WATER QUALITY AND ITS RELATIONSHIP WITH LOCAL GEOLOGY: A CASE STUDY OF KHANPUR AREA, KHYBER PAKHTUNKHWA, PAKISTAN

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ABSTRACT

This study deals with Water quality and its relationship with geology of Khanpur area Pakistan to assess the impact of human activities on groundwater quality and contribute to the understanding of hydrogeology and the interaction between local geology and water quality. Twenty-eight water samples were collected from different locations, and their physical and chemical parameters were analyzed in the laboratory. Physical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), salts, turbidity, and temperature, were measured using a calibrated digital meter. The chemical parameters examined included chlorides, carbonates, total hardness, total alkalinity, calcium and magnesium. The pH is affected by the chemical composition of the water and the presence of calcium carbonate in rocks such as sandstone, limestone, and dolomite. Electrical conductivity (EC) is determined by dissolved salts, including sodium, calcium, and chloride ions, with certain volcanic rocks exhibiting high conductivity. Total dissolved solids (TDS) concentrations depend on the types of rocks, with limestone or gypsum contributing higher mineral concentrations. Salt concentration is influenced by geological conditions, with sedimentary rocks having varying salt content and igneous rocks generally having low levels.Water temperature is influenced by sedimentary rocks with low thermal conductivity, such as shale or siltstone, and by higher elevations in mountainous regions. Turbidity is primarily affected by sediment runoff, organic matter, and human activities. Chloride concentration is influenced by rock types like limestone and granite, while high sodium concentrations can be found in evaporite deposits occurring in arid environments. Sodium bicarbonate can be released by rocks like limestone, dolomite, and marble, leading to higher levels of sodium carbonate in groundwater. Hardness levels are impacted by limestone and dolomite, which dissolve calcium carbonate and magnesium carbonate into the water. Alkalinity is affected by rocks containing calcium carbonate. Calcium and magnesium levels are influenced by various rock types, weathering processes, metamorphic activities, and the presence of calcium magnesium carbonate in carbonate rocks. These geological factors play a significant role in determining the characteristics of groundwater.

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With the blessings of the Almighty, we have successfully overcome yet another challenging task.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Rationale

Fresh water is essential for your health. Drinking water can prevent dehydration, it can cause change in health, mood change, cause your body to overheat, and lead to constipation and kidney stones. Water is the only drink that contains no calories, which means that it can help manage body weight by reducing calor Sie intake when consumed in place of drinks that do contain calories, such as sweet tea, regular soda, or other high-calorie beverages. (Water and Healthier Drinks, 2016). Access to clean and fresh drinking water is not just a vital necessity for a healthy life, but it is also considered a basic human right. After air, water is the second most crucial natural resource required for survival. Just like all other living organisms on the planet, humans rely on water as the primary component of life. Considering that the human body is composed of around 70% water, it is essential to consume fresh water to maintain this balance and keep the body hydrated. (Rehman, 2020)) Despite water being essential for life, only less than 1% of the world's water is freshwater, whether it comes from groundwater, surface water, rivers, lakes, streams, or glaciers, and everyone on the planet competes for this scarce resource. Both surface and groundwater are susceptible to the harmful impacts of water pollution, which can result from natural sources such as ore deposits and rock denudation or human activities such as wastewater, industrial processes, mining, agricultural practices, and the use of chemicals. Water pollution can cause adverse effects on human health, leading to illness, as well as financial losses in agriculture due to pollutants and the use of highly chemical fertilizers that may affect crops. The concern regarding access to fresh and clean water has gained significant attention in recent years, leading to the development of various water purification methods that remove unwanted chemicals, pathogens, unwanted elements, and debris from raw water. (Khan 2013). It is essential to note that water that appears fresh and uncontaminated can quickly become severely polluted due to a range of factors such as accidents, negligence, or natural events and processes. The chemical composition of both ground and surface water sources illustrates the connection between rock or soil and water quality. In many regions, the interplay between rock, soil, and water serves as a significant source of groundwater pollution.

1.2 Study area

The Khanpur area is a significant dam in Pakistan, boasting a storage capacity of over 100,000 acre-feet. Its construction was completed in 1983, creating a surface water reservoir with a maximum depth of 267 feet. One of the primary concerns regarding the dam is the delicate geology of the abutments, which leads to significant water losses due to seepage. This seepage results in an extraordinary recharge of groundwater in downstream areas. Unfortunately, the shallow aquifers in these areas are frequently contaminated due to industrialization and urbanization (Oliver & Lernerand Tellam, 1999; 1999 1992). Numerous studies conducted by researchers in the Dhamrah Kas Basin have unveiled the existence of a multi-layered aquifer system with a thickness of 400 feet and covering an area of 250 square kilometers. Unfortunately, the shallow aquifer layer is contaminated with regards to microbiological and other pollutants, exceeding the World Health Organization's guidelines. (Whitehead, 2008, 1984, 1999; Malik, 1995).An investigation was carried out to study the hydrogeology and its application for the protection of groundwater in the Dhamrah Kas Basin and the results indicated that a multi-layered aquifer system spread over an area of approximately 150 square kilometers exists. This was confirmed by 30 test holes and 10 dug wells that extended to depths of 300-600 feet. The aquifer is classified as a multilayered semi-confined fresh body, with an average well capacity ranging from 200-350 gallons per minute. In another study, 30 water samples were collected to investigate the microbiological contamination in the groundwater of the Wah Cantonment area. Of the 30 samples, 20 were collected from the unconfined shallow aquifer and 10 from the deep aquifer. (Ahmad, 2012) Researchers found that the average nitrate concentration in the unconfined shallow aquifer was higher than the World Health Organization's (WHO) permissible limit of 50 mg/L, reaching up to 83.3 mg/L. However, the deep aquifer had nitrate concentrations below the permissible limit. This indicates that the shallow aquifer is vulnerable to nitrate contamination due to human activities such as fertilizer use and wastewater disposal, while the deep aquifer remains relatively safe. The study recommended the implementation of proper agricultural and waste management practices to prevent nitrate contamination in the shallow aquifer and protect the groundwater resources in Wah area. (Khan, 2012) Seems that the impounding of Khanpur area reservoir may have had an impact on the water recharge and groundwater quality of Dhamrah Kas Basin. The researcher is conducting a Ph.D. research project to investigate the effects of the dam on groundwater quality, especially in the deeper horizon the basis of analysis from 27 dug wells and 3 tube wells revealed that 26% wells related the shallow aquifer in the area is highly contaminated with microbiological and nitrate pollutants, while the deep aquifer remains uncontaminated. The researcher also suggests management measures to protect and rehabilitate the contaminated aquifer.

Figure 1. 1 Map showing study area

1.3 Previous work

This study was conducted in order to perceive the water quality and microbial characterizations of Rawal and Khanpur area Dams that supply water to Rawalpindi. Water samples were collected at five points of the Rawal and Khanpur area dams from March to May 2019 with the furthest sampling points upstream situated at the Korang and Haro rivers entering into Rawal and Khanpur area dams. Water samples were obtained from various sites for physicochemical, microbiological examination, and heavy metals analysis. Different physico-chemical constraints together with pH, Total dissolved solids (TDS), Conductivity, Chlorides (Cl-), Florides (F-), hardness, and alkalinity were measured by standard methods. Atomic absorption spectroscopy was used to assess heavy metal concentrations such as arsenic (As), chromium (Cr), iron (Fe), lead (Pb), and nickel (Ni). The Standard Plate Count (SPC) method was employed to calculate the total viable count and total coliform count in water tasters. Different bacteriological colonies were extracted from water samples and identified using various biochemical assays, including Gram staining. The results indicated that several physicochemical parameters including pH, TDS, Cl-, F-, COD, and heavy metals such as As, Cu, and Fe were within World Health Organization (WHO) guidelines (Saima Akbar).

There were 42 samples (20 of soil and 22 of water) collected along the Haro River and Khanpur area in the autumn season after rain. (Saima Akbar)ArcGIS 9.3 software and 3D Analyst extension were used to interpolate the collected samples. It was found that water pH was in the range of 6.94 to 8.11 while EC dsm-1 was from 0.19 to 0.41 which was within the normal range having no salinity and sodicity hazard. Water is fit for irrigation. Soil data showed that pH was in the range of 7.2 to 8.32 and EC dsm-1 in the range of 0.04 to 1.166, while soil texture was sandy clay loam to sand type. Whereas all the soil in the study area was mostly calcareous. Organic matter was deficit in most of the soil samples. It was found that the remote sensing, GIS and GPS survey techniques were also very useful to identify and analyze the trends of soil and water parameters (Rehana Jamal), (Phytodiversity and plant life of Khanpur area dam, Khyber Pakhtunkhwa, Pakistan). The present study was aimed to record the flora of Khanpur area Dam, Khyber Pakhtunkhwa, Pakistan. For this purpose, the whole area was surveyed during 2009 to 2010 for the collection of plant specimens. A total of 221 plant species of 169 genera and 66 families were recorded from the study area, including two ferns, one gymnosperm, 39 monocots and 179 dicots (Rahmatullah Qureshi).

The study has focused on the status of weed herbaceous flora of the Khanpur area having moderate climate (Bashir et al., 2016) located at 33.7689 º N and 72.2453 º E (Khan et al., 2012). The dam was built to account for drinking purpose for twin cities of Islamabad and Rawalpindi and for irrigation purpose of Khyber Pakhtunkhwa (KP)(110 cusecs) and Punjab (87 cusecs) provinces, with storage capacity of 106,000-acre feet and 167 m height (Mr. Asim Rauf Khan, 2013), (Ejaz et al., 2012). Dam built on Haro River is fed by four tributaries i.e. Lora Haro, Stora Haro, Neelan and Kunhad (Khan et al., 2012). The aim of the study was to use ordinal techniques for studying weed status and impact of soil parameters over growing weeds (Hafsa Bashir).

1.4 Problem statement

In Khanpur, Pakistan, researchers have devoted considerable attention to studying the structural analysis of the Kanpur area, specifically examining the various formations and carbonate faces present in the region, as mentioned above as mentioned above in previous work and in different formations in following. Extensive efforts have been made to comprehend the geological complexities, fracture patterns, and overall structural characteristics of this area. This research has yielded valuable insights into the composition and formation of rocks, as well as the tectonic forces that have shaped the landscape. However, despite the significant focus on structural analysis, there has been a noticeable dearth of research in the field of hydrology. Hydrological studies, which investigate the distribution, movement, and quality of water in a particular area, play a crucial role in understanding local water resources and potential hazards. Unfortunately, the Kanpur area has not received the same level of attention when it comes to hydrological investigations (Saima Akbar, Aleena Nazir, Shoukat Ali Shah).

Acknowledging this knowledge gap, our study aims to bridge this divide by conducting comprehensive hydrological research in the Khanpur area. We endeavor to analyze various factors, including rainfall patterns, surface water flow, groundwater levels, and water quality. Through these investigations, we aim to gain a comprehensive understanding of the hydrological dynamics in the area, providing insights into water resources and identifying potential risks or challenges (Mr. Asim Rauf Khan). The significance of this research lies in its potential to inform decision-making processes pertaining to water resource management, land use planning, and disaster risk reduction. Understanding the hydrological characteristics of the Khanpur area is vital for promoting sustainable development, ensuring the availability of clean water, and mitigating the potential impacts of floods, droughts, and other water-related hazards (Hafsa Bashir). Through our study, we aspire to contribute to the existing body of knowledge and fill the current gap in hydrological research in the Kanpur area of Khanpur, Pakistan (Khan, 2013).

1.5 Aims and Objectives

The aims and objectives of this study are as follows:

i. To analyze the drinking water quality of Khanpur and surrounding area
ii. To determine and correlate the impacts of local Geology on drinking water quality of the study area

1.6 Methodology

1.6.1 Field work

Khanpur area, situated at approximately 26° 59 '53.01"N, 67° 41' 32.29"E , UTM 370°247°57 E and UTM 29°868°92N. The identified outcrops in the Khanpur area represent different geological eras, including the Paleozoic, Mesozoic, and Cenozoic. Moreover, the lithology of the outcrops in the Khanpur area encompasses a wide range of rock types, including sedimentary, igneous, and metamorphic rocks. The varying lithological compositions reflect the diverse geological processes that have shaped the area over millions of years. The collection of water samples from this region contributes to understanding the quality and health of the water bodies.

1.6.2 Water sampling

The methodology of this research involved gathering water samples from various ground and surface water sources such as fresh springs, tube wells, tap water from bore and water filtration plants. A total of 28 samples were collected and their exact locations were recorded using a mobile phone's Global Positioning System (Google Maps). The samples were collected in 250 mL plastic bottles that were rinsed three times with the water being sampled to prevent contamination. The bottles were immediately sealed after collection to avoid air exposure. Proper precautions were taken during the sampling process, including wearing gloves and ensuring that the bottle caps were tightly sealed to prevent leakage and exposure. The labeled bottles were then transported to the laboratory for multi-element analysis and spatial analysis of the data was also performed. This methodology aims to provide reliable and accurate data for making informed decisions about water quality.

Figure 1. 2 Map showing study area and sampling point and points sample collected (Goggle map link)

Table 1. 1 Sampling collection locations

S. No	Latitude (Decimal degrees)	Longitude (Decimal degrees)
1	33.8136	72.9163
2	33.8141	72.91500
3	33.8138	72.91444
4	33.8136	72.9147
5	33.8133	72.91138
6	33.8126	72.9088
7	33.8127	72.9099
8	33.8136	72.9163
9	33.8137	72.9164
10	33.8125	72.9086
11	33.8122	72.9052
12	33.8127	72.9127
13	33.8041	72.9066
14	33.8147	72.9055
15	33.8125	72.9088
16	33.8127	72.9121
17	33.8122	72.9055
18	33.8044	72.9066
19	33.8147	72.9052

1.6.3 Laboratory Method

The laboratory work was conducted in two stages. During the first stage, the physical properties of the water samples were tested, including color, pH, electrical conductivity (EC), total dissolved solids (TDS), salts, turbidity and temperature. The second stage involved testing the chemical properties of the samples, such as the levels of sodium, chloride, NaCl, calcium, carbonates, total hardness, alkalinity and Magnesium Content. Various analytical techniques were employed for testing and more detailed explanations can be found in subsequent chapters. The laboratory work was carried out with utmost care to ensure accuracy and methods such as averaging and repetition were utilized to enhance the precision of the results

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CHAPTER 2

STRUCTURAL AND HYDROGEOLOGICAL SETUP

2.1 Introduction

Hydrology is the study of the distribution, properties and effects of surface water, underlying rocks, soils and the atmosphere. However, even studying a small aspect such as the relationship between precipitation and surface runoff can be imprecise due to the complexity of the hydrological cycle. Factors such as climate change, including changes in precipitation patterns and temperature, as well as human activities have a significant impact on hydrological processes. For instance, Pakistan saw a considerable increase in annual precipitation between 1901 and 2007, along with changes in monsoon and winter precipitation. It is crucial to take into account the potential impacts of future changes when planning for long-term water resources. Understanding the hydrologic process of a watershed is essential for predicting floods and managing watershed development sustainably. However, modeling hydrological processes can be challenging due to uncertainties and the need to compare catchments with different characteristics. The comparative hydrology approach uses large datasets to identify similarities and interpret them in terms of climate change and human activities within watersheds. In the Khanpur area watershed, deforestation from illegal wood cutting, extensive grazing and rapid urbanization over the past few decades have also affected hydrology. This study examines the effect of precipitation on the surface flows of the Haro River in Khanpur area, Pakistan using rainfall-runoff software and Horton’s and Strahler’s methods to determine various watershed characteristics. The goal of the study is to predict hydrological changes and precipitation and to identify the behavior and structural disturbance of the watershed based on various morphological parameters.

2.2 Geological structures

The geological setting of the area around Khanpur area is characterized by the presence of rocks from the Siwalik Group, which are part of the Himalayan orogenic belt. The Siwalik Group consists of a series of sedimentary rocks that were deposited during the Neogene period (23-2.6 million years ago) in a foreland basin situated between the rising Himalayas and the stable Indian craton.

In the Khanpur area, the Siwalik Group is primarily composed of sandstones, conglomerates and clays. The sandstones are coarse-grained and contain angular to subangular pebbles and cobbles of minerals such as quartz and feldspar. The conglomerates consist of well-rounded sub angular clasts of minerals like quartz and feldspar embedded in a sandy matrix. The clays are mainly made up of smectite and Illite minerals. These rocks were deposited in a fluvial environment, meaning they were formed by the action of rivers and streams. The sandstones and conglomerates represent channel deposits while the clays represent floodplain deposits.

The Siwalik Group rocks in the Khanpur area have been deformed due to tectonic activity associated with the Himalayan orogeny. The rocks have been folded, faulted and uplifted, resulting in a complex structural setting. Khanpur area was constructed in a narrow gorge within the Siwalik Group rocks, providing a suitable location for building a concrete gravity dam. The dam's foundation was excavated in sandstones and conglomerates which were found to be strong and competent. However, during construction some issues arose due to weak zones and faults in the foundation rocks. These were addressed through grouting and other measures to ensure the dam's stability.

2.3 Hydrogeological Setting

Khanpur area is situated on the Haro River, approximately 40 km from Islamabad, Pakistan's capital city. It serves multiple purposes including water supply, irrigation and hydroelectric power generation. The dam is a concrete gravity type with a height of 51 meters and a length of 167 meters. Its reservoir has a capacity of 110,000 acre-feet and a maximum depth of 50 meters. The dam was completed in 1983 at a cost of around 1.3 billion Pakistani rupees.

The dam has four radial gates used to control the water level in the reservoir and a spillway with a capacity of 58,000 cusecs for releasing excess water during floods. It also has a powerhouse with a capacity of 72 MW that generates electricity for the national grid. The Haro River is the primary source of water for Khanpur area with a catchment area of approximately 2,400 square kilometers and an average annual rainfall of about 1,100 mm.

The inflow to the reservoir depends on rainfall in the catchment area and water demand for irrigation and other purposes. Water is released from the reservoir through turbines in the powerhouse for electricity generation and downstream irrigation. Khanpur area is an important source of water for Islamabad and Rawalpindi as well as surrounding agricultural areas. It has played a crucial role in regional development by providing water for domestic, agricultural and industrial use.

The Khanpur area has a multi-layered aquifer system composed of unconsolidated sediments and fractured rocks. The aquifer system is recharged by infiltration of precipitation and surface water from the Haro River and its tributaries. It consists of three main layers: an upper layer of unconsolidated sediments such as sands, gravels and clays with a thickness of about 100 meters; a middle layer of weathered and fractured rock with a thickness of about 50 meters; and a lower layer of hard and unfractured rock with a thickness of about 200 meters. The aquifer system is confined by overlying unconsolidated sediments and underlying impermeable rock layers.

Groundwater in the aquifer system flows under artesian pressure towards areas of lower elevation. The groundwater is of good quality with low salinity and high mineral content, making it suitable for domestic and agricultural use. The construction of Khanpur area has impacted the hydrogeological setting of the area by reducing the flow of the Haro River downstream of the dam, resulting in reduced recharge of the aquifer system. However, the dam has also created a reservoir that serves as a source of water for irrigation and other purposes, reducing reliance on groundwater.

The Khanpur area hydrogeological setting is influenced by geological and hydrological factors such as rock types including limestone, sandstone, shale and granite with varying permeabilities that affect water flow through the aquifer system. The presence of fractures and faults in rocks can affect groundwater flow and create preferential pathways for contamination. Proper management of the aquifer system is essential to ensure long-term sustainability of water resources in the area.

CHAPTER 3

STRATIGRAPHY OF STUDY AREA

3.1 Stratigraphy

The geology of the Khanpur area is characterized by a complex stratigraphy that reflects the region's tectonic history and sedimentation patterns. The stratigraphy consists of a series of sedimentary and volcanic rocks that have been deformed and faulted due to tectonic activity. The geology of the Khanpur areasite mainly comprises the Margalla Hill limestone Formation of Eocene age. The river valley at the dam site is filled with thick alluvial deposits and a series of anticline and syncline structures are present in the area. The river at the dam site flows through an eroded anticline while the right and left abutments are synclines. The rock units' strike is day-lighting in the reservoir, where a significant amount of water enters through contact planes and discontinuities, seeping downstream of the dam. Another source of seepage from the Chohae area is uninvestigated, where several normal faults are responsible for substantial water loss through seepage (Khan, 2023).

The lowest unit in the stratigraphy is the Precambrian basement, consisting of gneiss, schist and granitic rocks formed over 500 million years ago. These rocks are highly metamorphosed and have been intruded by granite and pegmatite bodies. The overlying unit is the Lower Paleozoic sequence, comprising a thick sequence of limestone, dolomite, sandstone and shale. This sequence is divided into several formations including the Hazara Formation, Jutana Formation and Khattak Formation which were deposited in shallow marine environments during the Cambrian to Devonian periods over 400 million years ago. The overlying unit is the Upper Paleozoic sequence consisting of a thick sequence of sandstone, shale and coal. This sequence is divided into several formations including the Dandot Formation, Patala Formation and Warcha Sandstone which were deposited in fluvial, deltaic and shallow marine environments during the Carboniferous to Permian periods over 300 million years ago. The overlying unit is the Mesozoic sequence consisting of a thick sequence of sandstone, shale and limestone. This sequence is divided into several formations including the Tobra Formation, Lockhart Limestone and Datta Formation which were deposited in shallow marine environments during the Jurassic and Cretaceous periods over 100 million years ago. The uppermost unit in the stratigraphy is the Quaternary sequence consisting of alluvial and colluvial deposits that have accumulated in valleys and on slopes of surrounding hills. These deposits include sand, gravel, silt and clay formed by erosion and weathering of older rocks. The stratigraphy of Khanpur area reflects its tectonic history and sedimentation patterns providing important insights into geological processes that have shaped its landscape over millions of years. The stratigraphy of Khanpur area comprises a sequence of sedimentary and volcanic rocks that have been deformed and faulted by tectonic activity. The stratigraphic units are divided into formations based on their lithology, sedimentary structures and fossil content.

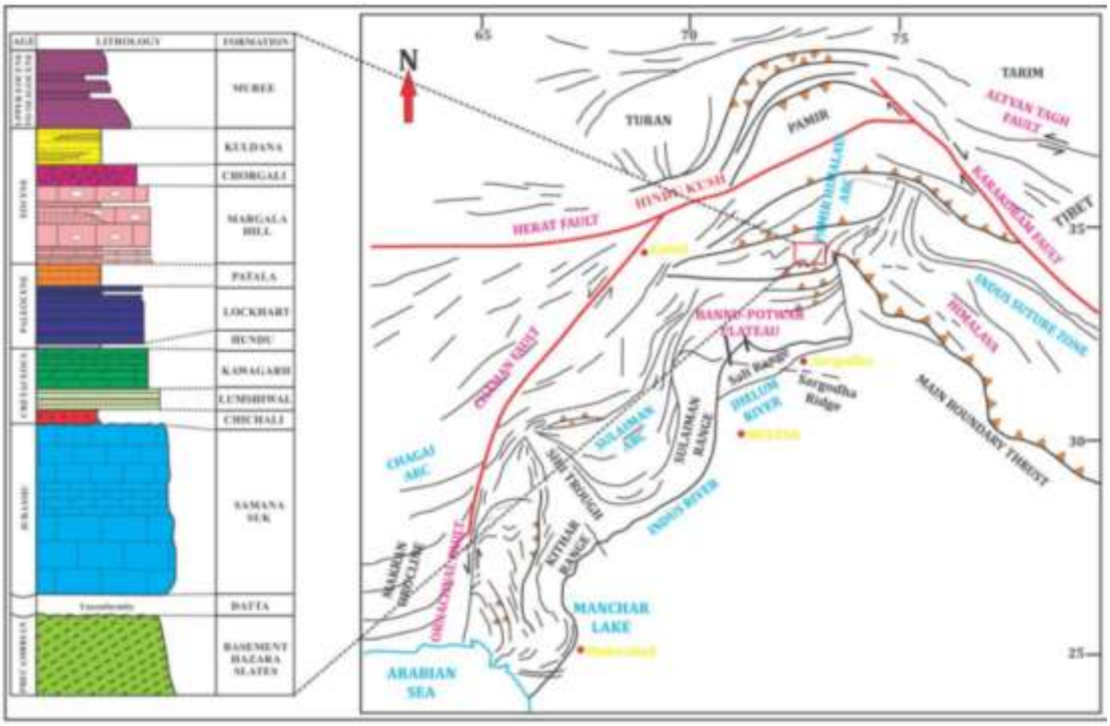


Figure 3. 1 Regional tectonic map of Pakistan and stratigraphic setting of Kahnpur area (Image source)

3.2 Samana Suk Formation

The Samana Suk Formation is a Middle Jurassic formation found in the Kala Chitta Range of the Khanpur area in North Pakistan. It consists of a uniform sequence of thin to thick-bedded bioturbated, cross-bedded, ripple marked, sandy, bioclastic carbonates with shale interbed (Ahmad et al., 2019). This rock unit is considered an excellent example of shallow to marginal marine carbonates due to its significant thickness, enhanced lithological variations and diverse diagenetic features (Ahmad, Z. 1969). To establish a potential link between the sequence stratigraphy and reservoir potential of this rock unit, outcrop and petrographic features were used to identify eight microfacies deposited in a wide range of shallow to marginal marine environments including mudflats, lagoons, back shoals and sand shoals ;(Hussain et al., 2013). Based on the vertical stacking pattern of microfacies during a given time of deposition (170–160 Ma), one second-order local cycle (SLC-1), three regressive systems tracts (RSTs) and two transgressive systems tracts (TSTs) were identified within the succession (Haneef, Hanif, & Swati, 2020). The primary and secondary porosity of selected microfacies from each systems tract were examined using petrography, scanning electron microscopy and energy-dispersive spectroscopy. Direct measurements of porosity and permeability of these microfacies types were performed using high overburden pressure plug porosity and permeability analyses. These investigations revealed that mudstones/wackstone microfacies of RST had higher reservoir potential compared to grainstone microfacies of TST (Hassan, Mustafa, & Ahmad, 2020). The higher porosity within RST and higher interconnectivity of available pores in both RST and TST suggest that the Samana Suk Formation has good reservoir potential (Bashir, H., Ahmad, S.S., Nawaz, M., Shahzad, S., Gishkori, R. and Jawad, Y., 2018).

3.3 Chichali Formation

The Chichali Formation is a significant geological formation located in the Khanpur area of Pakistan. It is a sedimentary rock unit that holds valuable insights into the geological history and paleo environmental conditions of the region. In this article, we will explore the Chichali Formation and its unique characteristics, shedding light on its geological significance. The Chichali Formation is part of the Siwalik Group, which is a sequence of sedimentary rocks primarily composed of sandstones, siltstones, and clays (Ali, Fahad & Haneef, Muhammad & Anjum, Naveed & Hanif, Dr Muhammad & Khan, Suleman. 2013). This group is well-known for its fossil-rich nature, providing crucial information about the flora and fauna that existed in the region millions of years ago. Geologically, the Chichali Formation is believed to have originated during the late Miocene to early Pliocene epochs, approximately 7 to 4 million years ago. It represents a period when the area was characterized by extensive fluvial and lacustrine environments, indicating the presence of rivers, lakes, and associated floodplain systems (Haneef, M., Khan, M. A. 2011). The sedimentary rocks of the Chichali Formation bear witness to the ancient depositional processes that occurred in the region. The sandstones, for instance, indicate high-energy environments with strong river currents, whereas the siltstones and clays point towards low-energy conditions such as calm lakes or stagnant water bodies. These sediments were gradually deposited over time, resulting in the layered structure visible in the formation today. One of the remarkable aspects of the Chichali Formation is its fossil content. Numerous plant and animal fossils have been discovered within its strata, providing valuable information about the past ecosystems and climate. Fossilized leaves, stems, and seeds of various plant species have been found, allowing scientists to reconstruct the vegetation that once covered the area. Additionally, the remains of small mammals, reptiles, and fish have been unearthed, offering insights into the diverse range of fauna that inhabited the region during that time. It is composed of sedimentary rocks with a diverse fossil record, shedding light on ancient plant and animal life. Ongoing research aims to further refine the formation's age and explore its hydrocarbon potential (Iftikhar, M., Bakht, B.K., Yasar, E.A., Tabinda, A.B. and Anwar, M.N., 2019).

3.4 Lumshiwal Formation

The Lumshiwal Formation is a geological formation located in Pakistan. According to a USGS Bulletin, within the Lumshiwal Formation, three major lithofacies were identified: two sandstone types (sandstone lithofacies A and B) and a combined facies made up of mudstone, claystone, carbonaceous shale, and coal beds (combined lithofacies). Additionally, there is a minor carbonate lithofacies made up of arenaceous limestone. These lithofacies are generally defined based on grain size, clay content, and depositional bedding characteristics. In the Khanpur areasection, the Lumshiwal Formation is thin and cannot be divided, while the Chichali Formation is absent. The Samana Suk and Kawagarh formations are thickly exposed along the Khanpur areaThrust and Khanpur areaThrust. These formations provide valuable insights into the geological history of the region and have the potential to reveal important information about the area's natural resources (Wadood, B., Khan, S., Li, H., Liu, Y., Ahmad, S. and Jiao, X., 2021).

3.5 Kawagarh Formation

The Kawagarh Formation is prominently visible in various sections of the Hazara basin (Ramkumar et al., 2019), (Wendte et al., 2009) However, its deep depositional settings make it less attractive to geologists for exploration as a hydrocarbon reservoir. This study examines the diagenetic settings of the Kawagarh Formation in chronological order to understand its diagenetic history and how different diagenetic phases affect its reservoir potential (Ronchi et al., 2012), (Sirat et al., 2016).The process of dolomitization is also thoroughly investigated as a key indicator of its reservoir potential (Haeri-Ardakani et al., 2013). Samples from the Kawagarh Formation were collected at the Khanpur areaSection for porosity analysis, taken randomly from both limestone and dolomite facies (Ahmed, W. (1986. The dolomites appear as veins and well-developed thick beds and are secondary in nature, hosted by fractures and joints in limestone, affecting approximately 25% of the limestone facies (Mansurbeg et al., 2016. Different types of dolomites were identified based on color and texture at the outcrop scale, including yellowish fine-grained, brownish-blackish coarse-grained at the top portion, and saddle dolomites. Petrographic analysis revealed both partial and complete dolomitization. Dolomites were classified into different types based on crystal size and geometry: (1) fine crystalline planar-euhedral dolomite, (2) medium crystalline planar-subhedral dolomite, (3) medium crystalline non-planar-anhedral dolomite, (4) coarse crystalline planar-subhedral dolomite, (5) coarse crystalline non-planar-anhedral dolomite, and (6) saddle dolomites (SD1) (Alqattan and Budd, 2017), (Blanchard et al., 2016). High levels of inclusions and disturbances were observed on the surfaces of dolomitic rhombs in petrographic analysis, indicating low Mg replacement or dolomitization phenomena. Image J porosity analysis revealed porosity in both limestone and dolomitic samples. Non-laminated mudstone in limestone facies had very low porosity, up to 2-3%, in the form of vugs and fractures (Rahman et al., 2016). In contrast, porosity in dolomitic facies ranged from 5% to 14%, with most samples having around 5% porosity. Structural analysis and examination of other carbonate formations suggest that this dolomitization occurred along the Khui da Maira fault in the Kawagarh Formation (Ramkumar et al., 2019), (Sirat et al., 2016). Near the fault, dolomites appear irregularly, but as one moves away from the faulted section, they become horizontal veins and beds. A model of dolomitization has been developed to better understand this phenomenon (Wadood, B., Aziz, M., Ali, J., Khan, N., Wadood, J., Khan, A., Shafiq, M. and Ullah, M., 2021).

3.6 Lockhart Limestone:

The Lockhart Formation is a significant carbonate unit of the Paleocene Charrat Group in the Upper Indus Basin of Pakistan. It comprises a larger foraminiferal-algal build-up that was deposited in a cyclic sequence on the carbonate ramp. The foraminiferal-algal assemblages of the Lockhart Formation are correlated with the larger foraminiferal biostratigraphic zone, specifically the Shallow Benthic Zone

(SBZ3) of the Thanetian Age. The formation is characterized by three main facies associations: inner ramp lagoon, shoal, and fore shoal open marine, all represented by wackstone and Packstone foraminiferal-algal deposits. These facies are arranged in a cyclic order and exhibit a retrograding carbonate ramp, indicating Thanetian transgressive deposits associated with eustatic sea level rise. The inner ramp lagoon facies is characterized by wackstone and Packstone foraminiferal-algal deposits, as are the inner ramp foraminiferal shoal facies and the fore-shoal open marine facies (Ahmed, W., Gauhar, S.H., and Siddiqi, R.A., 1986).

3.7 Patala Formation

This formation consists of a thick sequence of sandstone and shale. It was deposited during the Permian period, more than 250 million years ago. The Patala Formation is characterized by sandstone and shale with occasional limestone beds, and contains a variety of marine fossils, including brachiopods, bryozoans, and Fusulinids. The formation of Patala in the Khanpur area is an intriguing geological phenomenon that has captivated scientists and researchers alike. Patala refers to a particular layer of sedimentary rock that can be found deep within the Earth's crust in this region. This unique formation has provided invaluable insights into the Earth's history and the processes that have shaped its surface over millions of years. The Khanpur area, located in a geologically diverse region, has a rich and complex geological history. The formation of Patala can be attributed to a series of geological events that unfolded over an extensive period. Millions of years ago, this area was covered by ancient seas and experienced significant tectonic activity. During the process of plate tectonics, the movement and collision of continental plates resulted in the formation of mountains and the uplift of land. As the Earth's crust shifted and folded, layers of sediment accumulated over time. These sediments, comprising sand, silt, clay, and organic matter, gradually settled and compressed, forming the Patala formation. The Patala formation in the Khanpur area consists of various types of sedimentary rocks, including sandstone, shale, and limestone. These rocks have distinct characteristics that offer valuable clues about the environmental conditions that existed during their formation (American Society for Testing and Materials [ASTM], 1986). For instance, the presence of fossilized marine organisms within the limestone layers suggests that the area was once submerged under a shallow sea. Geologists have meticulously studied the Patala formation to unravel the Earth's past. By examining the composition, structure, and age of the rocks, scientists can infer the ancient climate, the depositional environment, and the geological processes that influenced the area. Additionally, the fossils preserved within the formation provide vital information about past life forms, enabling scientists to reconstruct the ecosystem and evolutionary history of the region. The Patala formation of the Khanpur area has not only contributed to scientific knowledge but also has practical implications. The rocks within this formation have significant economic value, as they often contain valuable minerals and hydrocarbon resources. Extensive exploration and extraction activities are conducted to tap into these resources, benefiting both the local economy and broader industrial sectors. In conclusion, the Patala formation of the Khanpur area represents a fascinating geological phenomenon that sheds light on the Earth's history. Through the examination of sedimentary rocks and fossils within this formation, scientists have gained valuable insights into past environments and geological processes (Cecil, C.B., Stanton, R.W., and Dulong, F.T., 1981). Moreover, the economic significance of this formation further underscores its importance in both scientific and practical realms.

3.8 Margalla hill limestone

The Margalla Hills, part of the larger Himalayan mountain system, are a prominent geological feature in northern Pakistan. The hills are composed of various rock formations, with the Margalla Hill Limestone being one of the most significant and prominent among them (Rahman, Maqsood & Ali, Fahad & Hayat, and Muhammad. 2017). This limestone formation has garnered considerable interest due to its unique characteristics and geological significance. The Margalla Hill Limestone is a sedimentary rock that was formed millions of years ago in a marine environment. It consists primarily of calcium carbonate, which accumulated over time through the deposition and compaction of marine sediments. The limestone is composed of fossilized remains of marine organisms such as corals, shells, and skeletal fragments, providing valuable evidence of the ancient marine ecosystem that once existed in the region (Hanif, Dr Muhammad & Imraz, Muhammad & Ali, Fahad & Haneef, Muhammad & Saboor, Abdus & Iqbal, Shahid & Ahmad, Sajjad. 2014). Geologists study the Margalla Hill Limestone to gain insights into the geological processes that occurred during its formation. By analyzing the composition, structure, and age of the limestone, scientists can deduce information about the environmental conditions and climate patterns prevalent during that era. Additionally, the presence of fossils within the limestone helps in reconstructing the past marine life and understanding the evolution of organisms in this region. Furthermore, the Margalla Hill Limestone plays a vital role in the conservation and preservation of the area's natural environment. The limestone formation acts as a natural water reservoir, facilitating groundwater recharge and maintaining a sustainable water supply for the region. It also supports a diverse array of flora and fauna, creating a habitat for numerous species and contributing to the biodiversity of the area. In conclusion, the Margalla Hill Limestone in the Kanpur area of Pakistan stands as a prominent geological feature with significant scientific and practical importance. Its composition, structure, and fossil content provide valuable insights into the Earth's past, aiding in the understanding of geological processes and ancient marine ecosystems. Furthermore, its use as a construction material and its role in environmental conservation highlight its relevance in both economic and ecological contexts.

3.9 Chorgali Formation

The Khanpur area in Pakistan is home to the Chorgali Formation, a distinctive geological feature that has garnered the interest of scientists and researchers. This formation, characterized by its unique composition and geological history, provides valuable insights into the region's ancient past and offers a glimpse into the Earth's geological evolution (Abid, A. I., Abbasi, I. A. 1984). Composed of sedimentary rocks such as sandstone, shale, limestone, and conglomerates, the Chorgali Formation spans a significant area in the vicinity of the Khanpur area Dam. Over millions of years, these rocks were deposited through a variety of geological processes, reflecting the ancient marine environments that once existed in the region. The Chorgali Formation's distinct layers bear witness to the ever-changing environmental conditions that prevailed over time. Sandstone layers indicate periods of high-energy deposition, likely resulting from strong river currents or wave action. In contrast, shale and limestone layers suggest more tranquil and stable marine conditions. The limestone found within the formation is a valuable resource widely used in the construction industry. Its extraction and utilization contribute to the local economy and various sectors such as building materials, cement production, and agriculture. Moreover, the Chorgali Formation plays a crucial role in the region's hydrological system. With its porous and permeable rock layers, it serves as a natural storage and conduit for groundwater. This groundwater is vital for agricultural irrigation and domestic water supply, further emphasizing the importance of this formation. In conclusion, the Chorgali Formation in the Khanpur area of Pakistan is a significant geological feature that provides valuable insights into the region's past and the Earth's geological evolution. Through its composition, layers, and fossil content, it reveals information about ancient marine environments, climate patterns, and geological processes. Additionally, its economic and hydrological importance underscores the multifaceted nature of this geological formation.

CHAPTER 4
METHODOLOGY

Following the collection of twenty eight (28) water samples from different locations, laboratory testing was conducted to estimate and analyze their physical and chemical parameters.

4.1 Analysis of Physical Parameters

The physical parameters were pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Salts, turbidity and Temperature. All these parameters were tested using a digital meter called the PCS Tester 35. Before use, all the apparatus and tools were calibrated properly and readings were repeated thrice and averaged for accuracy.

Figure 4. 1 Digital meter (PCSTester35) for analysis of physical parameter

4.2 Analysis of Chemical Parameter

The chemical parameters of the water samples included chlorides (Cl, Na, and NaCl), carbonates (CO3, Na2CO3, HCO3, and NaHCO3), total hardness, total alkalinity, and calcium.

Figure 4. 2 Titration process perform for the chemical parameters

4.2.1 Chloride

Chloride ions are present in solutions and can enter ground or surface water through both natural and human-related processes. The measurement of chlorides is determined using the titration method, employing the following equation:

$$AgNO_3+NaCl \rightarrow AgCl+NaNO_3$$

$$2AgNO_3+K_2CrO_4 \rightarrow AgCO_3+2KNO_3$$

Indicator used: Potassium Chromate K_2CrO_4

Standard Solution: 0.01N Silver Nitrate $AgNO_3$

End point: Brownish color

Procedure: A burette was filled up to mark with silver nitrate and 10 Ml of sample water was taken in a flask. A few drops of potassium chromate were added to the sample water and titrated against the silver nitrate till color change was noticed from yellow to orange-brown. The burette readings were notes and used to find the amount of chlorides, sodium and NaCl in the samples.

Calculations:

i. Mg Cl/L = V*N*35.45*1000/Sample volume
ii. Mg NaCl/L = V*N*58.45*1000/Sample volume
iii. Mg Na=mg Cl/L – mg NaCl/L
iv. N= Normality of silver nitrate= 0.01
v. V= Volume of silver nitrate used
vi. Sample volume= 10 Ml

4.2.2 Carbonate

Carbonates are created when metal ions with a positive charge react with carbonate ions, which are oxygen atoms bonded to carbon. The determination of CO3, Na2CO3, HCO3, and NaHCO3 was performed using the titration technique.

Indicator used: Methyl Orange

Standard solution: 0.1M HCL

End point: Red color

Procedure: A burette was filled with HCL. 50 Ml of sample along with 2-3 drops of methyl orange were taken in a flask and titrated against the HCL till the end point was observed. The burette reading was noted.

Calculations

i. M1V1=M2V2
ii. M1= Molarity of the whole sample
iii. V1= Sample volume= 50Ml
iv. M2= Molarity of standard solution= 0.1M
v. V2= Burette reading after end point
vi. After M1 is determined then amount of each carbonate can be found by: Amount/dm3= M*molecular weight of carbonate

4.2.3 Total Hardness

Water hardness is commonly defined as the concentration of dissolved calcium and magnesium in water. Hard water contains significant amounts of these minerals. As water passes through soil and rocks, it picks up small quantities of naturally occurring minerals and carries them into the groundwater. This poses a challenge for water systems that rely on groundwater as a source. If the soil surrounding a water-supply well contains calcium and magnesium minerals, households may receive hard water (USGS, 2018). The total hardness was determined using titration, following the procedure outlined below:

Standard Solution: 0.01M EDTA

Indicator: Eriochrome Black T (EBT)

End point: Blue color

Procedure: A burette was filled with EDTA standard solution. 10 Ml of sample water with a few drops of EBT indicator and 20 Ml of ammonium chloride buffer was taken in a flask and then titrated against standard solution till red/purple to blue color change was observed.

Calculations

i. Total hardness: A*B*1000/ Sample volume, Where
ii. A= Amount of EDTA used
iii. B= 0.01M
iv. Sample volume= 10 Ml

4.2.4 Total alkalinity

The alkalinity of water refers to its ability to counteract acidity and is measured based on its capacity to neutralize acids. The presence of bicarbonate, carbonate, and hydroxide ions is the primary factor contributing to alkalinity. In the case of surface water bodies, the alkalinity is mainly influenced by the surrounding rocks and land. When water flows over the terrain and enters a lake, for instance, a significant portion of it comes from precipitation runoff within the lake's watershed. If the terrain contains limestone, the runoff will absorb compounds like calcium carbonate, resulting in an increase in water pH and alkalinity (Water Science School, 2018).

Standard Solution: 0.02N Sulfuric acid H2SO4

Indicator: Methyl Orange

End point: Pink color

Procedure: A burette was filled with standard solution of sulfuric acid up to mark. 50 Ml of sample water was taken in a flask and a few drops of methyl orange were added and titrated against the standard solution till the end point was reached.

Calculations

i. Total alkalinity= Volume of acid *Normality of acid *50000/Volume of sample
ii. Where,
iii. Normality of acid= 0.02N
iv. Volume of sample= 50Ml

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Physical parameters

The research investigation centered around the analysis of various physical parameters, including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salts, Turbidity, and Temperature. These parameters played a crucial role in assessing the quality and characteristics of the studied samples.

To accurately measure these parameters, a highly reliable digital meter known as the PCS Tester 35 was utilized. Before commencing the experimentation, rigorous calibration procedures were implemented to ensure the proper functioning and accuracy of all the apparatus and tools involved in the testing process. This meticulous calibration step was vital in minimizing any potential errors or deviations in the obtained readings. To further enhance the precision of the measurements, each parameter was evaluated by repeating the readings three times. This repetition allowed for the identification and elimination of any outliers or anomalies that might have affected the overall accuracy. By averaging the replicated readings, a more reliable and representative value for each parameter was obtained.

Overall, the combination of the advanced PCS Tester35 digital meter, precise calibration of equipment, and the practice of repeated measurements with subsequent averaging helped to provide robust and trustworthy data for the study.

Following are the results of physical analysis that came after the experiment:

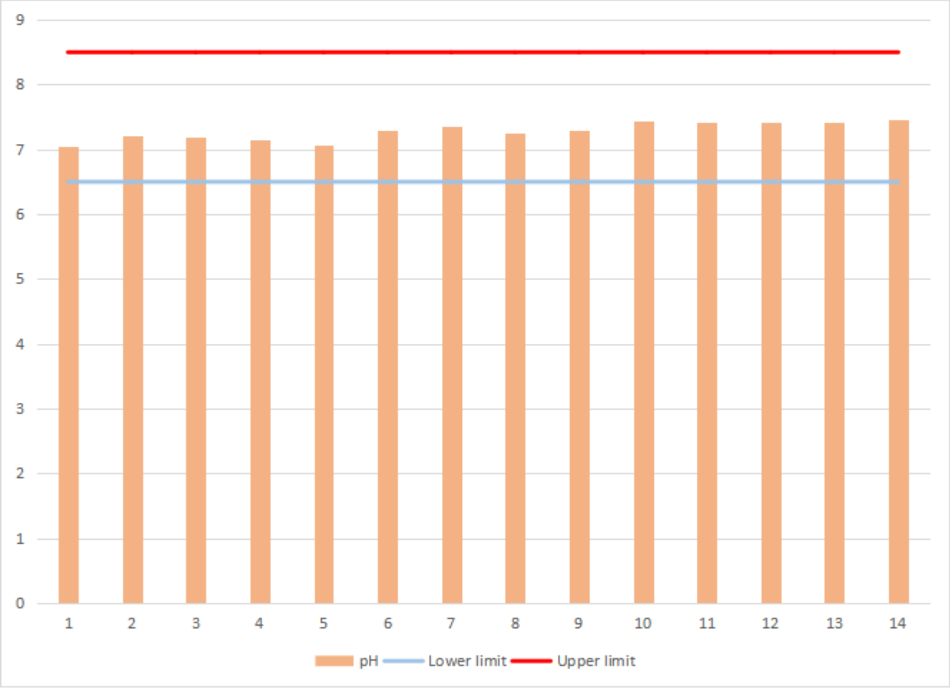
Table 5. 1 Physical analysis result

S. No	pH	EC (µs/cm)	TDS (ppm)	Salts (ppm)	Temperature (°c)	Turbidity (ntu)
1	7.05	262	188	126	22.9	0.0
2	7.21	255	181	122	22.7	0.0
3	7.20	271	193	129	22.8	0.0
4	7.16	304	216	145	22.2	0.0
5	7.07	385	274	183	22.7	1.24
6	7.29	289	206	137	22.2	0.0
7	7.35	299	212	141	22.4	0.0
8	7.26	284	202	135	22.1	0.0
9	7.30	283	201	134	22.5	4.24
10	7.45	282	200	134	22.7	0.0
11	7.43	287	204	136	22.5	0.0
12	7.43	289	205	137	22.2	0.0
13	7.42	287	204	136	22.6	0.51
14	7.47	285	202	135	22.5	1.89
15	7.44	284	202	135	22.6	0.73
16	7.50	309	220	147	22.5	0.0
17	7.42	313	222	148	22.6	0.0
18	7.57	285	202	135	22.4	0.0
19	7.48	288	204	136	22.3	1.84
20	7.50	472	336	225	22.6	1.91
21	7.50	473	336	226	22.7	0.0
22	7.28	488	347	233	22.7	0.0
23	7.32	486	345	232	22.4	0.0
24	7.57	265	188	126	22.4	0.84
25	7.38	290	206	137	22.6	0.0
26	7.52	269	191	128	22.5	1.28
27	7.31	274	195	130	22.6	1.65
28	7.50	295	212	141	22.5	0.0

5.1.1 pH

The pH of water serves as a measure of its acidity or alkalinity, ranging from 0 to 14, with 7 representing neutrality. A pH below 7 indicates acidity, while a pH above 7 indicates alkalinity (Water Science School, 2019). Our sample's pH values range from 7.0 to 7.9 with an average of 7.24.

Various factors, both natural and man-made, can influence the pH of water. Natural changes often arise from interactions with surrounding rocks, particularly those containing carbonate forms and other substances. Artificial sources such as acid rain and wastewater discharges can also impact pH levels. Limestone and carbonate materials possess the ability to stabilize pH fluctuations in water. Calcium carbonate (CaCO3) and other bicarbonates can combine with hydrogen or hydroxyl ions to neutralize pH. When carbonate minerals are present in the soil, they enhance the water's buffering capacity (alkalinity), helping to maintain a near-neutral pH even in the presence of acids or bases. Additionally, the presence of carbonate minerals can impart a slightly basic character to initially neutral water. (Fondriest Environmental, Inc., 2013).



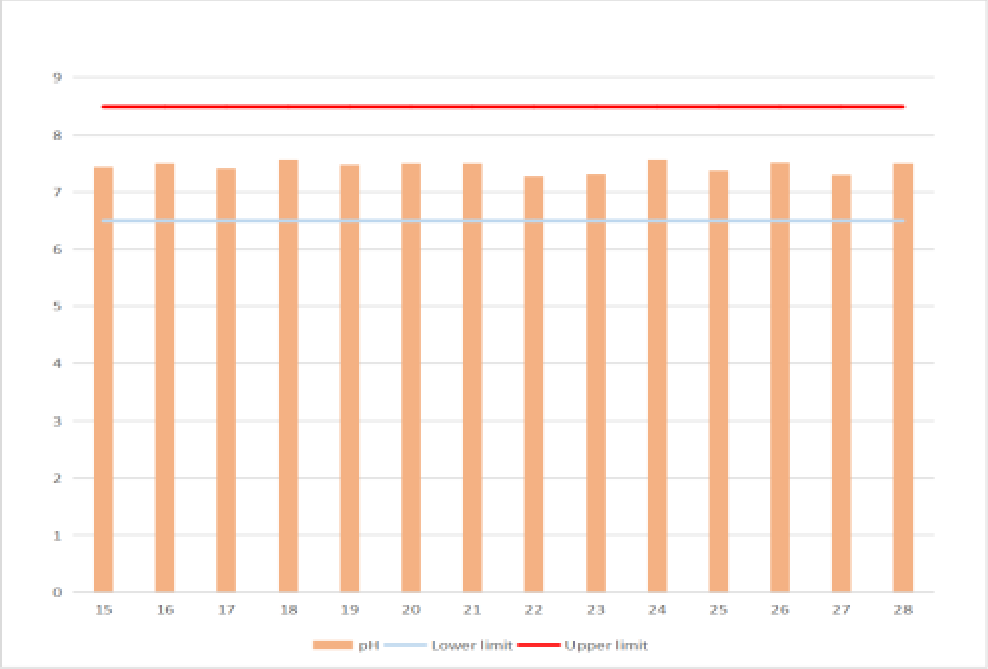


Figure 5. 1 Graphs showing the concentration of pH of sample 1-28

The World Health Organization recommends that the pH of the water be less than 8.0, because basic water does not allow for effective chlorination. The pH level of groundwater has varying effects on geological processes, notably mineral dissolution. An aquifer with an average pH of 7.2 typically indicates a neutral pH environment. The pH of an aquifer is primarily determined by the chemical composition of the water itself rather than the surrounding geology, although certain types of geological formations can indirectly influence water chemistry and pH. Geological formations composed of neutral or slightly alkaline minerals, such as sandstone, limestone, and dolomite, tend to have a neutralizing effect on the water passing through them. This means they can help maintain the pH of the aquifer water around a neutral value of pH 7. Limestone, in particular, is known for its ability to buffer acidic waters due to its high content of calcium carbonate. However, geologic formations containing acidic minerals like granite or volcanic rocks may have a slightly lower pH in the surrounding aquifer, although this is usually not significant enough to greatly impact the overall pH of the water. Other factors like dissolved minerals, organic matter, and human activities can also influence the pH of an aquifer. It is important to consider that aquifers can exhibit localized variations in pH due to specific geological and hydrological conditions. Therefore, while the average pH may be 7.2, there can be certain areas with slightly different pH values. If you provide more specific information about the geological formation or region in question, I can offer a more tailored response.

5.1.2. Electrical Conductivity

The ability of water to conduct electricity is referred to as its electrical conductivity, or EC. When salts or other compounds dissolve in water, they can create positively and negatively charged ions. The conductivity of water is influenced by the concentration of these free ions, as they are responsible for conducting electricity. Positively charged ions such as sodium, calcium, potassium, and magnesium, as well as negatively charged ions like chloride, sulfate, carbonate, and bicarbonate, have a significant impact on water conductivity. Various factors, including rainfall, geological composition, and evaporation, directly affect the electrical conductivity of water (Aquaread, 2020).

The EC of our samples ranges from 230-500 µs/cm with an average of 316 µs/cm.

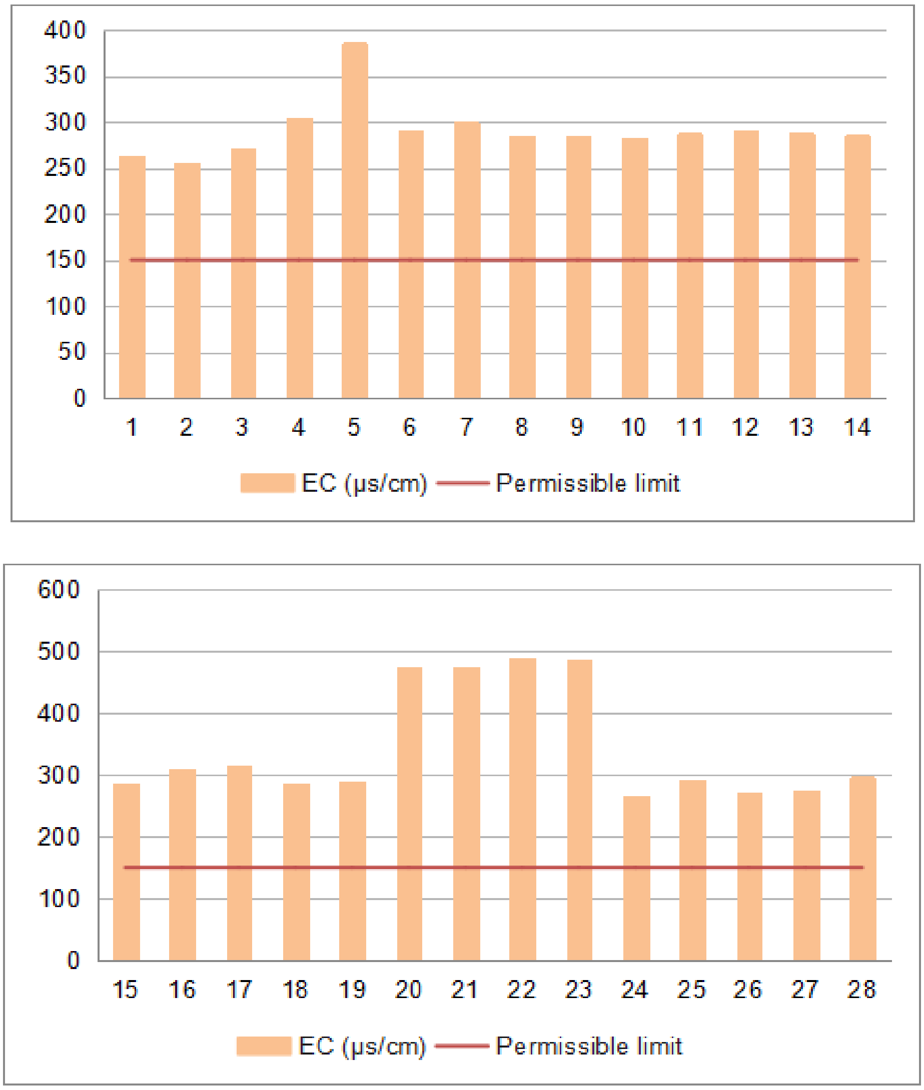


Figure 5. 2 Graphs showing the concentration of Electrical Conductivity of sample 1-28

According to WHO standards, EC value should not exceed 150 µS/cm.Under certain geological conditions and in the presence of specific rock types, the electrical conductivity can surpass the allowable limits. Several factors contribute to this phenomenon. Firstly, the presence of metallic minerals, such as sulfides or sulfates, within the rock or surrounding lithology can significantly enhance electrical conductivity. These minerals, when found in substantial quantities, contribute to the elevated levels of conductivity. Secondly, the existence of saline or brackish water within the rock formations or aquifers can also lead to increased electrical conductivity. The dissolved salts in the water, such as sodium, calcium, and chloride ions, further amplify conductivity levels. Additionally, fractured or faulted rocks can serve as pathways for fluid movement, including groundwater. When these fluids contain conductive substances like dissolved minerals or contaminants, they contribute to heightened electrical conductivity. Furthermore, rocks with high porosity, such as specific sandstones or limestone formations, have the capacity to retain significant amounts of water. If this water contains conductive substances, it can result in elevated electrical conductivity. Lastly, certain volcanic rocks, like basalts, contain minerals with high electrical conductivity, including magnetite or pyrite. The presence of these rocks in the subsurface can contribute to increased conductivity levels. It is crucial to note that the specific combinations of rocks and lithology that lead to excessive electrical conductivity can vary depending on the geological conditions and location. Permissible limits of conductivity are usually established based on the requirements of specific applications or industries, such as environmental studies, mineral exploration, or groundwater assessments.

5.1.3. Total Dissolved Solids

The measurement known as Total Dissolved Solids (TDS) determines the overall amount of soluble salts and minerals present in water. TDS can originate from various sources, including the water itself, the atmosphere, and the soil. Additionally, geological phenomena like leaching and dissolution contribute to the introduction of TDS into water. Although dissolved solids are naturally present in all water, their concentrations vary depending on the water source. For example, surface water from rivers and lakes generally contains fewer dissolved minerals compared to groundwater, and treated water, such as that obtained from filtration plants, typically has relatively low levels of dissolved solids (Winfield, 2022).

The TDS in our samples ranges from 180-400 ppm with an average of 224 ppm.

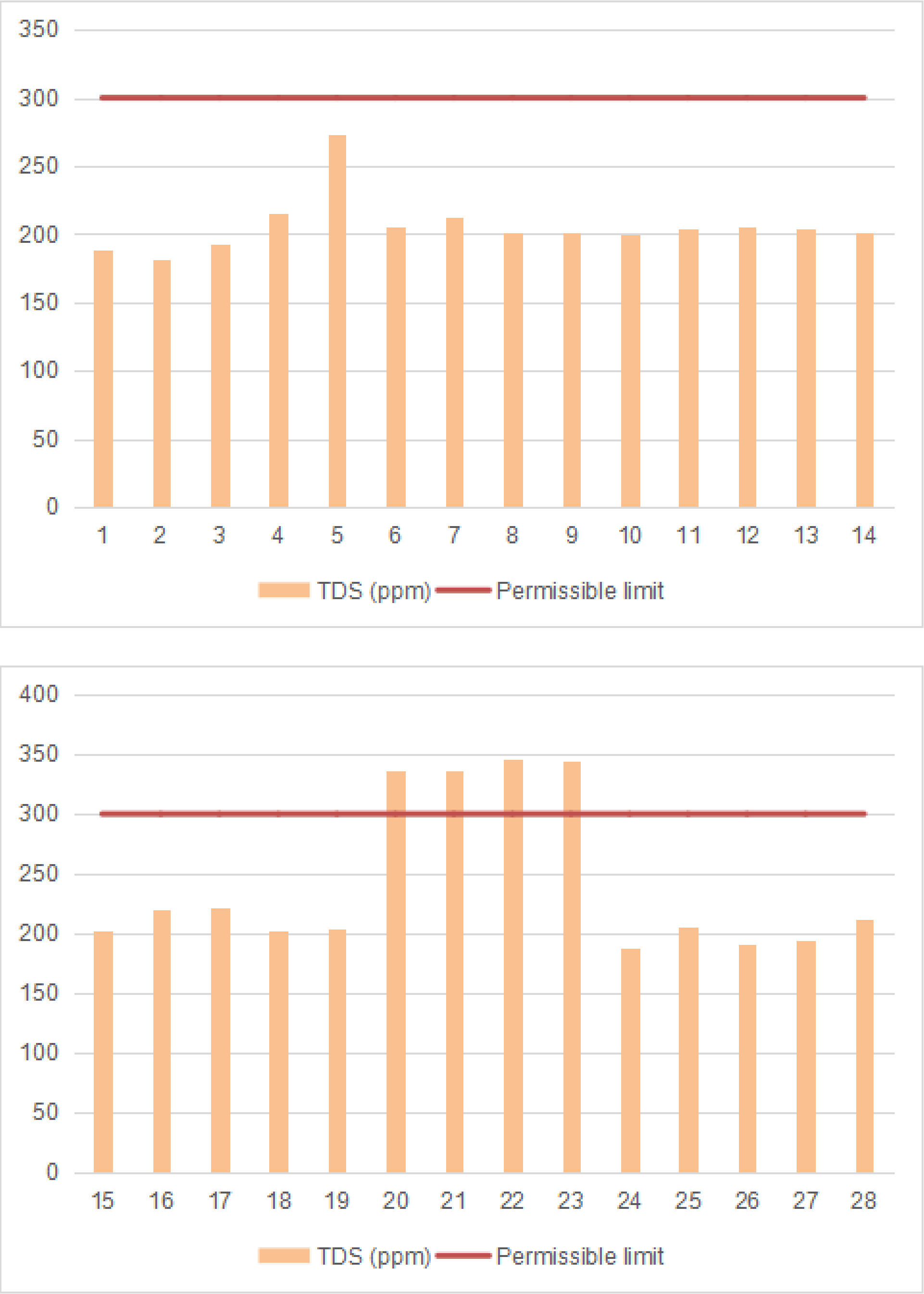


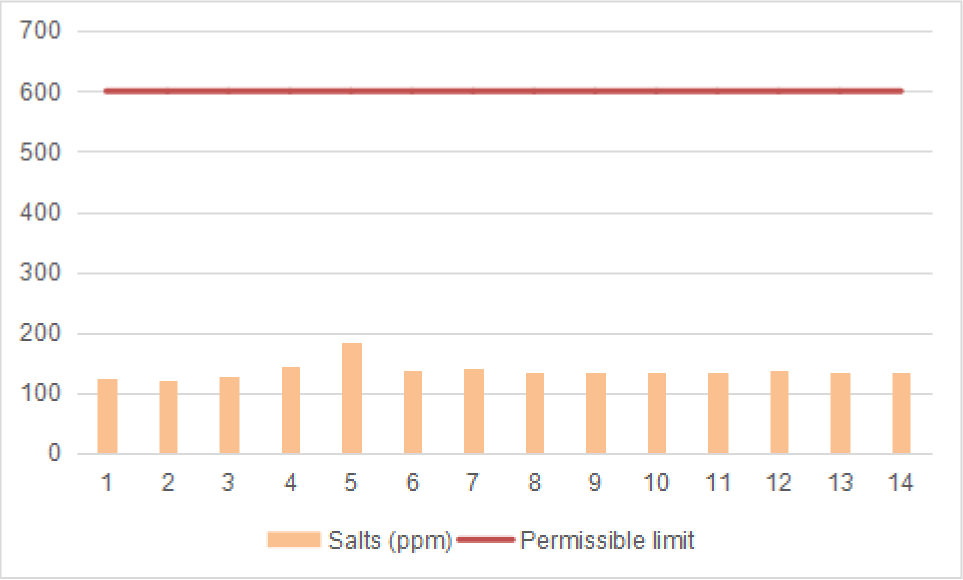
Figure 5. 3 Graphs showing the concentration of Total dissolved solid of sample 1-28

The TDS level recommended by WHO, not more than 300 ppm. Several geological factors can impact TDS levels in water sources. The composition of the bedrock plays a significant role, as certain types of rocks like limestone or gypsum can contribute higher concentrations of dissolved minerals to the water. Weathering and erosion processes also affect TDS by leaching minerals from rocks and soil into the water. The surrounding lithology and the extent of weathering can influence the TDS content as well. Additionally, the properties of the aquifer, such as its porosity and permeability, can affect TDS levels by interacting with the surrounding rocks and minerals. While geological conditions contribute to TDS levels, it is important to note that human activities can also impact water quality. Industrial discharge, agricultural runoff, and improper waste disposal can introduce pollutants and increase TDS concentrations in water sources. Therefore, considering both natural lithology and anthropogenic influences is crucial in assessing TDS levels. It's worth emphasizing that TDS levels alone do not provide a complete picture of water quality or its suitability for specific purposes. The specific composition of dissolved solids and their potential health effects should be taken into account. If necessary, water treatment methods such as filtration, reverse osmosis, or ion exchange can be employed to reduce TDS levels and improve water quality.

5.1.4. Salts

Sodium chloride salts, primarily composed of sodium, are the most prevalent elements found in water. These salts readily dissolve in water and have a colorless appearance. In large quantities, sodium chloride imparts a salty taste to the water. Salts can enter groundwater from both natural sources, such as evaporate deposits, and human activities. When rainfall permeates the ground, it may come into contact with rocks containing highly soluble minerals, resulting in saline water. As we go deeper into sedimentary layers, the water gradually becomes more saline. Close to the surface, water is rich in sulfates, followed by bicarbonate-rich saline water at a lower level, and more concentrated chloride water at greater depths. Saline water can form in sedimentary rocks through various processes, including the interaction of sediment and rock solutions. (USGS, 2018) and (Craig, 1980).

The salts in our samples range from 22.0-22.9 ppm with an average of 150 ppm.



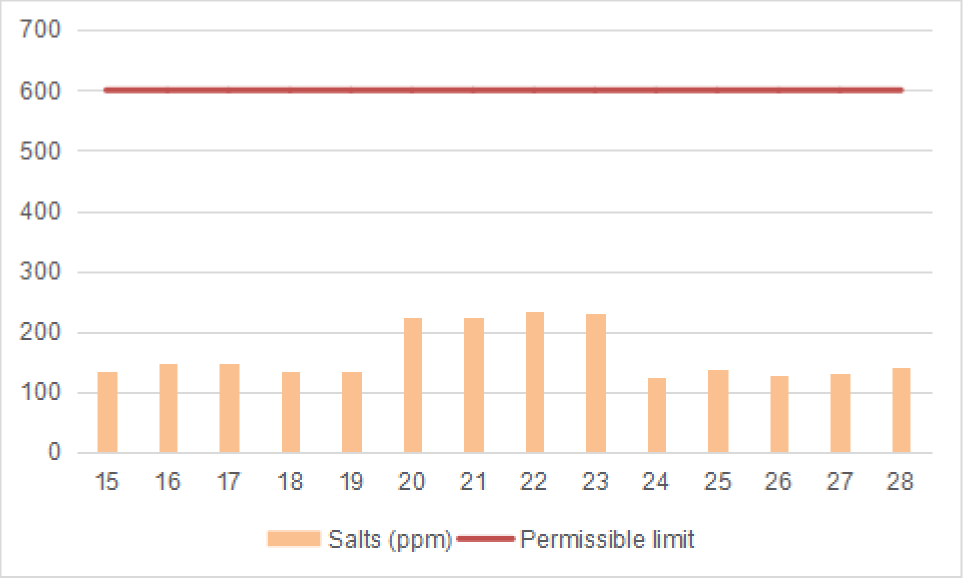


Figure 5. 4 Graphs showing the concentration of salts of sample 1-28

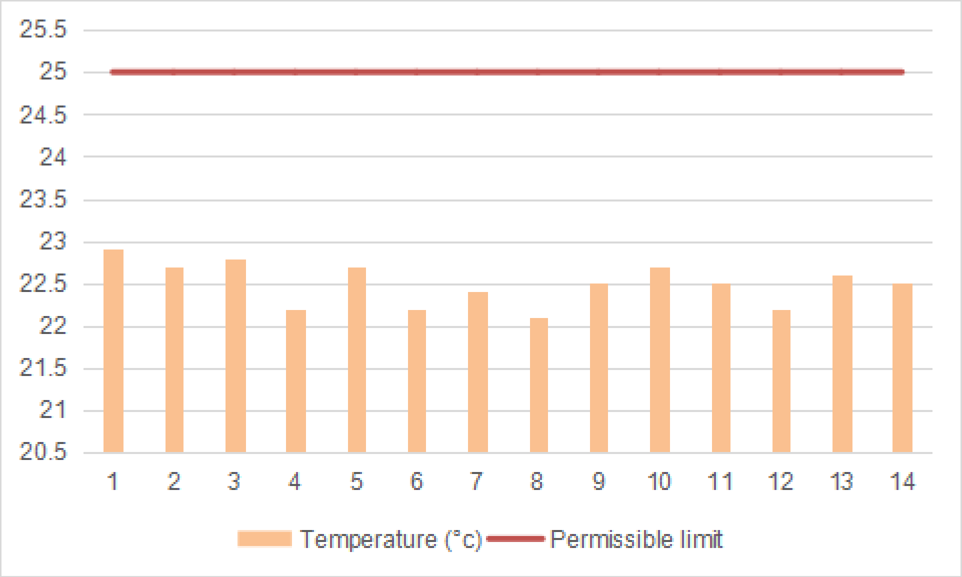
WHO standard for salinity in drinking water are less than 600 mg/L is regarded as good quality drinking water. 600 to 900 mg/L is regarded as fair quality.Geologic conditions and rock types can impact the concentration of salts within permissible limits. Various factors can influence salt content in different types of rocks and surrounding lithology. Sedimentary rocks like sandstone, limestone, and shale can have varying salt concentrations depending on their composition and mineralogy. Similarly, igneous rocks such as granite or basalt generally have low salt content, although hydrothermal activity and the presence of certain minerals can introduce salts. Permeable aquifers, which store and transmit water, may contain salts within permissible limits, influenced by the aquifer materials and hydrological conditions.

Groundwater recharge areas and coastal regions are also subject to salt intrusion, but geological features like filtration processes, clay layers, and freshwater lenses can help regulate salt concentration. It's important to conduct site-specific studies to determine the permissible salt limits in each geological setting, considering the intended use of water and local factors.

5.1.5 Temperature

The PCS Tester 35 utilizes a temperature sensor or probe to measure the temperature of the water samples. The probe is typically made of a thermistor or a thermocouple, both of which are common temperature-sensing devices. A thermistor is a type of resistor whose resistance changes with temperature. It consists of a ceramic or semiconductor material with a high sensitivity to temperature. As the temperature changes, the resistance of the thermistor varies, which can be measured and converted into temperature readings by the PCS Tester 35. On the other hand, a thermocouple is a device that generates a voltage proportional to the temperature difference between two junctions. It consists of two different types of metal wires joined together at one end. When there is a temperature difference between the two junctions, it creates a voltage that can be measured by the PCS Tester 35 and converted into temperature readings. The PCS Tester 35 is equipped with a built-in circuitry and algorithms to accurately measure and interpret the signals from the temperature sensor. The instrument takes into account the specific characteristics of the temperature sensor being used, such as the resistance-temperature relationship of a thermistor or the voltage-temperature relationship of a thermocouple.

The temperature in our samples range from 120-255 °C with an average of 22°C



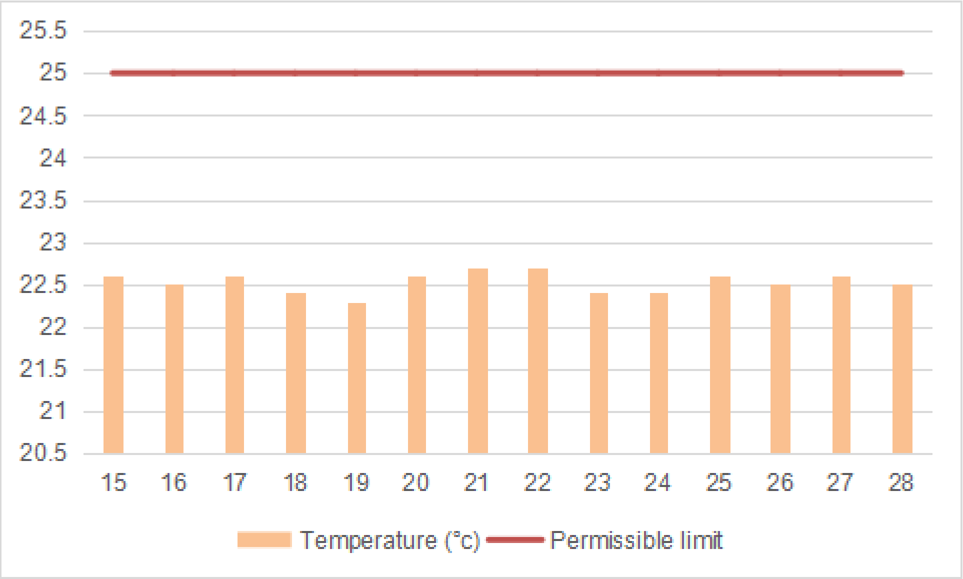


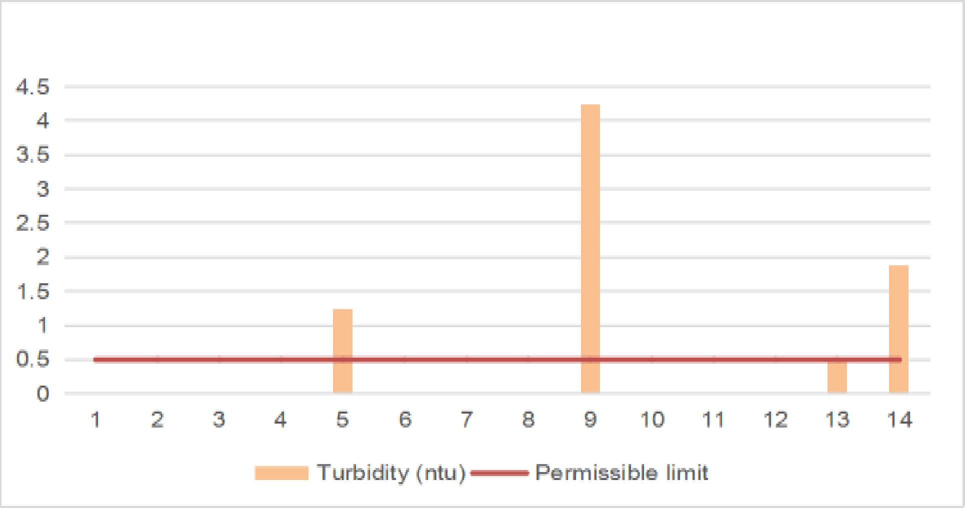
Figure 5. 5 Graphs showing the concentration of Temperature of sample 1-28

According to WHO water temperature is an important element of control strategies against Legionella. Wherever possible, water temperatures should be kept outside the range of 25–50 °C and preferably outside the range of 20–50 °C to prevent the growth of the organism.Various geological conditions and rock types can effectively maintain temperatures within permissible limits, depending on the specific requirements and context. One crucial factor is the presence of geothermal systems, which harness the Earth's heat. Regions near active volcanic areas or geothermal reservoirs often possess hot rocks, such as basalt or granite, capable of retaining substantial amounts of heat. Another aspect is the circulation of groundwater, which acts as a natural temperature moderator. Permeable rock formations like limestone or sandstone enable the flow of groundwater, aiding in the absorption and distribution of heat or cold. Additionally, certain rock formations can serve as insulators, minimizing temperature fluctuations. Sedimentary rocks with low thermal conductivity, such as shale or siltstone, create a stable environment by reducing heat transfer between layers. Furthermore, mountainous regions with higher elevations tend to offer cooler temperatures, and rocks like gneiss or schist found in these areas contribute to maintaining acceptable temperature levels. It is important to consider that the specific permissible temperature limits may vary depending on the particular application and that temperature control mechanisms can be implemented to regulate temperatures within rock formations, such as insulation or circulation systems.

5.1.6 Turbidity

Turbidity is a measure of the cloudiness or haziness of a liquid caused by suspended particles, such as sediment, algae, or other impurities. It is an important parameter in water sampling as it indicates the presence of particulate matter and can provide insights into water quality and clarity. To calculate turbidity in water sampling, various methods can be employed, with the most common method being the use of a turbidimeter or nephelometer. These instruments measure the amount of light scattered or absorbed by the suspended particles in the water, and based on this measurement, turbidity values are determined by taking 10ml sample, then shake and put it into machine and wait for results

The turbidity in our samples range from 0.0-4.9 ppm with an average of 0.57 (ntu).



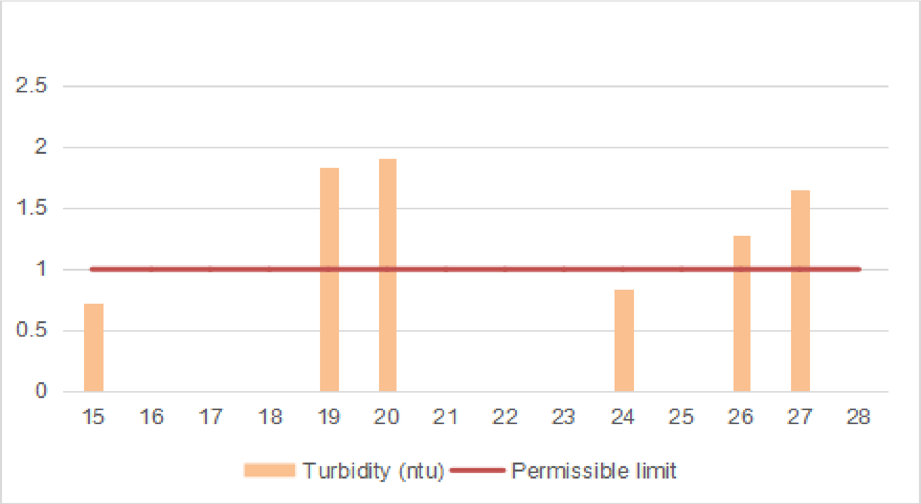


Figure 5. 6 Graphs showing the concentration of Turbidity of sample 1-28

The WHO (World Health Organization), establishes that the turbidity of drinking water shouldn't be more than 5 NTU, and should ideally be below 1 NTU. Turbidity is a measure of the cloudiness or murkiness of water or other fluids caused by suspended particles. It is not directly associated with specific geologic conditions or types of rocks. The level of turbidity in water is primarily influenced by factors such as sediment runoff, the presence of organic matter, and human activities. However, in certain cases where turbidity exceeds permissible limits in a geological context, it may be attributed to specific events or conditions. For instance, heavy rainfall or extensive erosion can result in high sediment loads in rivers or streams, leading to increased turbidity. Regions with loose or unconsolidated sediments, such as alluvial plains or areas prone to significant soil erosion, may have a higher likelihood of experiencing elevated turbidity levels. Nonetheless, it is important to note that turbidity is primarily a water quality issue rather than a characteristic of rocks or surrounding lithology. Therefore, when turbidity surpasses acceptable levels, it is more closely related to environmental factors and human activities impacting the water source rather than specific geological circumstances.

5.2. Chemical Parameters

Table 5. 2 Table showing values for Cl, NaCl and Na (mg/L)

S. No	Cl (mg/L)	NaCl (mg/L)	Na (mg/L)
1	53.25	887.5	824.25
2	28.40	46.8	18.4
3	40.11	66.105	25.99
4	23.43	38.61	15.18
5	46.14	76.08	29.9
6	22.36	36.85	14.48
7	33.50	58.5	23.0
8	22.35	35.85	14.47
9	15.9	26.91	11.01
10	24.85	40.95	16.10
11	23.45	38.61	15.77
12	23.45	38.61	15.77
13	23.45	38.61	15.77
14	23.45	38.61	15.77
15	23.45	38.61	15.77
16	60.35	99.45	39.15
17	28.40	46.80	18.4
18	35.50	77.80	42.30
19	37.63	62.01	24.38
20	57.86	95.35	37.49
21	50.70	83.65	32.95
22	60.35	99.45	39.1
23	47.2	77.80	30.60
24	30.76	50.31	19.55
25	30.76	50.31	19.55
26	35.5	53.5	23.00
27	51.85	85.41	35.58
28	63.90	105.3	41.40

5.2.1 Chlorides

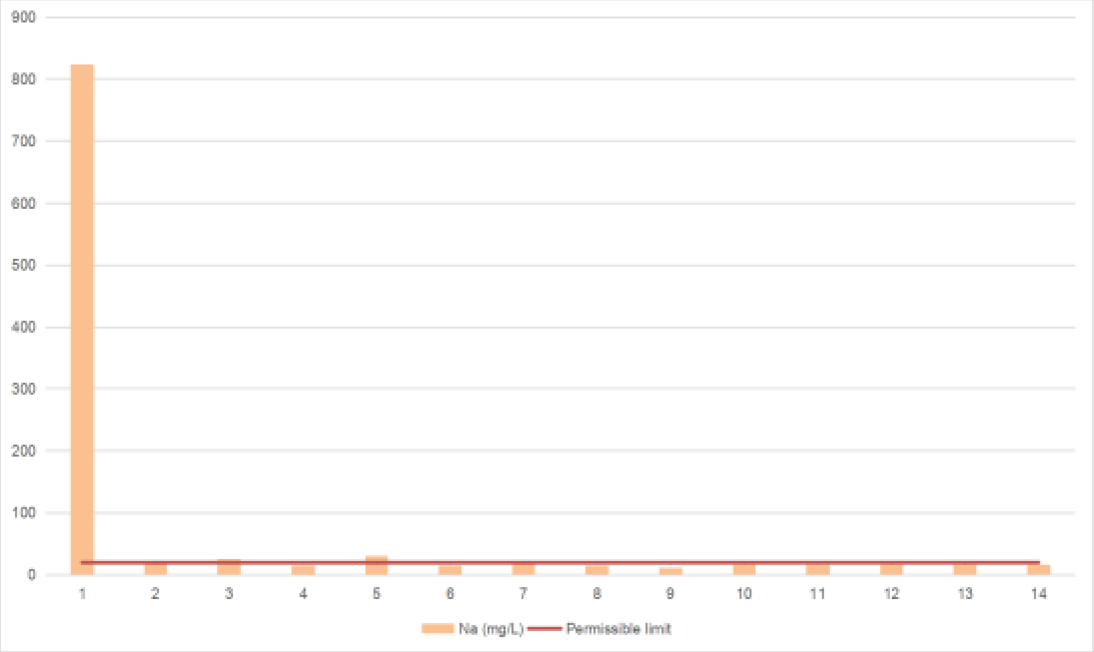
Chlorides in water can exist as chloride ions or salts such as sodium chloride (NaCl). They naturally occur in water. The concentration of chlorides found in our water samples range from 11.1-70.5 mg/L with an average of 36 mg/L. The concentration of sodium chloride in our samples ranges from 30.1-105.5 mg/L with an average of 89 mg/L.

Figure 5. 7 Graphs showing the concentration of Cl of sample 1-28

WHO standard for chloride in drinking water is the limit for chloride in drinking water is 250 milligrams per litre (mg/L). The chloride concentration in rocks and surrounding lithology can differ based on geological conditions, rock types, and environmental factors. Consequently, the acceptable limit of chloride concentration may vary depending on the intended use. However, certain rock types and surrounding lithologies generally exhibit chloride concentrations within permissible limits. For instance, sandstone, a sedimentary rock composed mainly of sand-sized mineral particles, often possesses relatively low chloride concentrations. This characteristic makes sandstone formations suitable for applications like construction materials and groundwater sources. Limestone, another sedimentary rock primarily consisting of calcium carbonate, typically contains chloride concentrations within acceptable ranges, making it suitable for construction and agricultural purposes. Granite, an igneous rock composed primarily of quartz, feldspar, and mica, tends to have low chloride concentrations as well, making it suitable for various applications where permissible chloride levels are necessary. Basalt, an iron and magnesium-rich igneous rock, usually exhibits low chloride concentrations, making it suitable for construction materials and aggregate purposes. Lastly, shale, a fine-grained sedimentary rock composed of clay minerals, generally falls within acceptable chloride limits for many applications. It is important to note that these descriptions are general and actual chloride concentrations in rocks and surrounding lithology can vary depending on specific conditions. Therefore, it is crucial to consult relevant guidelines and perform site-specific testing when evaluating the suitability of rocks and surrounding lithology for specific purposes.

5.2.2 Sodium

Sodium is a silvery white, soft and highly reactive metal. It is very common and is the sixth most abundant element present in the earth’s crust. Sodium can be found in many minerals including rock salt, sodalite, feldspars etc. Most of the salts formed by sodium are very soluble in water. The range of sodium in our samples is 14.9-830 mg/L with an average of 52mg/L.



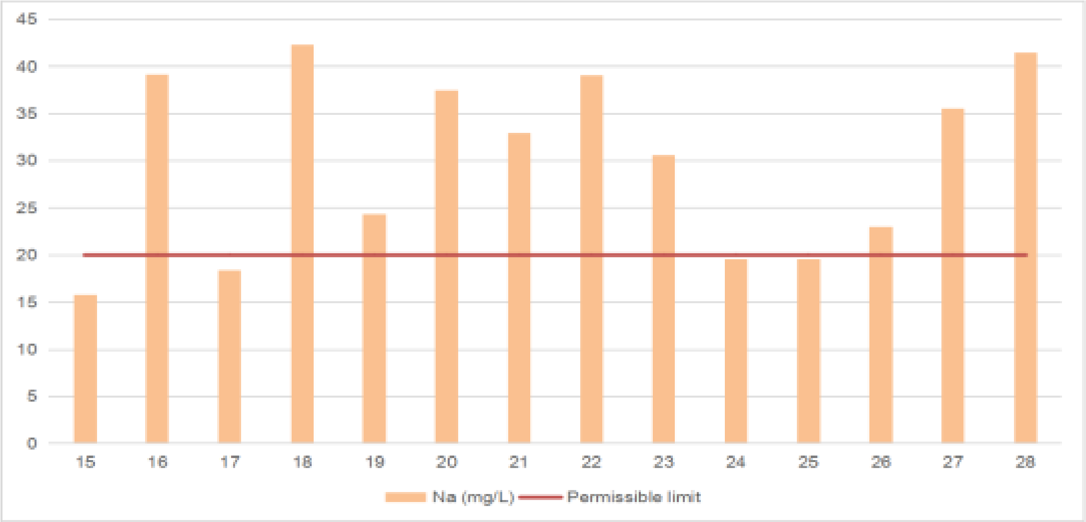


Figure 5. 8 Graphs showing the concentration of Na of sample 1-28

WHO standard for chloride in drinking water is the limit for chloride in drinking water is 20 milligrams per litre (mg/L).While there is no drinking water standard for sodium, state and federal agencies recommend sodium levels in water not exceed 20 milligrams per liter (mg/L) for people on very low sodium diets and 270 mg/L for people on moderately restricted sodium diets. Exceeding the allowable limit of sodium concentration in rocks and surrounding lithology can occur in various geological conditions. High sodium concentrations can be found in different scenarios. One such scenario is the formation of evaporite deposits, such as rock salt (halite) and gypsum, which typically occur in arid or semi-arid environments with high evaporation rates. These deposits can accumulate significant sodium ions, particularly in salt flats or saline lakes. Another situation is saline intrusion, where seawater infiltrates coastal aquifers, resulting in the intrusion of high-salinity water into freshwater reservoirs. This process can contaminate the surrounding lithology and cause elevated sodium concentrations. Additionally, in certain sedimentary basins, the presence of sodium-rich minerals like sodium feldspar or sodium-rich clay minerals can contribute to increased sodium levels in the surrounding lithology. The weathering of sodium-rich minerals, such as sodalite or nepheline, in the vicinity of rocks and lithology can also lead to higher sodium concentrations. It's important to consider that the acceptable limit for sodium concentration may vary depending on the specific context or application. Therefore, it is necessary to consult relevant guidelines and regulations to determine the permissible limit in a given situation.

5.2.3 Carbonates

The acceptable levels of NaHCO3 (sodium bicarbonate), Na2CO3 (sodium carbonate), HCO3 (bicarbonate), and CO3 (carbonate) in groundwater vary depending on local regulations and guidelines set by relevant authorities. These guidelines aim to ensure that the water is safe for human consumption and environmentally sustainable. To determine the acceptable levels of these substances in groundwater, it is important to consult the regulatory bodies responsible for water quality in your specific region. In the United States, for instance, the Environmental Protection Agency (EPA) establishes standards for drinking water quality, including guidelines for various contaminants.

Carbonates are salts of carbonic acid and are usually insoluble in water. Their presence can be attributed to the interaction of water with rock containing carbonates such as limestone. The concentration of Na2CO3 ranges from 420-1008 mg/L with an average value of 680 mg/L. The concentration of NaHCO3 ranges from 318-1166 mg/L with an average of 852 mg/L. The concentration of HCO3 ranges from 183-976 mg/L with an average of 489.5mg/L. The concentration of CO3 ranges from 180-920 mg/L with an average of 489 mg/L.

Table 5. 3 Table showing concentrations of various carbonates present

S. No	**NaHCO3 (mg/l)**	**Na2CO3 (mg/l)**	**HCO_3 (mg/l)**	**CO_3 (mg/l)**
1	840	1060	610	600
2	756	959	549	540
3	505	636	366	360
4	1008	1272	732	920
5	904	1166	671	660
6	588	742	407	420
7	420	530	305	300
8	504	636	366	360
9	672	848	488	480
10	552	318	183	180
11	504	636	366	360
12	588	742	427	420
13	1008	1272	732	720
14	420	530	305	300
15	504	636	366	360
16	504	636	366	360
17	840	1060	610	600
18	588	742	427	420
19	420	530	305	300
20	1092	1378	793	780
21	840	1060	610	600
22	840	1060	610	600
23	1344	1696	976	960
24	588	742	428	420
25	672	848	488	480
26	420	530	305	300
27	504	636	366	360
28	756	959	549	540

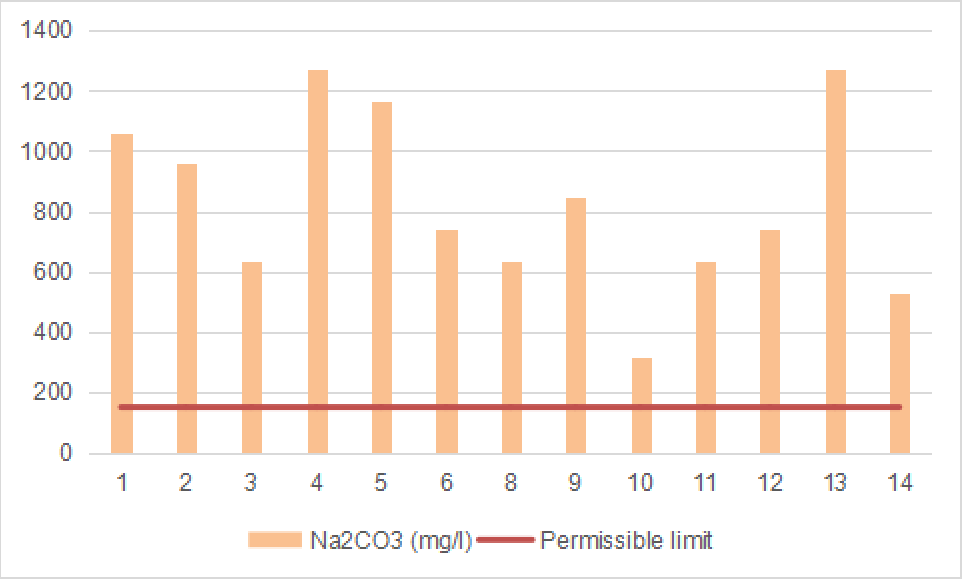
Generally, the acceptable levels for these substances in drinking water are as follows:

NaHCO3 (sodium bicarbonate): There is no specific limit for sodium bicarbonate in drinking water. However, elevated sodium levels can impact the taste of the water and may be of concern for individuals on sodium-restricted diets

Figure 5. 9 Graphs showing the concentration of NaHCO3 of sample 1-28

WHO standard for drinking is sodium bicarbonate, 420 mg/liter. Geological conditions and the composition of rocks, as well as human activities, can contribute to the exceeding of permissible limits for sodium bicarbonate concentration in rocks and the surrounding lithology. In regions with arid climates, where there is limited rainfall and high evaporation rates, sodium bicarbonate concentration can increase as water containing this compound evaporates, leaving behind concentrated deposits like salt flats or playas. Hydrothermal activity involving hot water or steam can also cause the leaching of sodium bicarbonate from minerals, particularly when interacting with sodium bicarbonate-rich minerals such as trona or nahcolite. The weathering or dissolution of carbonate rocks like limestone or dolomite can release sodium bicarbonate into surrounding waters, potentially surpassing permissible limits. Additionally, the natural weathering or erosion of minerals with high sodium bicarbonate content, like nahcolite, natron, or thermonatrite, can lead to the accumulation of excessive sodium bicarbonate concentrations in the lithology. Furthermore, anthropogenic factors such as mining or industrial processes can introduce sodium bicarbonate or its precursors into the lithology, further influencing the concentration levels. It is crucial to consider the environmental impacts of exceeding permissible limits, as it can affect water quality, vegetation, and overall ecosystem dynamics. Compliance with specific regulations and guidelines is necessary to effectively manage and mitigate these potential consequences in different jurisdictions and contexts.

$Na2CO3$ (sodium carbonate): Sodium carbonate is typically not naturally found in groundwater. Its presence may indicate contamination or human activities, and acceptable levels would depend on the specific situation and potential effects on human health and the environment.



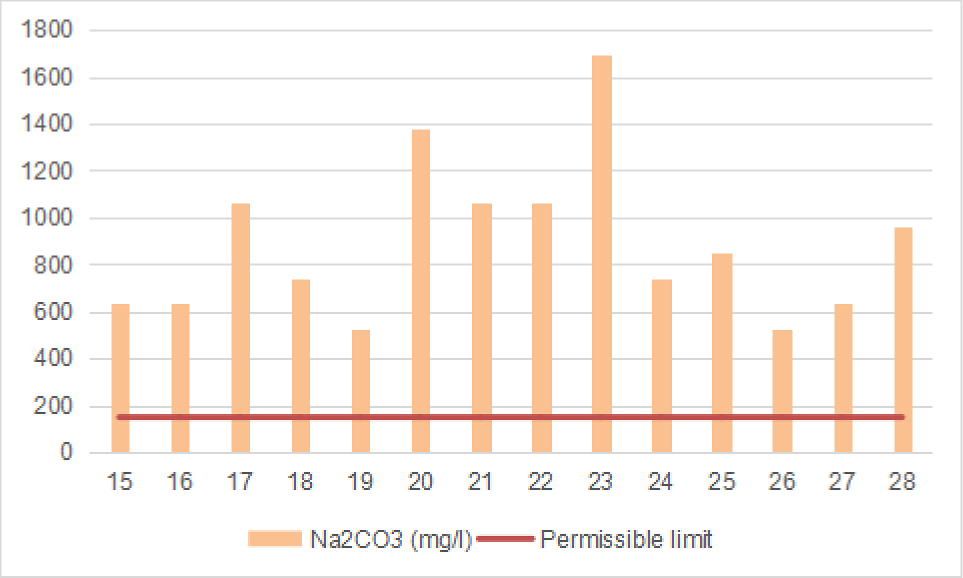


Figure 5. 10 Graph showing the concentration of Na2CO3 of sample 1-28

WHO standard for drinking is sodium carbonate, 150 mg/liter . Exceeding the allowable limit of sodium carbonate in a sample can be influenced by various geological factors, the type of rocks present, surrounding conditions, and lithology. However, it is crucial to note that sodium carbonate is not typically associated with specific rock types or lithologies, as its presence is more closely linked to environmental and hydrogeological factors. Nevertheless, several general geological factors can contribute to elevated levels of sodium carbonate. Hydrogeology plays a significant role in the occurrence of sodium carbonate in a sample. The hydrogeological conditions of an area, such as the presence of sodium carbonate-rich water sources or brines, can lead to groundwater or surface water carrying higher levels of sodium carbonate. Certain geological formations may also contribute to elevated sodium carbonate levels. Sedimentary formations like evaporites or saline lake deposits have the potential to contain sodium carbonate minerals, which can affect the surrounding environment. Mineralization and weathering processes can release sodium carbonate into the environment. The weathering of sodium-rich minerals, such as trona or nahcolite, can result in the release of sodium carbonate. Anthropogenic activities can introduce or concentrate sodium carbonate in the environment. Industrial processes, mining operations, or agricultural practices, including the use of sodium carbonate-rich water for irrigation, can contribute to increased levels of sodium carbonate in the area. It is crucial to conduct a detailed investigation and analysis of the specific area to identify the precise geological factors and sources responsible for the high levels of sodium carbonate. Local geological surveys, hydrogeological assessments, and chemical analyses of water and rock samples would be necessary to determine the specific causes in a given scenario.

HCO3 (bicarbonate) the acceptable level of bicarbonate in drinking water varies, but it is generally considered safe when concentrations are below 100-200 mg/L. Bicarbonate levels above this range can affect the water's taste or contribute to scaling in plumbing fixtures.

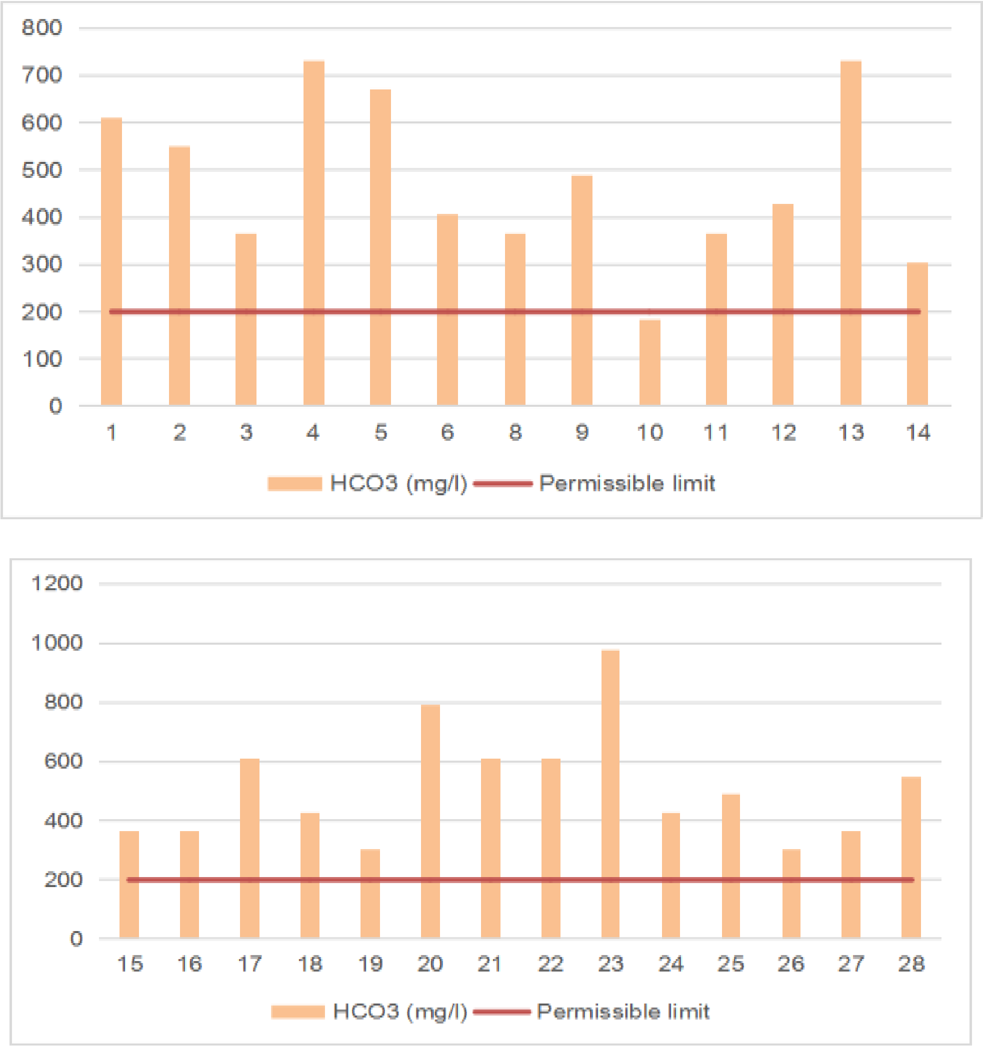


Figure 5. 11 Graph showing the concentration of HCO3 of sample 1-28

WHO standard for drinking is sodium carbonate, 200 mg/liter for HCO3 (bicarbonate). When the concentration of sodium carbonate exceeds the acceptable limit in rocks or surrounding lithology, it can have significant geological implications and impact different rock types. Elevated bicarbonate concentrations beyond permissible limits in water can be influenced by various geologic factors and the types of rocks, lithology, and surrounding environment. These factors include the composition of the bedrock, particularly rocks such as limestone, dolomite, and marble that contain carbonate minerals prone to dissolution and the release of bicarbonate ions. Areas with karst topography, characterized by soluble rocks like limestone, are also more likely to have increased bicarbonate levels due to underground drainage systems and the dissolution of carbonate rocks. Weathering and erosion processes of rocks, hydrological conditions such as proximity to groundwater or surface water bodies, and human activities such as agriculture and industrial practices can further contribute to elevated bicarbonate concentrations. Understanding these geological factors is essential for assessing the causes of high bicarbonate levels and implementing appropriate remediation measures.

CO3 (carbonate): Similar to sodium carbonate, carbonate is not commonly found in natural groundwater sources. If carbonate is present, it may indicate contamination or other factors, and acceptable levels would depend on the specific circumstances.

Figure 5. 12 Graph showing the concentration of CO3 of sample 1-28

WHO standard for drinking carbonate is 400 mg/liter . When the permissible limit of carbonate is exceeded in geologic conditions, it can result in the formation of rocks that are rich in carbonate and have an impact on the surrounding lithology. Several rock types and lithologies can be associated with an excessive carbonate content. Limestone, for instance, is a sedimentary rock primarily composed of calcium carbonate. It typically forms in shallow marine environments where calcium-rich organisms accumulate, such as coral reefs or areas with abundant shell fragments. Dolomite, on the other hand, contains a significant amount of magnesium and forms through the replacement of calcium carbonate in limestone by magnesium-rich fluids. Another rock type is chalk, which is a soft, white, porous sedimentary rock composed mainly of microscopic calcium carbonate shells from marine organisms. Marl, a calcareous clay or mudstone, can also be influenced by excessive carbonate content. Calcareous sandstone forms when sand grains are cemented together by calcium carbonate or when calcium carbonate fills the pore spaces between sand grains. Furthermore, excessive carbonate content in the lithology can lead to the development of karst topography, characterized by sinkholes, caves, and underground drainage systems, due to the dissolution of carbonate rocks such as limestone and dolomite by acidic water. The formation of these rock types and the specific geological conditions depend on various factors including the source of carbonate, depositional environment, and diagenetic processes involved.

5.2.4 Total Hardness

Total hardness is an important parameter to consider during water sampling. It refers to the concentration of calcium and magnesium ions present in the water, which can have significant implications for various applications. To determine the total hardness, a common method involves titration using a chelating agent like EDTA. Accurate measurement and proper calibration of equipment are crucial for obtaining reliable data. Understanding the total hardness of water samples is essential for assessing drinking water quality, industrial processes, and the health of aquatic ecosystems. By evaluating total hardness, stakeholders can make informed decisions regarding water treatment, management, and environmental conservation. The range for total hardness of our samples range from 220-5700 mg/L with an average of 3379 mg/L.

Table 5. 4 Table showing Total Hardness (mg/l) values of samples

S. No	Total Hardness (mg/l)
1	5100
2	4100
3	3900
4	2600
5	5500
6	3500
7	2500
8	3600
9	2300
10	2700
11	2800
12	220
13	2800
14	3100
15	3300
16	2600
17	2900
18	3000
19	5700
20	5500
21	4200
22	4200
23	5700
24	2500
25	2400
26	2300
27	2600
28	3000

Figure 5. 13 Graph showing the concentration of Total Hardness of sample 1-28

WHO standard for drinking is Total hardness should not exceed 120 to 170 mg/L Exceeding the permissible limit of total hardness in a water sample can be attributed to various geological factors associated with the type of rock and surrounding lithology. These factors can lead to elevated hardness levels in water. One such factor is the presence of rocks with high mineral content. Rocks like limestone, dolomite, and gypsum naturally contain significant amounts of calcium and magnesium minerals, which are major contributors to water hardness. Additionally, carbonate rocks, such as limestone and dolomite, can have a substantial impact on water hardness due to the dissolution of calcium carbonate and magnesium carbonate into the water. Regions characterized by karst topography, where soluble rocks like limestone are prevalent, can also experience increased water hardness as water passes through and picks up dissolved minerals. Geological weathering processes that break down rocks over time can contribute to higher hardness levels as minerals dissolve into the water. Moreover, proximity to saline or mineral deposits can introduce additional minerals, elevating water hardness. While these geologic factors play a significant role, it's important to consider other factors like human activities and water treatment methods to accurately determine the causes of exceeding the permissible limit of total hardness in water samples.

5.2.5 Alkalinity

Alkalinity refers to the water's capacity to resist pH changes, particularly towards acidity. It plays a significant role in understanding the water's ability to neutralize acids and acts as a buffer. To determine alkalinity, a common method involves titration using a standardized acid solution. A water sample is collected and then titrated until a specific endpoint is reached. Typically, an indicator such as phenolphthalein or bromocresol green is used to detect the endpoint, which is indicated by a color change. By evaluating the alkalinity of water samples, researchers and professionals in the field of water quality gain valuable insights into the water's buffering capacity and its potential impact on aquatic ecosystems and industrial processes. This understanding of alkalinity is crucial for maintaining the overall balance and stability of water systems. The values of alkalinity of our samples range from 16-110 mg/L with an average of 87 mg/L.

Table 5. 5 Table showing Alkalinity values of samples 1-28

S. No.	Alkalinity (mg/L)
1	98
2	82
3	80
4	96
5	134
6	80
7	82
8	78
9	76
10	64
11	74
12	150
13	52
14	78
15	72
16	80
17	98
18	68
19	64
20	152
21	156
22	80
23	16
24	80
25	70
26	78
27	94
28	110

Figure 5. 14 Graph showing the concentration of Alkalinity of sample 1-28

WHO standard for drinking Alkalinity that should be in our water is 20-200 mg/L for typical drinking water. The alkalinity of a sample is influenced by various geological factors, including the type of rock, surrounding environment, and lithology. If the alkalinity remains within permissible limits, it suggests that these factors are not significantly contributing to excessive alkalinity. However, it should be noted that the specific permissible limits may vary depending on the intended use of the sample and the applicable regulatory standards. One important geological factor that affects alkalinity is the type of rock present. Different rock types have distinct mineral compositions that can influence alkalinity. For example, rocks such as limestone and dolomite contain calcium carbonate, which can contribute to alkalinity when dissolved in water. Conversely, silicate-rich rocks like granite or basalt are generally less alkaline. The surrounding environment also plays a role in determining alkalinity. Factors such as vegetation cover, soil composition, and proximity to human activities or industrial sites can introduce substances into the water that affect its alkalinity. For instance, agricultural runoff or industrial waste discharge can elevate alkalinity levels in nearby water sources. Lithology, which refers to the physical and chemical characteristics of rock layers, is another important factor. Variations in lithology within a region can impact groundwater alkalinity. For instance, the presence of carbonate-rich layers within an otherwise non-carbonate lithology can significantly influence alkalinity levels in the surrounding water sources. To accurately assess the geological factors influencing alkalinity in a specific location, it is crucial to conduct thorough analyses and consider additional factors. Geological surveys, hydrogeological studies, and water quality assessments can provide more comprehensive insights into the geological influences on alkalinity and help ensure that the alkalinity levels remain within acceptable limits for the intended use of the sample.

5.2.6 Calcium

Monitoring and measuring calcium levels provide valuable insights into water quality. It helps assess water hardness, evaluate scaling and corrosion risks, and determine environmental impacts. Additionally, recorded calcium content assists in selecting suitable treatment processes to address specific water quality concerns effectively. It is a primary contributor to the overall hardness of water, which refers to the presence of dissolved minerals like calcium and magnesium ions. By documenting calcium concentrations, it becomes possible to determine the hardness of the water sample accurately. This information is vital for evaluating its appropriateness for domestic, industrial, or agricultural use. Another aspect influenced by recorded calcium levels is scaling and corrosion. Elevated calcium content in water can contribute to scale formation and corrosion in plumbing systems, pipes, and industrial equipment. By keeping a record of calcium concentrations, it becomes possible to assess the likelihood of scale buildup and corrosion, allowing for appropriate preventive measures to be implemented and contributes to assessing the overall ecological health of the water system.

The values for Calcium range from 124-560 mg/L with an average of 333.25 mg./L.

Table 5. 6 Table showing concentrations of Calcium (mg/l)

S. No	**Calcium (mg/l)**
1	240
2	340
3	212
4	284
5	256
6	256
7	124
8	340
9	264
10	196
11	560
12	452
13	248
14	280
15	168
16	232
17	560
18	400
19	500
20	260
21	360
22	680
23	560
24	308
25	211
26	368
27	352
28	320

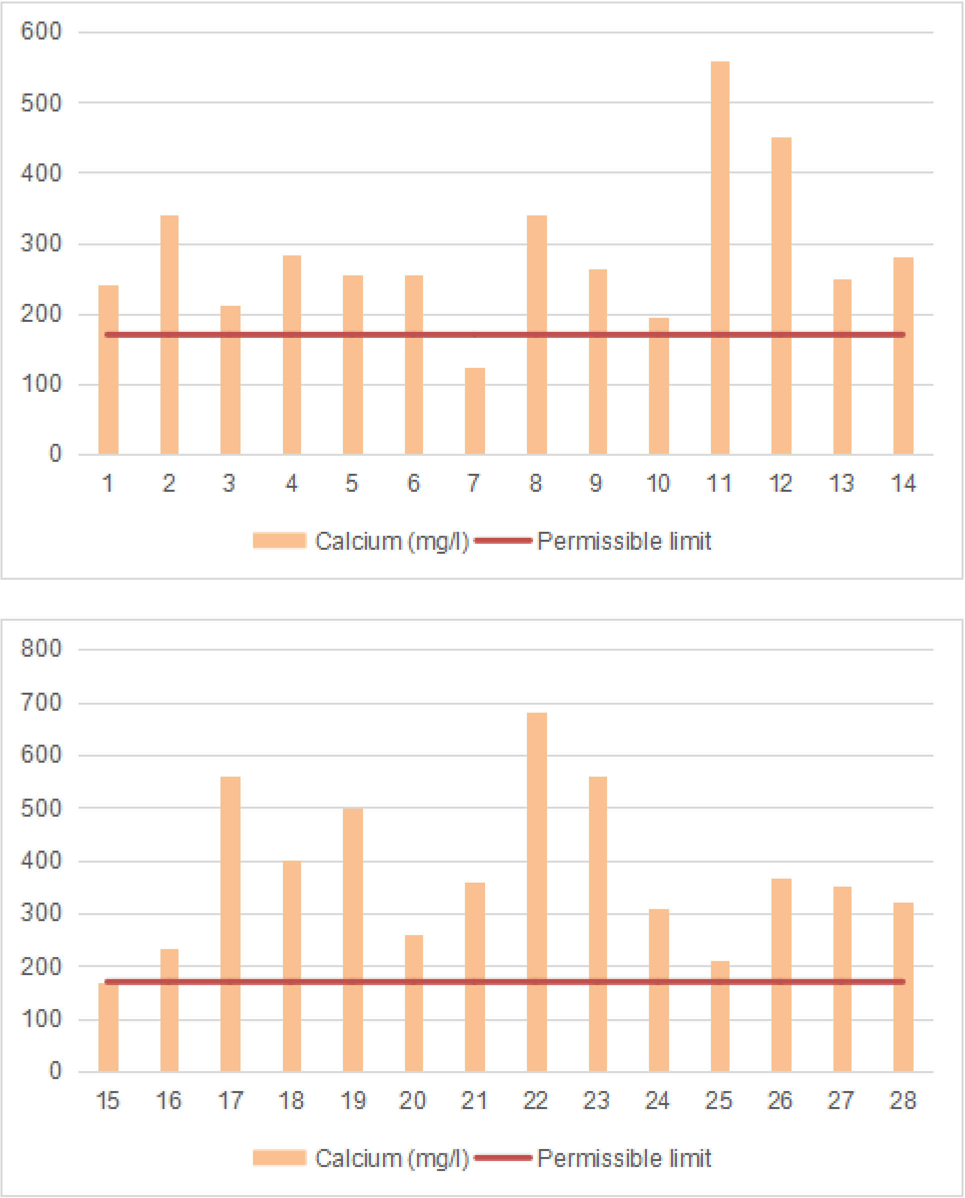


Figure 5. 15 Graph showing the concentration of Ca of sample 1-28

WHO standard for drinking for is Calcium with hardness being somewhere in the middle of soft and hard, 60 mg/L to 120 mg/L. Some also advise to not go beyond 170 mg/L, which indicates very high levels of calcium. When the calcium levels in a sample exceed the permissible limit, various geologic factors can be responsible for this occurrence. These factors include specific types of rocks, the surrounding geological conditions, and the lithology of the area. For instance, the presence of limestone, a sedimentary rock composed primarily of calcium carbonate, can lead to elevated calcium levels due to weathering and dissolution processes. Dolomite, another carbonate rock containing calcium magnesium carbonate, can also contribute to increased calcium content if it is present in the surrounding geology. Additionally, evaporite deposits containing minerals like gypsum and anhydrite, which are rich in calcium, can result in higher calcium levels. Metamorphic rocks such as marble, formed from the recrystallization of limestone, tend to have significant calcium carbonate content as well. Factors like contact metamorphism, hydrothermal activity, groundwater interactions, and leaching processes can further influence the calcium levels in the sample. It is important to consider the specific geological context and conduct a thorough analysis to identify the precise causes of excessive calcium content.

5.3.7 Magnesium

The magnesium content is an essential aspect to consider in water sampling. Monitoring and analyzing the presence of magnesium in water samples provide valuable information about water quality and its suitability for various applications. Measuring the magnesium levels helps assess the overall mineral content and hardness of the water. Magnesium is a divalent cation that contributes to water hardness along with calcium. High levels of magnesium can result in increased water hardness, which may have implications for domestic, industrial, and agricultural purposes. Accurate measurement and monitoring of magnesium levels contribute to informed decision-making regarding water management, treatment processes, and maintaining the overall balance of aquatic ecosystems.

The values for Calcium range from 1000-5500 mg/L with an average of 3016.7mg./L

Table 5. 7 Table showing concentration of Mg (mg/l) in samples

S. No	**Magnesium (mg/l**
1	4860
2	3760
3	3688
4	2316
5	2445
6	3244
7	2376
8	3260
9	2036
10	2504
11	2240
12	1748
13	2552
14	2820
15	3137
16	2368
17	2340
18	2600
19	5200
20	5240
21	3840
22	3520
23	5140
24	2192
25	2184
26	1932
27	2248
28	2680

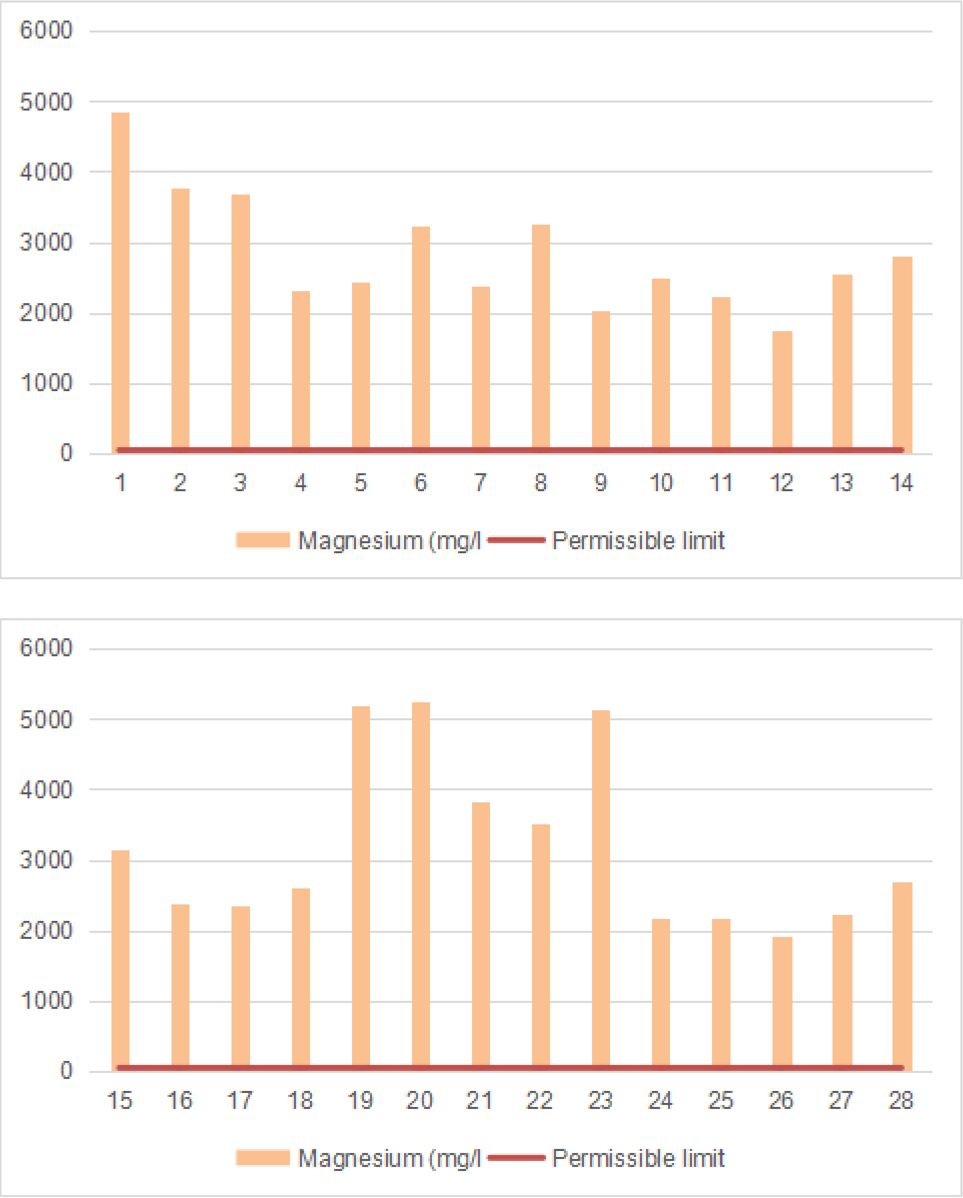


Figure 5. 16 Graph showing the concentration of Mg of sample 1-28

WHO standard for drinking for iHuman body contains about 25 g of magnesium (60 % in bones and 40 % in muscles and tissues). According to WHO standards, the permissible range of magnesium in water should be 50 mg/l. When the concentration of magnesium in a sample exceeds the permissible limit, various geological factors can contribute to this occurrence. One significant geological factor is the presence of ultramafic rocks, such as peridotite and dunite, which are rich in magnesium. These rocks can release high concentrations of magnesium into the surrounding environment. Another contributing factor is the formation of serpentine, a metamorphic rock that derives from the alteration of ultramafic rocks. Serpentine contains substantial amounts of magnesium and can release it into the environment. Dolomite, a sedimentary rock composed primarily of calcium magnesium carbonate, can also contribute to elevated magnesium levels when it weathers or dissolves. Certain volcanic rocks, like basalt and andesite, are additional sources of magnesium, which can be released through weathering processes. Hydrothermal alteration associated with volcanic or geothermal activity can introduce magnesium into surrounding rocks and sediments. Finally, in karst regions, soluble rocks such as limestone and dolomite can undergo dissolution, leading to the release of magnesium into water sources. It's important to conduct local studies and geological assessments to determine the specific geological factors causing elevated magnesium levels in a particular area.

5.4 Discussion

According to the World Health Organization (WHO), the physical parameters for water quality are crucial in determining its suitability for various purposes. Groundwater pH is influenced by the chemical composition of the water and the geological formations it passes through. Geological formations like sandstone, limestone, and dolomite, which contain neutral or slightly alkaline minerals, help maintain a pH around 7. In contrast, formations with acidic minerals may result in a slightly lower pH in the aquifer, but this typically doesn't have a significant impact on overall water pH. Other factors such as dissolved minerals, organic matter, and human activities can also affect aquifer pH, leading to localized variations. Presence of metallic minerals, saline or brackish water, fractured or faulted rocks, high-porosity rocks, and volcanic rocks with minerals like magnetite or pyrite can elevate the EC. Excessive conductivity varies across geological conditions and locations, and permissible limits are established based on specific applications or industries. TDS levels are influenced by the composition of bedrock, weathering and erosion processes, aquifer properties, and human activities. Certain rock types like limestone or gypsum contribute to higher concentrations of dissolved minerals, while weathering and interactions with the aquifer can also affect TDS content. Anthropogenic influences such as industrial discharge and agricultural runoff play a significant role in TDS concentrations. Considering both natural lithology and human influences is crucial for assessing TDS levels and water quality accurately. The salt concentration in water is affected by geological conditions and rock types. Sedimentary rocks like sandstone, limestone, and shale can have varying salt content, while igneous rocks like granite or basalt generally have low salt levels. The permeability of aquifers and specific geological features regulate the salt concentration. Site-specific studies are necessary to determine permissible salt limits based on water use and local factors. Control of water temperature is important to prevent the growth of organisms like Legionella. Geothermal systems, hot rocks, groundwater circulation, insulating formations, and cooler mountainous regions contribute to maintaining acceptable temperatures within permissible limits. Specific rock types and geological conditions can effectively moderate temperatures, but control mechanisms may be implemented as needed. Turbidity is primarily influenced by sediment runoff, organic matter, and human activities rather than specific geologic conditions or rock types. Factors such as heavy rainfall, erosion, loose sediments, and areas prone to soil erosion can contribute to elevated turbidity levels. However, turbidity is primarily an issue of water quality impacted by environmental factors and human activities rather than specific geological circumstances. However, the acceptable limit of chloride concentration may vary depending on the intended use, as it can be influenced by geological conditions, rock types, and environmental factors. Certain rock types such as sandstone, limestone, granite, basalt, and shale generally exhibit chloride concentrations within permissible limits for various applications. It's important to note that these descriptions are general, and actual chloride concentrations can vary, so site-specific testing and adherence to relevant guidelines are crucial for evaluating suitability. Exceeding these limits can occur in geological conditions such as evaporite deposits, saline intrusion, the presence of sodium-rich minerals, or weathering of sodium-rich minerals. The specific geological context and rock types influence the sodium concentration in surrounding lithology. Compliance with regulations and guidelines is necessary to manage and mitigate potential consequences. Exceeding the permissible limits can occur due to geological conditions, human activities, and rock compositions. Factors like evaporite deposits, hydrothermal activity, weathering of sodium bicarbonate or sodium carbonate-rich minerals, or anthropogenic processes can contribute to elevated concentrations. The environmental impacts should be considered, and adherence to guidelines is necessary for effective management. Exceeding the permissible limit can be attributed to geological factors associated with the type of rocks present, surrounding conditions, and lithology. Rock types like limestone, dolomite, chalk, and marl can contribute to elevated carbonate levels. Additionally, weathering or dissolution processes, as well as anthropogenic activities, can influence carbonate concentrations. Understanding the specific causes requires detailed investigation and analysis.

Elevated hardness levels can be attributed to geological factors such as rocks with high mineral content, carbonate rocks, karst topography, or weathering processes. Other factors like human activities and water treatment methods should also be considered. Rocks like limestone and dolomite containing calcium carbonate can contribute to alkalinity, while silicate-rich rocks like granite have lower alkalinity. Environmental factors and proximity to human activities can introduce substances affecting alkalinity. Detailed analyses and assessments are necessary to determine specific influences. Specific rock types like limestone, dolomite, gypsum, and marble can contribute to increased calcium levels. Weathering, dissolution, and metamorphic processes also play a role. Understanding the geological context and conducting comprehensive analyses are important. Geological factors like ultramafic rocks (peridotite and dunite), serpentine formations, dolomite, and volcanic rocks (basalt and andesite) are additional sources of magnesium.

In summary, the physical and chemical parameters of water quality are influenced by geological factors, rock types, lithology, environmental conditions, and human activities. Understanding these influences and conducting site-specific analyses is crucial for evaluating water suitability and ensuring adherence to WHO standards and guidelines.

CONCLUSIONS

The conclusion derived from the provided paragraph is that the physical and chemical parameters of water quality are influenced by a range of factors including geological conditions, rock types, lithology, environmental factors, and human activities. The pH of groundwater is influenced by the chemical composition of the water and the geological formations it passes through. Other factors such as dissolved minerals, organic matter, and human activities can affect aquifer pH. Electrical conductivity (EC) varies across geological conditions and locations, with factors such as metallic minerals, saline water, and specific rock types affecting its levels. Total Dissolved Solids (TDS) concentrations are influenced by bedrock composition, weathering processes, aquifer properties, and human activities. Salt concentration is affected by geological conditions and rock types, with sedimentary rocks generally having varying salt content and igneous rocks having low levels. Water temperature can be influenced by geothermal systems, groundwater circulation, and specific rock types. Turbidity is primarily influenced by sediment runoff, organic matter, and human activities. Chloride concentration in water can be influenced by geological conditions and rock types, with certain rock types generally exhibiting permissible levels. Sodium concentration is influenced by the specific geological context and rock types. Carbonate levels can be attributed to rock types, weathering processes, and anthropogenic activities. Hardness levels can be influenced by geological factors, including rocks with high mineral content and carbonate rocks. Alkalinity is affected by rock types and environmental factors. Calcium levels can be influenced by specific rock types, weathering processes, and metamorphic activities. Magnesium levels can be sourced from various geological factors such as ultramafic rocks, serpentine formations, dolomite, and volcanic rocks. Therefore, a comprehensive understanding of these factors is necessary for assessing water suitability and ensuring compliance with WHO standards and guidelines.

Geological factors, rock types, lithology, environmental conditions, and human activities all impact water quality parameters.

- The pH of groundwater is influenced by the chemical composition of the water and high content of calcium carbonate. The sandstone, limestone, and dolomite, tend to have a neutralizing it . Aquifer pH can be affected by dissolved minerals, organic matter, and human activities.

- Electrical conductivity (EC) varies based on dissolved salts in the water, such as sodium, calcium, and chloride ionscertain volcanic rocks, like basalts, contain minerals with high electrical conductivity, including magnetite or pyrite
- Total Dissolved Solids (TDS) concentrations depend on types of rocks like limestone or gypsum can contribute higher concentrations of dissolved minerals to the water.
- Salt concentration in water is influenced by geological conditions and rock types, with sedimentary rocks having varying salt content and igneous rocks generally having low levels.
- Water temperature can be influenced by sedimentary rocks with low thermal conductivity, such as shale or siltstone, create a stable environment by reducing heat transfer between layers. Furthermore, mountainous regions with higher elevations tend to offer cooler temperatures, and rocks like gneiss or schist found in these areas contribute to maintaining acceptable temperature levels.
- Turbidity is primarily affected by sediment runoff, organic matter, and human activities.
- Chloride concentration can be influenced by limestone, calcium carbonate, making it suitable for construction and agricultural purposes. Granite, an igneous rock composed primarily of quartz, feldspar, and mica, tends to have low chloride Basalt, an iron and magnesium-rich igneous rock. Lastly, shale, a fine-grained sedimentary rock composed of clay minerals.
- High sodium concentrations can be found in different scenarios. One such scenario is the formation of evaporite deposits, such as rock salt (halite) and gypsum, which typically occur in arid or semi-arid environments with high evaporation rates.
- limestone or dolomite can release sodium bicarbonate. Sodium carbonate-rich water sources or brines, can lead to groundwater or surface water carrying higher levels of sodium carbonate. limestone, dolomite, and marble that contain carbonate minerals prone to dissolution and the release of bicarbonate ions.Limestonr ,calcium , marls, dolomite, calcareous sandstone and magnesium cause carbonate level exceed.

- Hardness levels are influenced by limestone and dolomite, can have a substantial impact on water hardness due to the dissolution of calcium carbonate and magnesium carbonate into the water.
- Alkalinity is affected by rocks such as limestone and dolomite contain calcium carbonate, which can contribute to alkalinity when dissolved in water.
- Calcium levels can be influenced by specific rock types, weathering processes, and metamorphic activities.
- Magnesium levels can be sourced from geological factors like calcium carbonate, dolomite, metamorphic rocks such as marble, ultramafic rocks, serpentine formations, dolomite, and volcanic rocks, carbonate rock containing calcium magnesium carbonate, can also contribute to increased calcium content

Understanding these factors is essential for assessing water suitability and ensuring compliance with relevant standards and guidelines.

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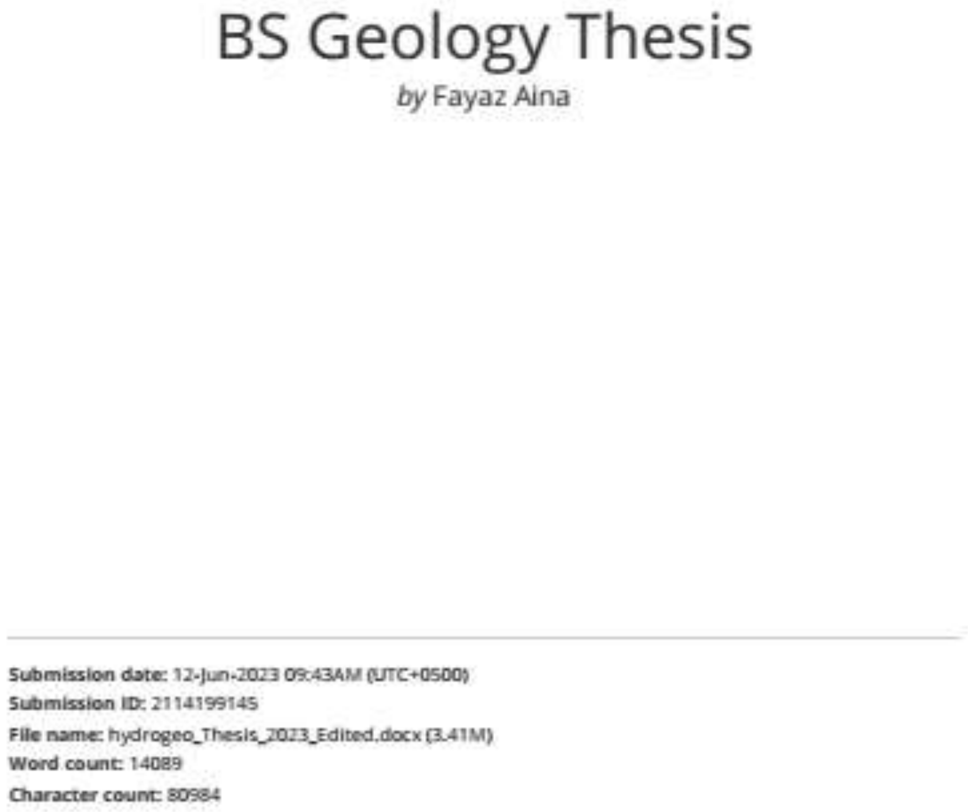

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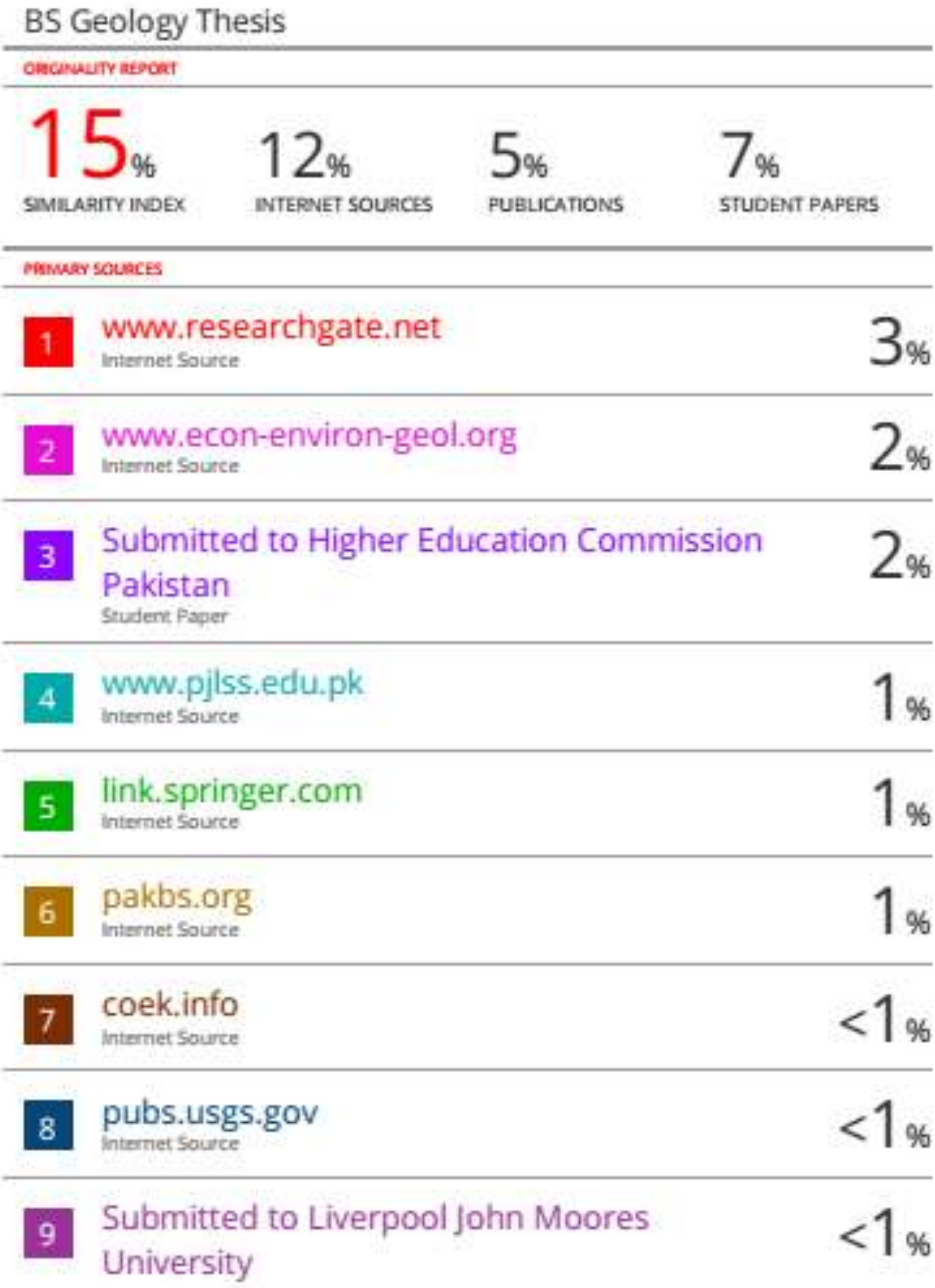

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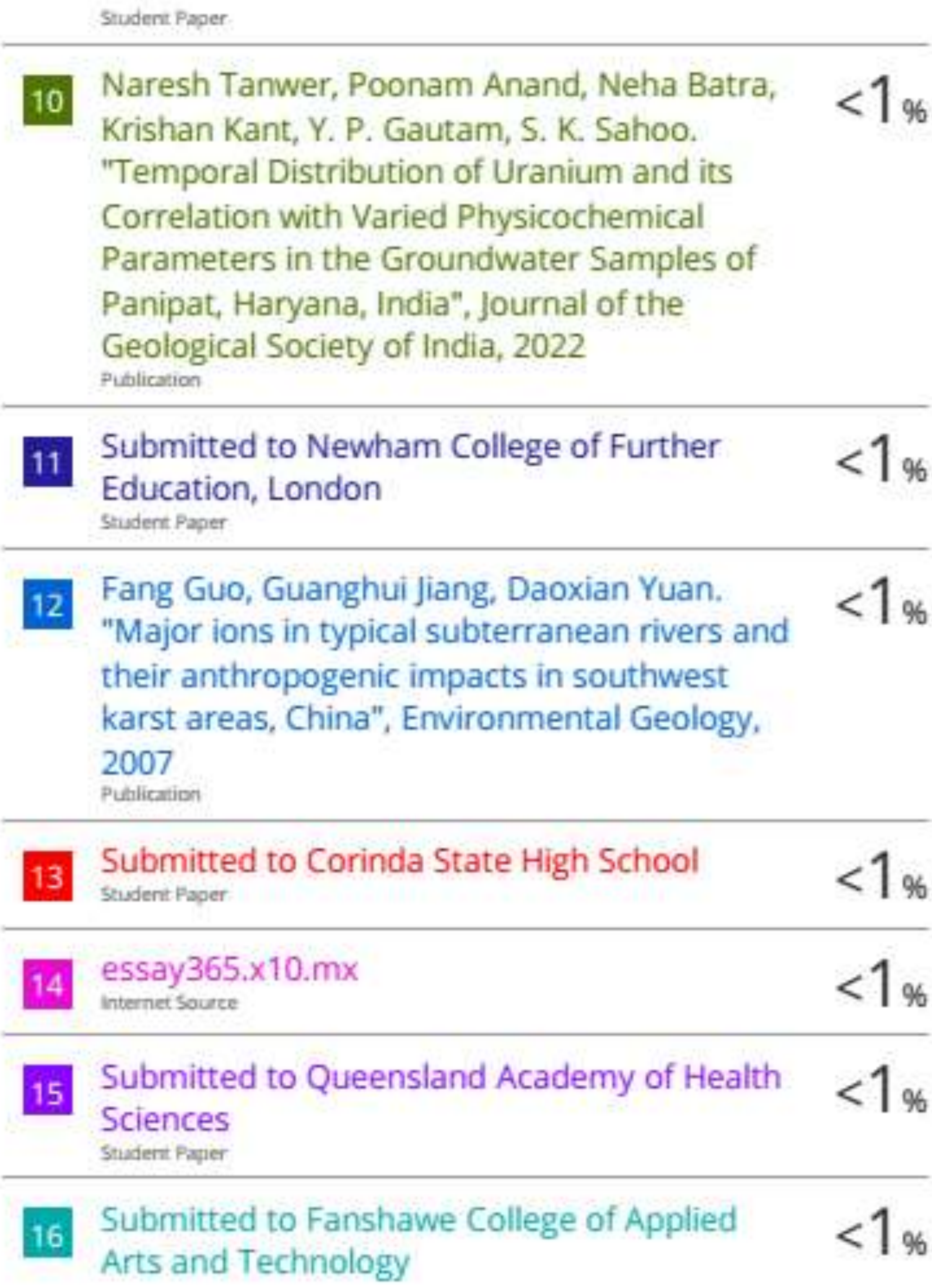

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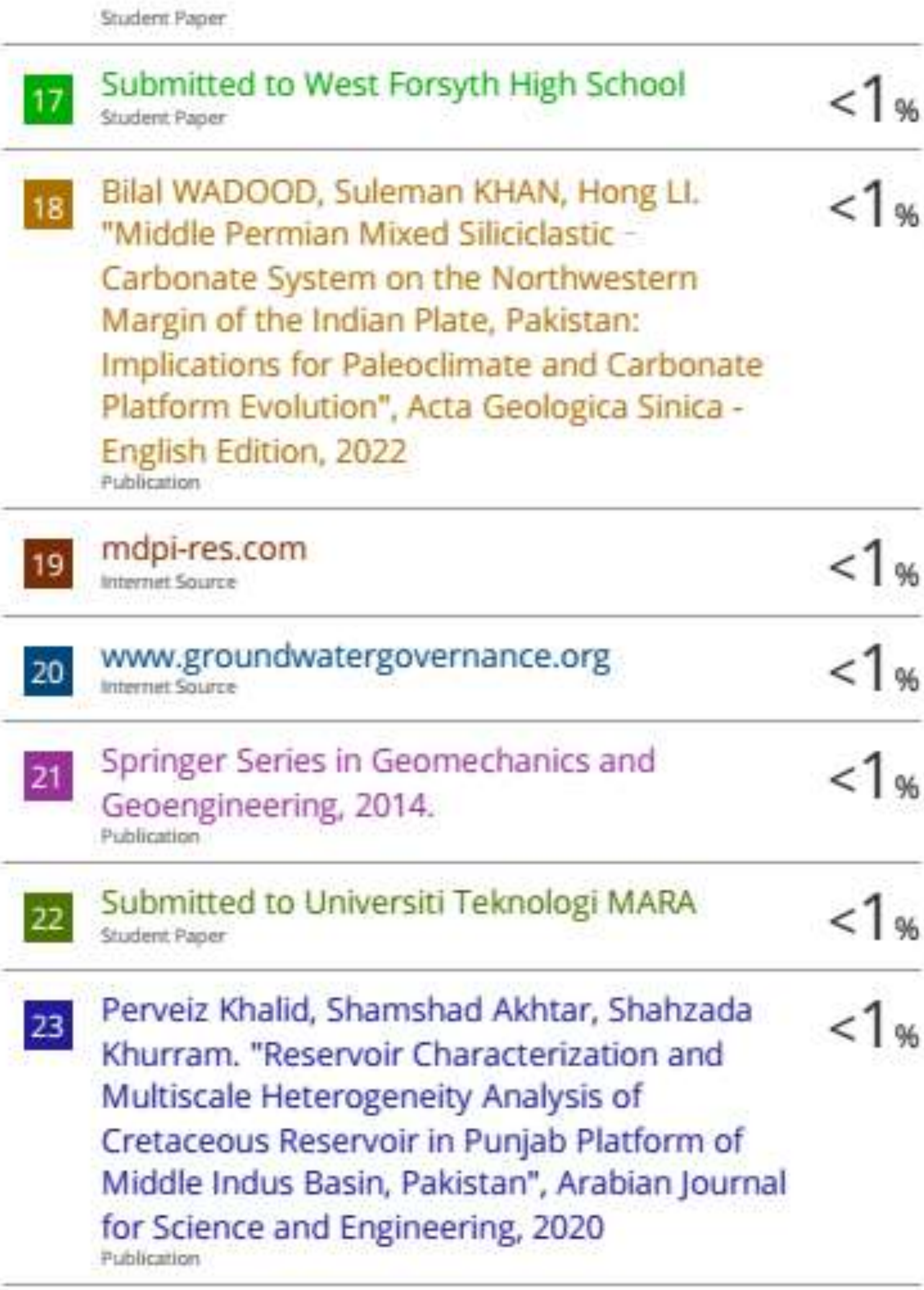

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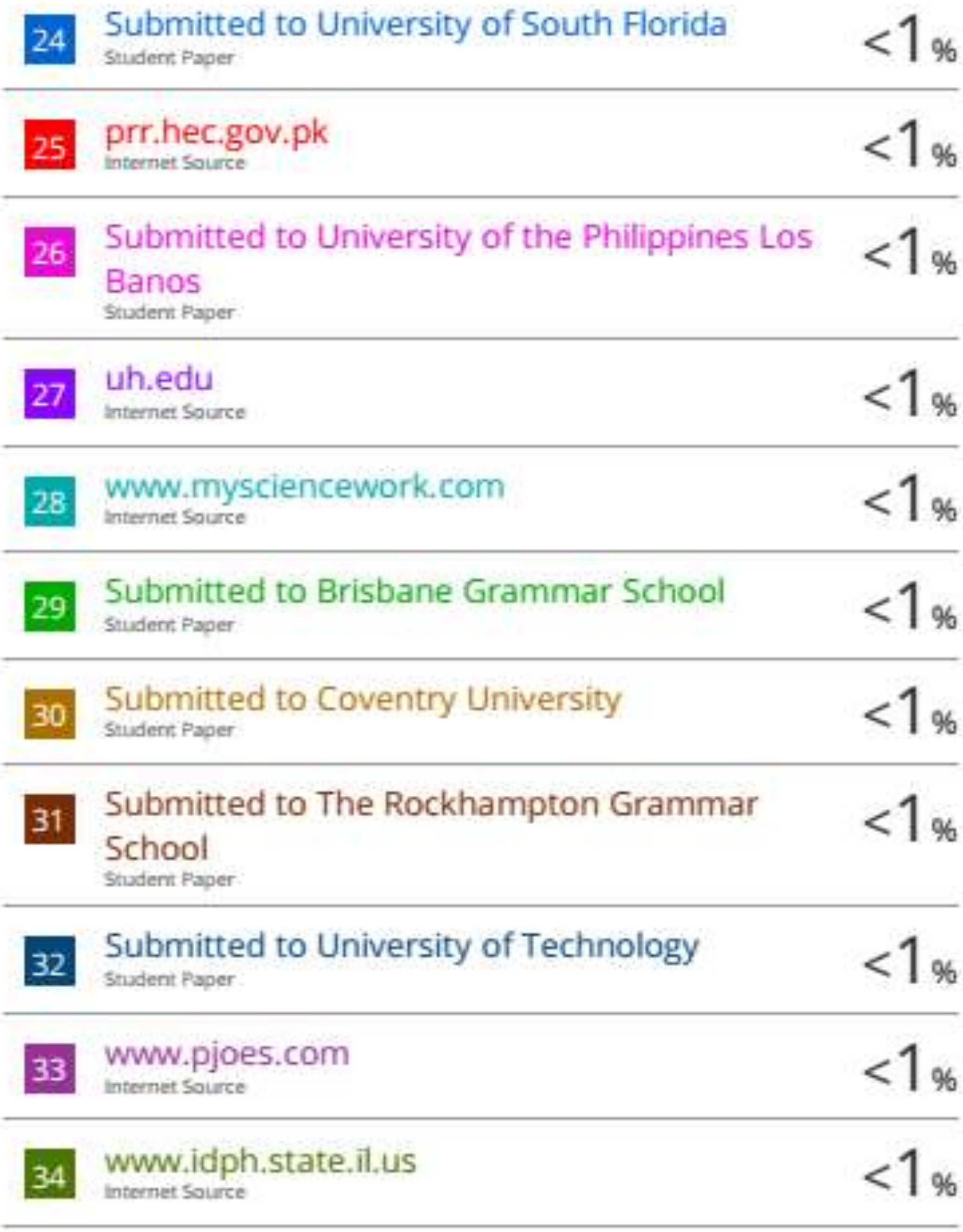

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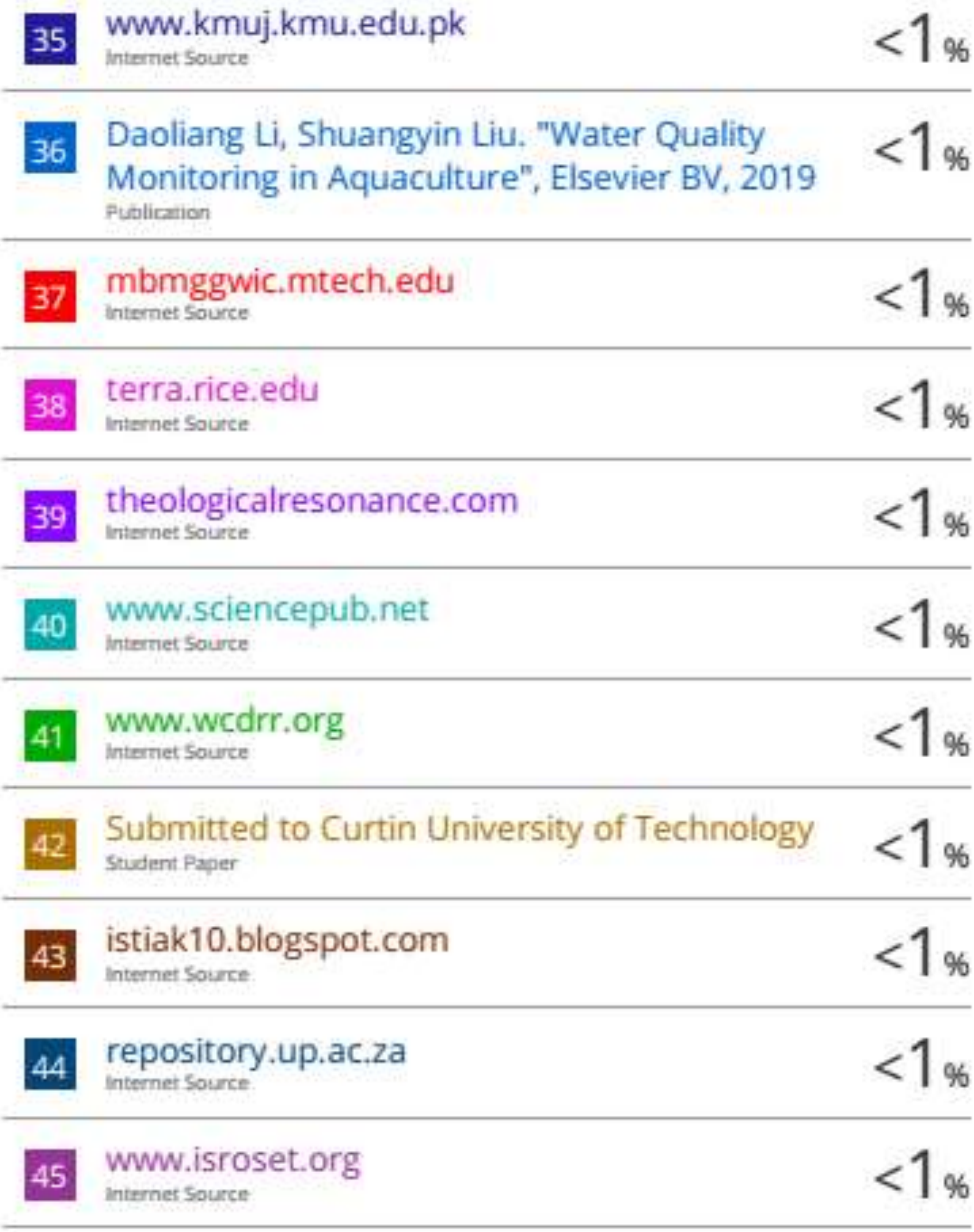

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