings as well as animal health. This study highlights the detrimental elements which are present in our groundwater with the projection of python programming. Python programming will help to find out the effective element which is present in our groundwater and is less time-consuming. The main purpose of using python programming is that it analyses the given data at on higher level and it also gives the output very fast which is very necessary for us because the physio-chemical properties of the groundwater have been degraded day by day. This output will help us to improve the quality of groundwater by taking the action against the analyzed detrimental status of groundwater. Python Programming has erecting as the most popular language for computer programming over difficult acrolect on accounts of its simplicity in the programming.

1. Introduction

Groundwater is that water that is found below the surface of the earth. This water presents underneath the surface of the earth in rock and soil pores and the cleavage of rock formation. In the world almost 30% of groundwater is available. Groundwater has three types of properties such as (i) Physical Properties, (ii) Chemical Properties (iii) Biological Properties. Due to urbanization and industrialization, these three properties which are mentioned above are getting worse day by day. Therefore, the quality of groundwater is degraded gradually. It is guesstimated that approximately 37.7 million Indians are afflicted by waterborne diseases annually. Approximately 80% of diseases and 1/3 of deaths are caused or happened by water-borne diseases only. Once the quality of the groundwater is contaminated then it cannot be put back by terminating the pollutants from the resources. Nearly everywhere below the surface of the land is groundwater, which is a crucial component of the intricate hydrologic cycle that involves the constant movement of water on Earth. One of the main reasons that drinkable groundwater is used as a source of water supply globally is that it is commonly found. Groundwater aquifers are the primary source of water supply in both rural and urban areas, particularly in the world's arid and semiarid regions. Due to anthropogenic activities such as the overuse of groundwater for agriculture, industry, and drinking, groundwater shortage during dry seasons attracts global attention and is regarded as a risk. As a result, the misuse of groundwater has dangerous effects, particularly on the amount and quality of water overall. Moreover, anthropogenic activities and geogenic pollutants bearing rocks and soils affect groundwater supplies. Hence, changes in land

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use, cropping practices, high water demand, high-yielding crop races, and water availability are what is responsible for the groundwater catastrophe. Ineffective management has further altered the global water cycle, which is probably hastening climate change and groundwater pollution.

Groundwater is one example of untapped resources. Information is gathered from a variety of sources, including specific wells and spring locations, indirect measuring methods like surface geophysics, and measures of flow and water level at hydrologically related water bodies including streams, lakes, and wetlands. These facts are used to infer the existence, flow, and properties of groundwater.

1.1 Water quality parameters

These are the parameters which generally uses to describe the quality of groundwater. Water quality parameters are divided into three categories:

(i) Physical Parameter
(ii) Chemical Parameter
(iii) Biological Parameter

Some physical, chemical and biological parameters of groundwater are mentioned in table 1.

Table 1: Physical, chemical and biological parameters of groundwater

S.No	Types of water quality parameters		
	Physical parameters	Chemical parameters	Biological parameters
1	Turbidity	pH	Bacteria
2	Temperature	Acidity	Algae
3	Color	Alkalinity	Viruses
4	Taste and odor	Chloride	Protozoa
5	Solids	Chlorine residual	
6	Electrical conductivity	Sulfate	
7		Nitrogen	
8		Fluoride	
9		Fe and Mn	
10		Copper and Zinc	
11		Hardness	
12		Dissolved oxygen	
13		Biochemical oxygen demand	

For the sake of maintaining the food supply, preserving ecosystems, and safeguarding human health, our groundwater resources must be protected. Several regions and nations rely on naturally clean groundwater since it is economically unviable to treat water using advanced technologies. A crucial and indispensable part of our life support system is groundwater. Drinking water, irrigation, and industrial uses all make use of groundwater resources. Concern over the deterioration of groundwater quality resulting geogenic and human activities is developing. In both urban and rural India, the main source of drinking water is groundwater. Also, it is a significant supplier of water for the industrial and agricultural sectors. According to predictions, groundwater usage will be around 50% in 2000.

The majority of the groundwater in shallow aquifers is of the mixed and calcium bicarbonate types and is generally appropriate for use for a variety of applications. Yet there are other kinds of water too, such as water with sodium chloride. Although the quality of deeper aquifers varies from location to place, it is typically thought to be suitable for everyday uses. Groundwater has only sometimes been proven to be unfit for a particular purpose due to a variety of contaminations, mostly because of geological factors.

1.2 About python programming

Python is the most recent and cutting-edge programming language for general-purpose use in all engineering disciplines. Python is simple easy to grasp syntax emphasizes readability. The python was founded by Guido Van Rossum in the year February 20,1991. Python allows code readability, a syntax permitting programmers. Python makes the code very easy & also develop the codes in little and small lines. Python Programming is widely used by software engineers in the whole world. Eventually a civil engineer can also be used this language. Python has a wide standard library which is widely used for civil engineering purpose which are mentioned below: -.

- Pandas
- Matplotlib
- Numpy
- Scipyetc.

1.2.1 NumPy

Python's NumPy package allows for numerical computation. It offers resources for using arrays and matrices, which are essential in groundwater quality analysis. NumPy arrays are efficient for storing large datasets, and they support mathematical operations such as addition, subtraction, multiplication, and division. NumPy is commonly used in groundwater quality analysis for data preprocessing, filtering, and transformation.

1.2.2 Pandas

Pandas is a Python library for handling and analyzing data. It offers data import tools., export, cleaning, and filtering. Pandas data frames are a popular data structure for handling tabular data, which is common in groundwater quality analysis. Pandas also provides tools for time-series analysis, which is useful for monitoring changes in water quality.

1.2.3 Matplotlib

The Python data visualization toolkit Matplotlib. It offers tools for making a variety of graphs and charts, such as heat maps, scatter plots, line plots, and histograms. Matplotlib is commonly used in groundwater quality analysis for visualizing data distributions, trends, and relationships.

1.2.4 Seaborn

Seaborn is a Python package for visualizing statistical data. It offers resources for building sophisticated and complicated visualizations. than Matplotlib. Seaborn is commonly used in groundwater quality analysis for creating box plots, violin plots, and regression plots. Scikit-learn is a Python library that supports machine learning. It offers instruments for feature selection, model training, and evaluation, as well as data preprocessing. Scikit-learn is commonly used in groundwater quality analysis for predicting water quality parameters based on environmental variables and identifying contamination sources.

1.3 Applications of python in civil engineering

Python programming has been increasingly utilized in various fields due to its versatility and efficiency. In civil engineering, Python has gained immense popularity in recent years, primarily due to its ability to automate repetitive tasks and its extensive libraries that can be used to solve complex engineering problems.

Here are some areas in civil engineering where Python programming can be used:

(i) To forecast the population for distribution of water supply and sewerage system in environmental engineering.
(ii) Structural elements monitoring in structural engineering.
(iii) To reduce the hand calculation in traffic trends python can be used in Highway Engineering.
(iv) Soil Simulation and Modelling in geotech Engineering
(v) Earthquake and flood assessment with the help of machine learning.

1.3.1 Data analysis

Python is well-known for its data analysis capabilities. In civil engineering, data analysis can be used to identify patterns and trends, assess risk, and optimize construction processes. Python libraries such as Pandas, NumPy, and Matplotlib are commonly used to analyze data and create visualizations.

1.3.2 Structural analysis

Python can be used for finite element analysis, a technique for breaking down large structures into more manageable, simpler elements for examination. Python libraries such as FEniCS and PyFEA can be used to perform structural analysis, including stress and deformation analysis.

1.3.3 Geotechnical engineering

Python can be used in geotechnical engineering to analyze soil properties, such as shear strength and consolidation. Python libraries such as GeoPandas and Shapely used for spatial data analysis, which is useful in site planning and analysis.

1.3.4 Building information modeling (BIM)

Python can be used in BIM, which is a process of creating a digital model of a building. Python can be used to automate BIM tasks, such as creating 3D models from 2D drawings, and extracting data from BIM models.

1.3.5 Environmental engineering

Python can be used in environmental engineering to model environmental systems, such as water flow and air quality. Python libraries such as PyEcoLib can be used to model ecological systems and analyze environmental data.

1.4 Applications of python in ground water analysis

Python programming has numerous applications in groundwater quality analysis, including:

1.4.1 Data cleaning and preprocessing

Groundwater quality data is often collected from various sources and can be messy and inconsistent. Python libraries such as Pandas and NumPy provide tools for cleaning and preprocessing data, such as removing missing values, handling outliers, and normalizing data.

1.4.2 Data visualization

Python libraries such as Matplotlib and Seaborn provide tools for creating visualizations that help identify patterns and trends in groundwater quality data. These visualizations can help identify contamination sources and provide insights into changes in water quality over time.

1.4.3 Statistical analysis

Python libraries such as SciPy provide tools for statistical analysis, such as hypothesis testing, regression analysis, and clustering. These analyses can help identify relationships between water quality parameters and environmental variables and provide insights into the factors that affect groundwater quality.

1.4.4 Machine learning

Python libraries like Scikit-learn offer tools for machine learning that may be used to forecast water quality metrics based on environmental variables and locate the sources of contamination. Machine learning algorithms can also be used for classification tasks, such as identifying contaminated sites based on water quality data.

1.4.5 Web scraping

Python libraries such as Beautiful Soup and Scrapy can be used to scrape groundwater quality data from websites and online

databases, making it easier to collect and analyze large amounts of data.

1.5 Advantages of python in groundwater quality analysis:

There are several advantages to using Python programming in groundwater quality analysis, including:

- Python is an open-source programming language, allowing users to freely alter and share the source code. This makes it easier to collaborate and share code with others, which can improve the quality and efficiency of groundwater quality analysis.
- Python has a sizable and vibrant developer community that contributes to the creation of new libraries and tools. This community provides support and resources for users and helps ensure that Python remains up-to-date and relevant in groundwater quality analysis.
- Python is accessible to people with various degrees of programming experience since it is a straightforward and simple language to learn. Its syntax is easy to read and understand, which makes it easier to write and debug code.
- Python is a flexible language that may be used for a variety of applications, such as machine learning, data analysis, and scientific computing. This makes it a useful tool for groundwater quality analysis, which often requires a range of data analysis and visualization tasks.
- Python has a large and robust set of libraries for scientific computing, data analysis, and machine learning. These libraries provide tools for data manipulation, visualization, statistical analysis, and machine learning, which are essential for groundwater quality analysis.

2. Some studies are mentioned below:

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2.1 Marine water quality prediction based on machine learning for costal hydro environment management

In this study, Harmful algal blooms (HAB) have been a common occurrence in the past three decades in the marine waters near numerous coastal towns worldwide, including Hong Kong. Millions of dollars have been lost as a result of HAB's severe effects and harms on marine aquaculture and the water environment. One of Hong Kong's most severely afflicted places, for instance, is Tolo Harbour, where more than 30% HAB occurred. In order to forewarn against upcoming HAB catastrophes, machine learning (ML) techniques are increasingly being used in modelling and forecasting water quality issues. This study applies and enhances two distinct machine learning (ML) methodologies, artificial neural networks (ANN) and support vector machine (SVM), in order to accurately predict algal development and eutrophication in Tolo Harbour in Hong Kong. The application's results show how well these two ML techniques can be applied and how accurate they are at forecasting the direction and rate of algal development. The findings explicitly demonstrate that SVM is better suited to precisely identify the optimum model while necessitating longer training time. It is also demonstrated that the employed ML approaches may offer robustness to understand intricate connections between algal dynamics and other coastal environmental variables and, as a result, to accurately identify key variables. The results analysis and discussion of this work also highlight the advantages and potentials of using machine learning (ML) models to comprehend the mechanism and evolution of the HAB outbreak, which will help to increase the accuracy of water quality predictions for coastal hydro-environment management. These two methods are mentioned below on which this study were done are mentioned below:

(1) Artificial Neural Networks (ANN) - It is used to achieve quick response with satisfactory results.

(2) Super Vector Machine (S V M) – It is used to identify the optimal model.

2.2 A simple approach of groundwater quality analysis classification & mapping

This study evaluated the quality of ground water and used mapping to determine if the water is potable or not, which is particularly helpful for metropolitan areas. Any dangerous organism may be easily located and eliminated as soon as possible with the aid of mapping. Groundwater is an essential supply of water for home purposes like drinking, farming, and other domestic uses. Yet, as a result of rapid population growth, industrialization, and slack enforcement of environmental laws and regulations, both the quantity and quality of this irreplaceable source of water have decreased. There were a number of choices, however this study used a simple methodology to evaluate, classify, and map the quality of groundwater used for potable use in an urban region in Pakistan (Peshawar valley). Over 100 samples of groundwater were collected, and physio-chemical factors were assessed in a lab. Hierarchical clustering analysis (HCA) and classification and regression tree (CART) analysis were sequentially applied to the groundwater quality data in order to identify potential clusters/groups (groundwater quality classes), extract the threshold values of the clusters, classify and map the groundwater quality data. The majority of places didn't have the best groundwater quality. This study offers a simple technique for classifying groundwater quality according to a variety of aesthetic criteria, which might assist decision-makers in developing and defending laws and/or policies to manage groundwater resources.

2.3 Applicability of Python Programming in Civil Engineering

In this study, Python Programming is used to analyses the R.C.C Design of structures and Seismic analysis is also done with the help of python. Because reinforced concrete structures make up the majority of construction projects in India, civil engineering students often focus on designing reinforced concrete structures as a potential career path.

It is essential to use computer tools for structural analysis and

design with enlarged underlying setups. There are many commercial tools available for designing concrete structures, but they are expensive and only allow for a small number of users. Before being implemented in a design, any software program contains underlying assumptions that must be understood. As is routinely done in the majority of planning organizations, creating one's own projects for a structure's plan is wise, whether using a Computer program like MS-Excel or not. The only drawback of these systems is their high cost and undeniable lack of customizability or adaptability for specific needs. Because of its programming simplicity, Python has become the most popular language for computer programming above other dialects. In this study, we attempted to provide a review of the usage of Python in civil engineering with a particular emphasis on the benefits of Python over existing methods of parameter computing.

2.4 Assessment of groundwater quality in Meerut city, India

In this study, the quality of ground water was assessed in some selected industrial areas of Meerut city in northern India. To analyze the quality of ground water, water samples were collected from 30 hand pumps and from 30 tube wells in the year of 2011 and 2012 from the different selected locations in Meerut city. Then these collected samples are analyzed according to the standard methods and by standard tests. Water Quality Index was also calculated in this study.
This study highlights that almost 50% of collected water samples in the year of 2012 and 53.3 of collected water samples in the year of 2011 were non-potable and the water quality index of hand pump's collected water sample is lower than the water quality index of tube well's collected water sample which means tube well having the better quality of groundwater than the hand pump's quality of groundwater.

2.5 Prediction of water quality based on the techniques of machine learning

One of the most vital natural resources for all earth's living organisms is water. To the protection of the ecosystem and for the stability and conservation of the environment, it is the crucial to monitor the quality of treated waste water outflow. Collecting and examine the water samples in the laboratory, it takes too much time & energy.
Many machine learning techniques, including Multivariate Linear Regression (MLR), Artificial Neural Networks (ANN), Super Vector Machine (SVM), etc., have been suggested in recent years to detect the problem. The complicated linear and non-linear correlations in the quality of water dataset, however, prevent a linear regression analysis from providing an accurate quality of predicted water.
It has been demonstrated that the adaptive neuro - fuzzy inference system (ANFIS) is a useful tool in constructing the complex linear and non – linear relationships that datasets conceal. Although the ANFIS model can accurately estimate water quality, it has several limitations. Initially, the training dataset's size shouldn't be smaller than the number of training parameters. Secondly, the data of testing dataset should not have reflected to the data of training dataset, otherwise the ANFIS models may produce out of range errors. Finally, there must be a good relation between the input and the target parameters. If there is little association, the hidden relationship cannot be effectively formulated by the ANFIS model.

2.6 Ground water quality assessment in central India

Rice crops are frequently irrigated using groundwater. In many parts of the country and the world, excessive groundwater use results in water quality degradation (i.e., a sharp rise in conductivity, hardness, ion and metal levels, etc.). This article discusses the groundwater quality in the densely populated region of Saraipali, Chhattisgarh, Central India. Because of its sodic composition, the water has a very high electrical conductivity. The mean (n = 30) concentrations of F-, Cl-, NO3-, SO42-, NH4+, Na^+, K+, Mg2+, Ca2+, and Fe in the water were, respectively, 1.2 0.2, 98 31, 46 15, 56 9, 19 4, 206 25, 9.2 2.3, 39 6, and 114 19 mg/L. Using the factor, the sources of the contaminants are distributed. The suitability of the groundwater for irrigation and drinking is assessed.

2.7 Analysis of groundwater quality

It is crucial to have access to clean water for drinking. Finding locations with declining groundwater quality is crucial since there has been a recent lack of clean drinking water. In the Alappuzha district of Kerala, this discovery led to the research of groundwater quality close to the industrial estate of Aroor Gram Panchayat.
The selected location exhibits a recent drop in groundwater quality. Groundwater quality has come under increasing scrutiny due to inappropriate methods of toilet waste disposal, the discharge of industrial effluents, and unclean sewage.

2.8 Response spectrum analysis of tall building using python programming

Response spectrum is a crucial tool for earthquake study and building design. With regard to large and tall constructions, design accuracy and precision become crucial. In order to perform such sophisticated computations, a lot of consulting structural engineers and construction firms have started using a variety of user - friendly software during the past few years. With this research, we attempt to use Python v3.7 as a programming language for the dynamic analysis of a building using the response spectrum approach in accordance with Indian norms. 1893:2002: Part 1. The results from ETABS are compared to a sequence or results received.

2.9 An exploratory data analysis process on groundwater quality data

Finding relevant data from enormous data sets is the goal of one of the most fundamental and exciting areas of research known as data mining. Massive open information resources are

altering how people do logical investigation. Data Science biological system and machine learning structures can be used by partners of various kinds to make use of those information assets. The purpose of this study is to share our experience with using exploratory data analysis as a tool to promote teamwork and the development of hypotheses while evaluating ground water quality. Several research hypotheses for future study were generated by the exploratory data analysis carried out in those use case studies. This study is an excellent example of how exploratory data analysis with Python can be used to generate hypotheses in a data science approach. Despite the fact that the study being described is for ground water quality analysis, the technique and experience can be applied to various fields.

2.10Assessing the Groundwater Quality using Geographical Information System (GIS)

Our nation's groundwater resources include groundwater as a vital component. It is crucial to providing the different user sectors of the nation with the water they need. The natural resource cannot be used and maintained in an ideal manner without first examining the quality of the water. The current study investigated the impact of mining activities on groundwater quality in the 530 sq. km. region surrounding the Korba coalfields in the Indian state of Chhattisgarh, which is situated between latitudes 22°15′ and 22°30′N and longitudes 82°15′ and 82°15′E. For the study, maps, toposheets, water quality data, well locations, mining lease areas, village sites, and other information are gathered. The information stated above was compiled from a number of Chhattisgarh government organisations.

Following data collection, a base map has been produced using ArcMap 9.3. Before being used as an attribute database to produce maps showing the distribution of various water quality parameters, the water quality database is evaluated. The water quality index has been calculated using a variety of variables, including pH, turbidity, total hardness, chloride, total dissolved solids, calcium, nitrate, iron, and fluoride.

Moreover, a map of the Water Quality Index is produced. The data are presented as maps to help the reader better understand the current water quality situation in the study area. According to research, the groundwater in the area needs to go through a special treatment process before being utilized.

3. Methodology

Groundwater is a critical natural resource that plays a vital role in sustaining life on Earth. It is a key component of the global water cycle and provides drinking water for millions of people worldwide. Groundwater analysis is essential for understanding the health of this resource and ensuring its sustainability. With the increasing availability of data and computational resources, Python programming has emerged as a powerful tool for analyzing and visualizing groundwater data. This review paper explores the various methodologies and applications of Python programming in groundwater analysis. Groundwater analysis typically involves collecting water samples from wells or springs, and analyzing them for various parameters such as pH, conductivity, dissolved oxygen, total dissolved solids, and specific contaminants. Python can be used to analyze and visualize this data in a variety of ways. Here are the general steps for analyzing groundwater data with python shown in fig.1:

- Import data: Import the data into Python using a library such as Pandas or NumPy.
- Data cleaning: Clean the data by removing any irrelevant or incomplete data points.
- Data exploration: Explore the data using descriptive statistics such as mean, median, and standard deviation.
- Data visualization: Visualize the data using libraries such as Matplotlib, Seaborn, or Plotly.
- Statistical analysis: Perform statistical analysis on the data using libraries such as SciPy or StatsModels.
- Machine learning: Apply machine learning algorithms such as regression or clustering to identify patterns or predict future trends.
- Reporting: Present the findings using interactive dashboards or reports.

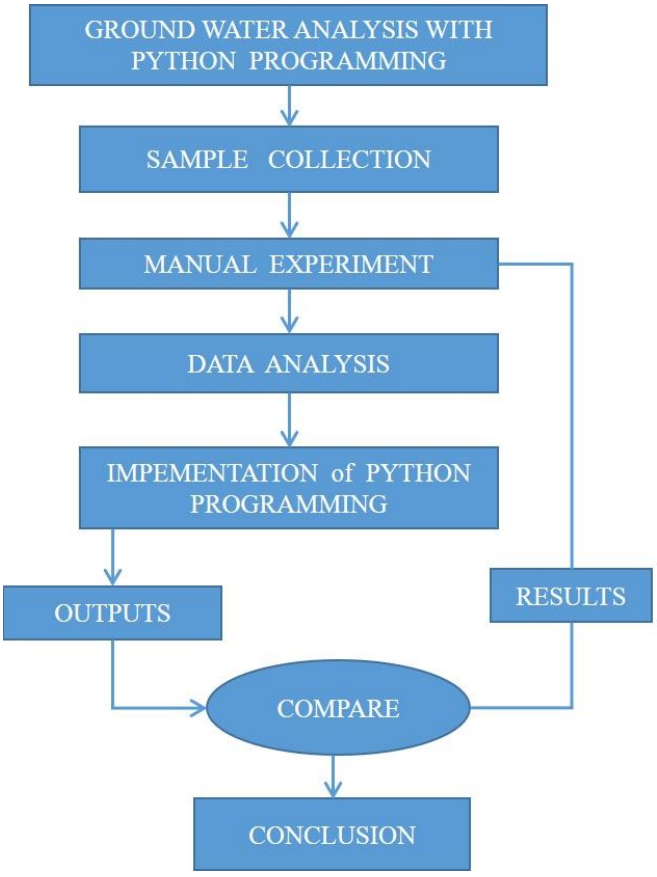

Figure 1: Flow chart for groundwater analysis

Here are some specific examples of how python can be used for groundwater analysis:

- Analyzing trends in groundwater levels over time using time-series analysis techniques such as auto regression or moving averages.
- Identifying relationships between groundwater quality parameters and environmental factors such as temperature, rainfall, or land use using correlation or regression analysis.
- Creating interactive maps of groundwater quality using libraries such as Folium or Plotly.
- Predicting the possibility of groundwater contamination using machine learning algorithms like decision trees or neural networks based on environmental and geological parameters

Overall, Python provides a powerful and flexible platform for analyzing and visualizing groundwater data, allowing researchers and practitioners to gain insights into groundwater systems and make informed decisions about water resource management.

4. Conclusions and future scope

Due to a variety of variables, the globe now forewarns quickly and dynamically. All engineering departments are impacted by machine learning and AI, but civil engineering is particularly affected. This research work analyses the quality of ground water in a crucial way for future work using python programming. In this study the useful tool which means python programming is playing the most vital role to analyses the data. The collected data which is used to check the quality of ground water is broadly divided into three categories such as training, testing and validation in this research. This study can help us to save the life of the human beings as well as animal's life at on higher level. This study generates output with less time consuming which is helpful for us to find out the harmful elements such as pH, chloride, fluoride, turbidity, hardness, nitrate, total dissolved solids (TDS), alkalinity etc. through which we can take action against these harmful contents and then our quality of ground water can be improved as soon as possible. The death rate which gradually increased by the water borne diseases can be reduced at on higher level. In this study the output which is given by the python programming compared the values which are mentioned in the Indian Standard Code IS10500:2012. Like other engineering departments' specialties, civil engineering has applications for data science. The most popular programming language used in data science is Python. The new graduated persons are confronting the boosting of python programming in process of teaching and learning. Execution of python programming in all the fields will upgrade the analytical skills in every field's students.

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