GEOSTATISTICAL ANALYSES OF HISTORICAL HYDRO-GEOLOGICAL PARAMETERS IN DERA ISMAIL KHAN SUBBASIN, NWFP, PAKISTAN

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ABSTRACT

Dera Ismail Khan is one of cities of the N.W.F.P. The growing population in this area manifests the increased water demands because utilization has increased manifolds in recent years. In this area, major source of water is groundwater. For the understanding of the groundwater, the historical behavior of the groundwater is crucial to determine the fore coming changes in response to the variation in the climate and other factors.

The research conducted over here describes the historical spatial behavior of the groundwater. The technique used for its study is Covariance Analyses. Electrical conductivity (Ec), Total Dissolved Solids (TDS), pH of water, Sulfate, Calcium, Magnesium, Alkalies and Chloride are analyzed against latitude, longitude and depth of some test holes.

The variation in the analyses has been determined by four relationships. So it has been found that TDS, Ec, Mg, Na+K v/s depth and pH, SO_4 v/s latitude show strong negative relationship. And TDS, Ec, Ca, Mg, Na+K v/s latitude, pH v/s longitude and chloride v/s depth show moderate negative relationship. While TDS, Ec, SO_4, Ca, Mg, Na + K and chloride show moderate positive relationships. The Empirical relationships between the parameters were also found.

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CHAPTER NO. 1
INTRODUCTION

Dera Ismail Khan is a city in N.W.F.P (North West Frontier Province), Pakistan (Figure 1.1). Dera Ismail Khan takes its name from Ismail Khan, a Baluch chief who settled here towards the end of the 15th century in 1469 A.D. "Dera" means a place people gather for different activities. The old town was swept away by a flood in 1823, and the present town stands four miles back from the permanent channel of the river.

Though economically underdeveloped, this seven-century old city is rich in socio-cultural heritage, the archaeological antiques and the remnants of the glorious past. Among others, Rahman Dheri, 14 kilometers north of the city, is 3500 BC old and has been the resort of the archaeologists from various advanced countries.

The Gomal Pass in the Sulaiman mountainous range is historical one and the Gomal valley has been one of the most significant sites of the origin of Indus civilization. Eighteenth longest river of world the mighty Indus glides magnificently in the east while the alluvial soil of Daman (foot of mountain) has been kept uncultivated due to lack of proper and reliable irrigation system. The completion of Chashma right bank canal and Indus highway has substantially contributed to the development of irrigation system and transformation of socio-economic life in this part of the country.

Figure 1.1 Location map of Pakistan showing Dera Ismail Khan by red dot

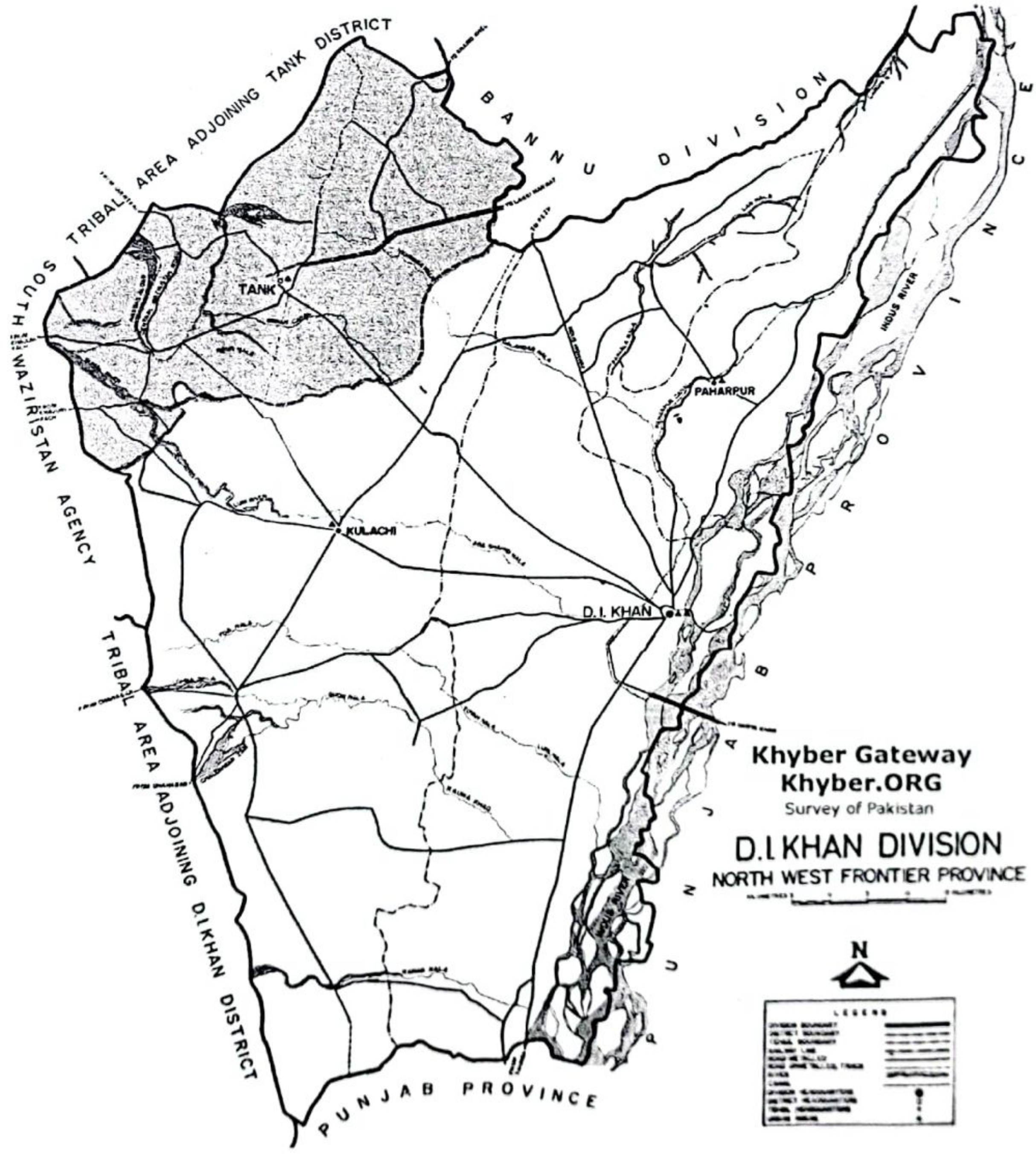

Figure 1.2 Division map of D.I.Khan produced by G.S.P

1.1 LOCATION AND ACCESSIBILITY

Dera Ismail Khan is located at 31° 49′ N and 70° 55′ E on the west bank of Indus river and in the west of Punjab province with a ground elevation of 172 meters. Bannu division is on north side of D.I.Khan within Tank district and South Waziristan Agency. Dera-Darya Khan bridge is the main link connecting Dera Ismail Khan with major cities of the country. D.I.Khan is linked with the rest of the cities of the province by roads which stretch about 300 kilometers down from Peshawar passing through Kohat and Bannu. Rail link is also available from Kotla Jam railway station lying between Darya Khan and Bhakkar. Air service provides an additional and more comfortable link to the provincial capital and other parts of the country.

1.2 CLIMATE

The climate of the D.I.Khan is arid and semi-arid. Because of low humidity, continental location and dearth of vegetation there are the usual expected extremes in temperature, both diurnal and seasonal. Continentality, especially with respect to high summer temperatures, is the most outstanding climatic feature of the area. Beginning in May and lasting till August the area, including the hills, often experiences a mean maximum shade temperature of more than 100°F.

Meteorological data of year 2006 from Dera Ismail Khan supplied by Pakistan Metrological Department are presented Table 1.1;

Table 1.1 Meteorological data of D.I.Khan for year 2006 by Pakistan Meteorological department

MONTH	HIGH TEMPERATURE F/C	LOW TEMPERATURE F/C	PRECIPITATION INCH/mm	AVERAGE PERCENT SUNSHINE
JANUARY	69/20	40/4	0.39/10.0	31
FEBRURY	72/22	45/7	0.69/17.5	29
MARCH	80/27	55/13	1.37/34.8	33
APRIL	S92/34	65/18	0.85/21.7	36
MAY	102/39	74/23	0.68/17.2	40
JUNE	107/42	80/27	0.57/14.4	34
JULY	101/38	80/27	2.39/60.8	34
AUGUST	99/37	80/26	2.26/57.5	36
SEPTEMBER	98/37	75/24	0.69/17.6	38
OCTOBER	92/33	63/17	0.19/4.8	39
NOVEMBER	82/28	51/10	0.08/2.1	35
DECEMBER	71/22	42/5	0.41/10.4	31

The precipitation varies from 2mm in November to 60mm in July which was maximum precipitation in D.I.Khan during in 2006 as shown in the bar chart (Figure1.3);

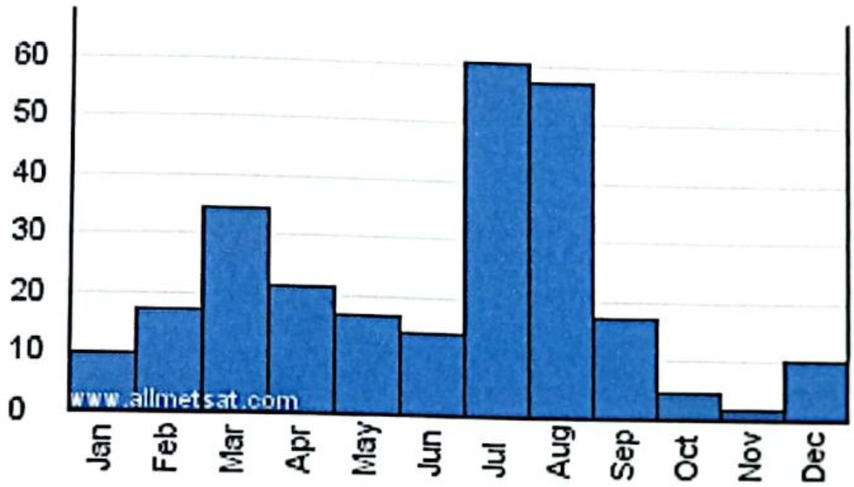

Figure 1.3 A bar chart showing precipitation (mm) in D.I.Khan for 2006

The sunshine in D.I.Khan varies from a maximum of 9.5 hours in May which is about 40% to a minimum of 7 hours in December which is about 31% as shown in the bar chart (Figure1.4);

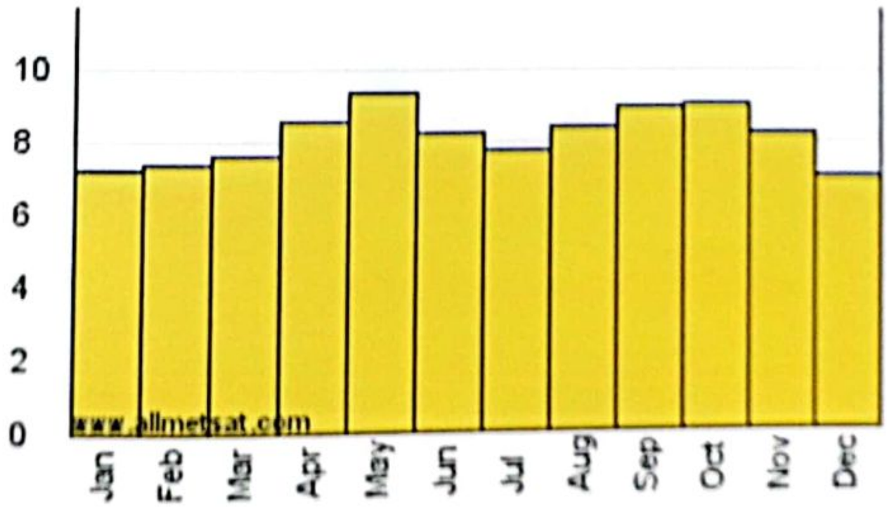

Figure 1.4 A bar chart showing sunshine hours in D.I.Khan for 2006

1.3 AIMS AND OBJECTIVES

The study area of this project has been studied on various aspects of Geology, including Tectonics, Sedimentology, Straitigraphy and Geomorphology but no such studies have been carried out on the quality and Geostatistical analyses of hydrogeological parameters. The main purpose of the present study is to determine the geostatistical analyses of the hydrogeological parameters for the utilization in environmental and geochemical modeling as follows;

1. Variance calculations of cations and anions
2. Covariance analyses of cations and anions
3. Empirical relationship of cations and anions

CHAPTER NO. 2
GEOLOGY AND HYDROLOGY

2.1 GEOLOGY OF AREA

The project area comprises of three main physiographic units, i.e. Derajat, highlands and Indus river plains, all units are described below;

2.1.1 DERAJAT

The 'Derajat' is an integral part of the natural unit known as the Indus plains, a vast geosynclines lying between the Himalayan foothills and the central core of the Indian subcontinent. This depression, which once may well has been an off-shoot of the sea, has now been filled with tremendous amounts of sediments brought down by streams from mountains. In the project area a small part in the east is built up with floodplain material of the Indus river, and its surface is marked by meander scars and old river channels. The main western part of the survey area ('daman') is a piedmont that slopes gently up to the mountains and is surfaced with outwash materials derived from them.

2.1.2 HIGHLANDS

Sulaiman Mountains

Although the Sulaiman exhibit the same north-south trend and even the exact rock sequence as the Waziristan hills, their scale is so much greater and their alignment is so much regular that are usually treated as a separate mountain Range. Together with their eastern extremity, the Shirani hill, they may be described as a huge easterly dipping anticline, the axis of which corresponds to the ridge of highest peak culminating in Takht– I–Sulaiman (throne of Solomen).

The outer hills of this mountains system, the Swaliks (comprising of conglomerates and sandstone) rise abruptly from the plains of the Derajat to a height of approximately 5000 feet. Immediately back of these are an older tertiary, the Nummulitics, which are also disposed in a succession of parallel ridges, in this case the anticline corresponding with the harder sandstone rock bands. From the western edge of these ridges the Takht (mail) ridge rises abruptly in the succession bare rocky slopes and precipices, to an elevation of 11,000 feet. This represents the oldest rock formation in the entire range and though La Touché classes it as being massive cretaceous limestone, Vrendenburg takes exception to this and dates it as middle Jurassic.

The erosional physiography of the area as a whole is typical of arid and semi-arid terrains and is illustrated particularly by the marked contrast and abrupt boundary between the steep-sided rocky mountains and the wide, very gently sloping piedmonts. Relatively little, talus lies at the foot of the hills. On the other hand, alluvial fans are prevalent features; most of them coalesced as bahadas, and grade into the relatively level part of the piedmont.

2.1.3 INDUS RIVER PLAINS

Active floodplain

This landform occurs as a narrow discontinuous strip of more adjacent to the active riverbed. The area is flooded once or more during summer and receives fresh sediments almost every year. Levees meander scars and back swamps are the prominent features of this area. These features are subject to continual change because of river erosion and deep flooding. The soils range from sand to clay, but these variations are mainly due to different depositional patterns. All the soils are young, show no signs of profile development and are underlain by sand at relatively shallow depths.

Recent level floodplains

This unit covers relatively higher areas adjoining the Active floodplains from which they are generally separated by low bluffs. The general topography is nearly level, broken only by occasional meander scars or levees. The soils are medium or moderately-coarse textured and sand occurs at relatively shallow depths. During exceptionally high floods however, they are shallowly inundated for short periods. The soils show no signs of profile development. (Shahdara, Khair, Malik and Sodhra soil series).

Recent meander bar complex

The recent meander bar complex is found adjacent to recently abandoned river channels now left as meander scars which are often clearly visible both on the ground and on the air photos. The complex comprises meander bars and natural levees in such a manner that it is not possible to map them separately. The soils of the higher levees are coarse in texture. In the meander bars and meander bars and meander scars there is a concentration of silty material and saline-alkali conditions have developed particularly in areas with a high water table. (Kasur and Sodhra soil series, Khair saline-alkali variant).

Recent basin and channel in fills

This landform comprises deposits left in abandoned cutoff channels and those lay down in the flood basins at the back of natural levees. The soils consist of stratified layers of silty and clayey material carried and deposited by slow-moving spill waters from the Indus at times of high floods. They are lower than their surroundings and are subject to pounding of runoff or high water-table. In the basins the older drainage lines have been mostly obscured by successive flooding (Rustam and Malik soil series).

Recent levees

This unit comprises low ridges that parallel active or abandoned river creeks. The levees are highest near the creeks and slope gradually away from them. The greater height near the channels is owing to the cumulative effect of sudden loss in transporting power when streams overflow their banks. The soils are mostly coarse-textured and have, in places, blown into dunes. (Sodhra soil series).

Sub-recent level floodplains

These are plains which have long been abandoned by the rivers, and features such as meander scrolls, bars and levees have been obliterated by somewhat uniform sediments of later slow-moving sheet floods. The sub-recent level floodplains usually lie at about the same level as the recent level plains, but are father removed from active or abandoned channels and are not subject to annual accretion. The soils are clayey or silty and the soil profiles, except those in high areas, show homogenization to depths ranging from 40 to 75 cm. (Sultanpur, Notak, Shahdara and Khair soil series).

Marwat Piedmont

The Marwat Piedmont, or Pezu plain as referred to in some former works (Colombo Plain, 1967), consists of sandy outwash deposits lying along the southern foot of the Bhittanni, Marwat and Khisor ranges. All three ranges are narrow and low and there are no large torrents due to the small catchment area. Most of the soils are sandy. Finer-textured materials however do occur in low-lying strips along torrents, but these are not extensive enough to be represented in mapping. The Marwat piedmont overlies the Sulaiman piedmont at their contact.

Sulaiman Piedmont

This region is bounded by the lower edge of the Marwat piedmont on the north, by the foot of the Sulaiman range in the west and by the Indus river floodplains in the east. Its southern limit lies beyond the survey area. It predominantly consists of clayey and silty outwashes derived from the Sulaiman range from which it slopes away imperceptibly to the plains of river alluvium. The sharp contact between the piedmont and the floodplains is marked in many places by a low bluff. The piedmont contains numerous torrents, some of which are shallow, others incised deeply below the surface. The normal gradation of particle sizes on piedmonts, with coarse materials near the mountains and finer materials below, is, for the large part, absent from this piedmont.

2.2 HYDROLOGY OF THE AREA

The area is marked by a great contrast in water supply ranging from excessive to scanty. The Indus river flows at the eastern boundary of the area in a somewhat south direction. It is low in winter but begins to rise in April and gradually floods most of the rivers by rain in July to September.

The 'daman' (piedmonts) which makes up more than 80 percent of area, contains numerous hill torrents. Their general direction is west to east with a slight inclination to the south, but the Paniala nalah is an exception. Most of the tributary streams that debouch from the hills into the 'daman' are gradually dissipated by distributary's channels on the alluvial fans or piedmont slopes and do not join the trunk streams of the piedmont as large channels. Virtually all the streams are smaller at their ultimate destination than farther upstream. The water rushing down is usually blocked by temporary earthen dams and diverted by means of channels to irrigate embanked fields. Sometimes the current is so strong that the dams give way to the first onslaught of water. Fed, as they are, by short-lived downpours the torrents are active only for a few days or even hours and generally do not persist over long distances. The bulk of the cultivation in the area however is based on this flood water.

Perennial streams in the area are known as 'zams'. The most important are the Gomal and Tank zams; of lesser important are the Zarkanni, Daraban and the Chaudwan zams. Although classed as perennial, little, if any, water from these streams actually reaches the Indus except in times of seven floods.

Groundwater in the floodplains of the Indus, and in an adjoining very narrow belt of piedmont, is of fair quality and is used for irrigation through an increasing number of tube wells and Persian wells. In the remainder of the area however, the ground water is too saline and generally too deep to be used for irrigation.

The only canal of note is the government inundation canal known as the Paharpur canal. Taking off from a cut in the Indus river at Chasma, the canal parallels the Indus for its total length of about 60 miles. It has 15 miles of distributaries and an authorized discharge of 480 cusecs designed for a cultural commanded area of 103,591 acres. The actual discharge however, is much less than the designed capacity and the irrigated area varies between 47,000 and 65,000 acres depending upon the discharge. The cropping intensities in its commanded area vary from 55 to 80 percent.

CHAPTER NO. 3
METHODOLOGY

3.1 COVARIANCE

Covariance is a statistical value measuring the simultaneous deviations of x and y variables from their means. In probability theory and statistics, the covariance between two real-valued random variables *X* and *Y*, with expected values $E(X) = \mu$ and $E(Y) = \nu$ is defined as;

$$\operatorname{cov}(X,Y) = \mathrm{E}((X-\mu)(Y-\nu)),$$

where E is the expected value Operator, which is defined as;

$$\operatorname{cov}(X,Y) = \mathrm{E}(X \cdot Y) - \mu\nu.$$

Intuitively, covariance is the measure of how much two variables vary together (as distinct from variance, which measures how much a single variable varies). If two variables tend to vary together (that is, when one of them is above its expected value, then the other variable tends to be above its expected value too), then the covariance between the two variables will be positive. On the other hand, if when one of them is above its expected value, the other variable tends to be *below* its expected value, then the covariance between the two variables will be negative.

If X and Y are independent, then their covariance is zero. This follows because under independence,

$$E(X \cdot Y) = E(X) \cdot E(Y) = \mu\nu.$$

The converse, however, is not true: if *X* and *Y* have covariance zero, they need not be independent. The units of measurement of the covariance cov(*X*, *Y*) are those of *X* times those of *Y*. By contrast, correlation, which depends on the covariance, is a dimensionless measure of linear dependence. Random variables whose covariance is zero are called uncorrelated.

3.1.1 PROPERTIES OF COVARIANCE

If *X*, *Y* are real-valued random variables and *a*, *b* are constant ("constant" in this context means non-random), then the following facts are a consequence of the definition of covariance;

$$\operatorname{cov}(X, X) = \operatorname{var}(X)$$

$$\operatorname{cov}(X, Y) = \operatorname{cov}(Y, X)$$

$$\operatorname{cov}(aX, bY) = ab \operatorname{cov}(X, Y)$$

3.1.2 MODELS OF COVARIANCE

There are several types of models for covariance or accountable variance. They differ with respect to what is known, or what information is specified by the model, and the certainty of their predictions.

3.1.2-A CAUSE EFFECT METHOD

It is necessary to experimentally manipulate the relevant variables to prove that a cause-effect relationship exists.

Mechanistic Models

Some things, like a billiard ball moving as the result of being hit by the cue ball can be seen in a cause-effect framework where each step in the process is well understood. A light switch and room illumination is another example.

Functional Models

Things often stabilize in predictable ways without us understanding (or caring about) the reductionistic processes involved. Planets stabilize at known speeds and positions, water runs down to the sea, the rate of responding changes in orderly ways when the reinforcement rate changes, and so on. It helps little to explain celestial mechanics by saying that an unspecifiable force causes it or the rate changed because the animal knew something.

3.1.2-B CORRELATION MODEL

Some times the things look together. But one thing is not known to cause the other. Additionally, may not even know which comes first. Social respectability and wealth covary. One can be predicted from the other but one does not force the other. Any of three relationships could underlie the prediction. It could be A' B; B' A; or C' A and B. (No manipulation; predictor' predicted with unknown order of effect.) (Experimental research could find order of effect.)

3.1.3 EMPIRICAL RELATIONSHIPS

In the case of continuous calculations of x and y, the outcome get weak or strong relationships, positive and negative relationships. As shown in the Figure 3.1;

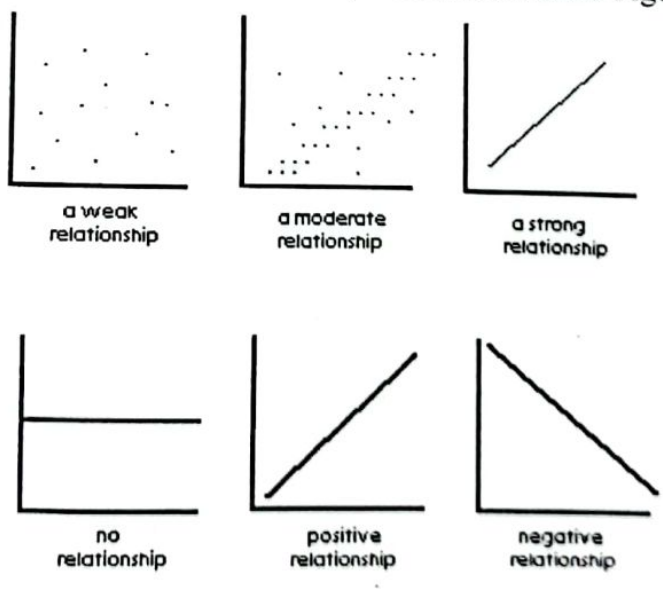

Figure 3.1 Diagrams showing Empirical relationships between two parameters

3.2 TEST HOLES AND PARAMETERS

In D.I.Khan area, water and soil investigation division (WASID) of WAPDA carried out detailed investigation for development of groundwater. Several test holes and test wells were drilled by WAPDA (Water and Power Development Authority) in this area, which were named as 'WASID Test Holes and Test Wells'. These test holes were drilled mainly for lithological logs in D.I.Khan area and for water sampling from each test hole. Water sampling was done to determine the subsurface water quality in D.I.Khan with the help of various hydrogeological parameters; some of them are listed below;

- Ec (Electrical conductivity)
- TDS (Total Dissolved Solid)
- pH
- Sulfate (SO_4^{-})
- Calcium (Ca)
- Magnesium (Mg)
- Sodium + Potassium (Na+K)
- Chloride (Cl^{-})

The 28 test holes were selected for covariance analysis in different locations of D.I.Khan as shown in the map of D.I.Khan (Figure 3.2). This project is mainly based on above parameters and spatial data (lat/long). In this study is mainly based on the covariance analysis of each parameter with respect to latitude/longitude value of each test hole; and discussion of the variation of these parameters along latitude/longitude and depth of each test hole.

The covariance analysis for each parameter was based on the data collected from WASID (Water and Soils Investigation Division) test holes D.I.Khan as marked in the lat/long (Figure3.2);

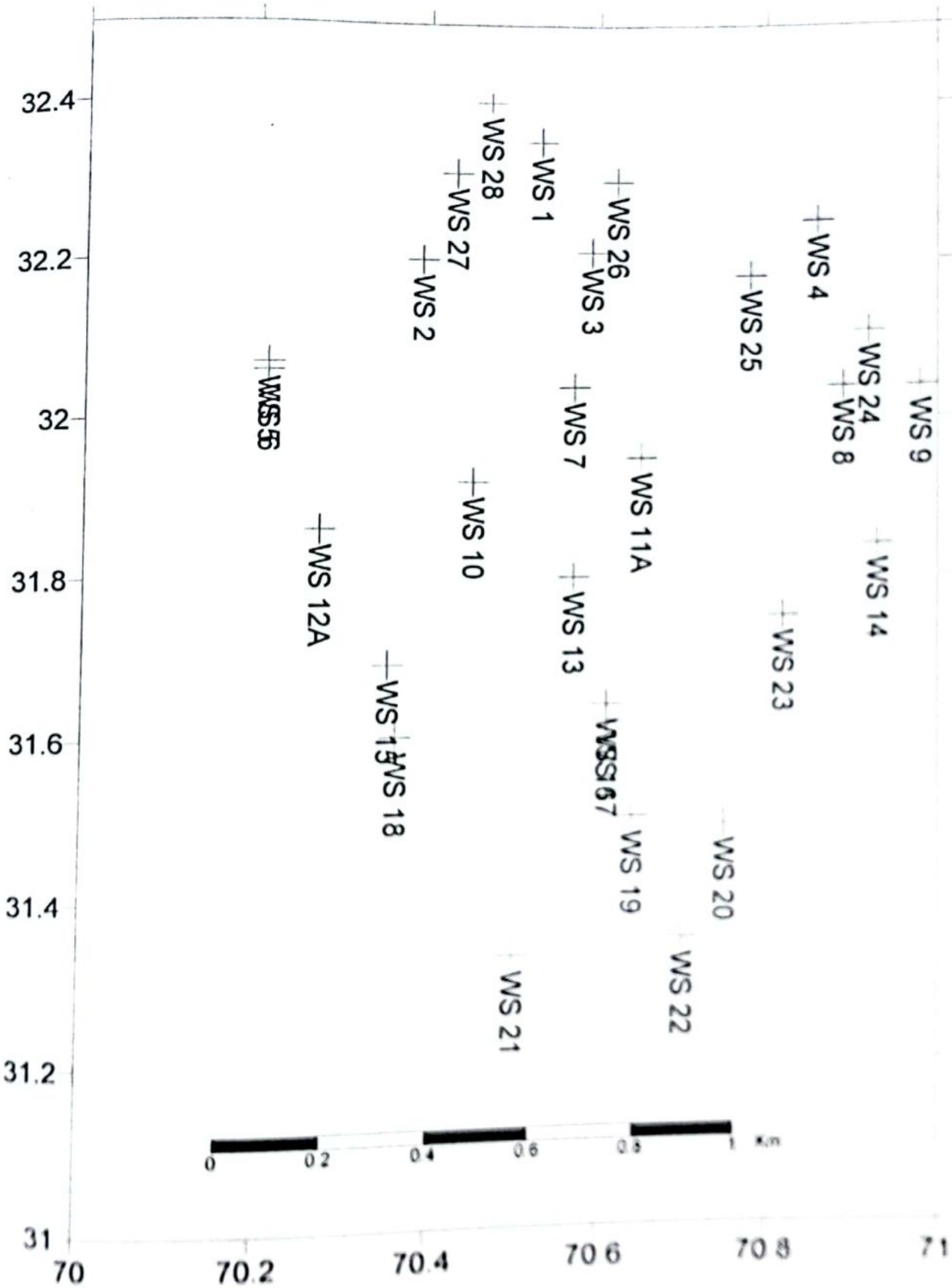

Figure 3.2 Location of selected WASID test holes for analysis in D.I.Khan area

4	Sulfate	Latitude	-235.4965714	Strong Negative	y = -0.0076x + 32.05
		Longitude	9.2729	Moderate Positive	y = 0.0003x + 70.587
		Depth	-35483.5	Strong Negative	y = -0.1549x + 59.44
5	Calcium (Ca)	Latitude	-34.90333571	Moderate Negative	y = -0.0175x + 31.99
		Longitude	2.07725	Moderate Positive	y = 0.001x + 70.587
		Depth	-6865.94	Moderate Negative	y =-0.03x + 14.139
6	Magnesium (Mg)	Latitude	-32.0343	Moderate Negative	y = -0.0158x + 31.98
		Longitude	-0.0055	Moderate Negative	y = -3E-06x + 70.595
		Depth	-11887.5	Strong Negative	y = -0.0519x + 18.91
7	Alkalies (Na+K)	Latitude	-139.4064357	Moderate Negative	y = -0.0059x + 31.99
		Longitude	25.17925	Moderate Positive	y = 0.0011x + 70.57
		Depth	-35205.8	Strong Negative	y = -0.1537x + 55.87
8	Chloride (Cl)	Latitude	9.512092857	Moderate Positive	y = 0.001x + 31.845
		Longitude	22.88745	Moderate Positive	y = 0.0023x + 70.574
		Depth	-15582.9	Moderate Negative	y = -0.068x + 59.442

4.1 INTERPRETATION

The interpretation of cations and anions are mostly based on latitude, longitude, depths and their Empirical relationships.

4.1.1 ELECTRICAL CONDUCTIVITY (Ec)

Conductivity is a measure of water's ability to conduct an electric current and it is directly related to the total dissolved salt content of the water. Variation in electrical conductivity in WASID test holes with respect to latitude, longitude and depth is shown in the Figure 4.1;

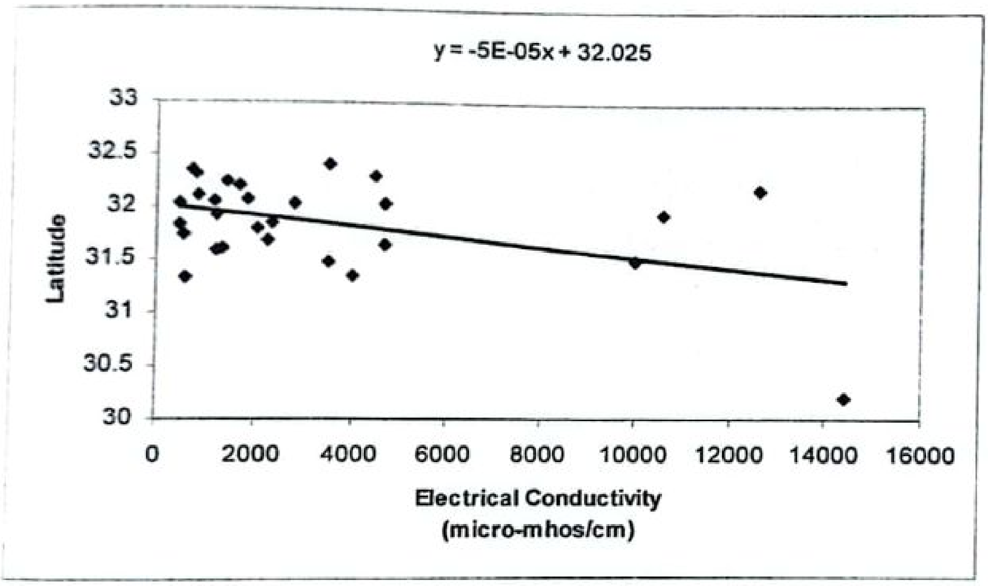

Figure 4.1 Ec variations with respect to latitudes in WASID test holes

Figure 4.1 has shown an inverse relationship between electrical conductivity and latitude data because if we move northward, the water in the holes conduct low electricity. The electrical conductivity shows a negative behavior along longitudes but not very strongly. Figure 4.2 has shown variation of Ec along longitudes.

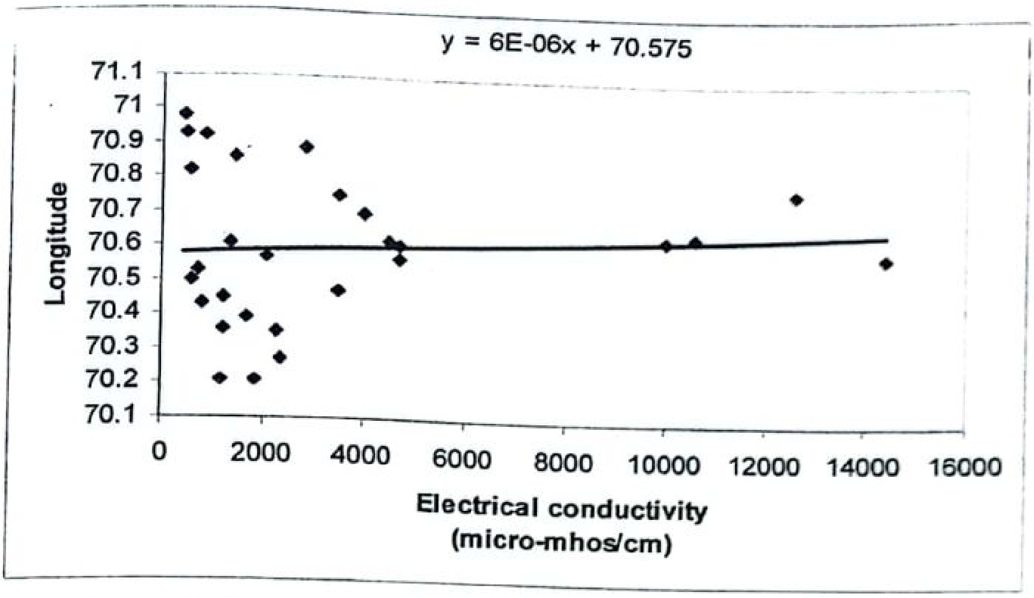

Figure 4.2 Ec variations with respect to longitudes in WASID test holes

The trend line has shown a direct relationship of Ec with longitude value because after 70.5 longitudes holes contain water which conducts more electricity. Trend line is not very strong but it shows a positive behavior so it can be called a moderate positive trend line.

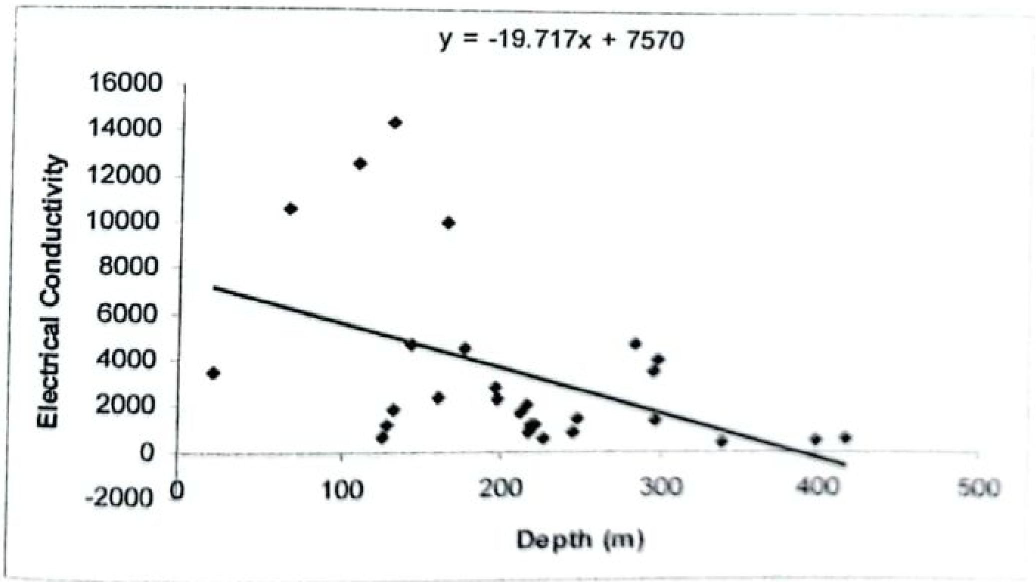

Figure 4.3 Graph showing Ec at different depths in WASID test holes

Figure 4.3 has shown that Ec decreases at greater depths like at 400 meters, it remains approximately 460 micro-mhos/cm. While at a depth of 100-150 meters it has shown a higher value 10,000 – 14,000 micro-mhos/cm.

4.1.2 TOTAL DISSOLVED SOLIDS (TDS)

Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/l), also referred to as parts per million (ppm).TDS variations in WASID test holes with respect to latitude are shown in the Figure 4.4;

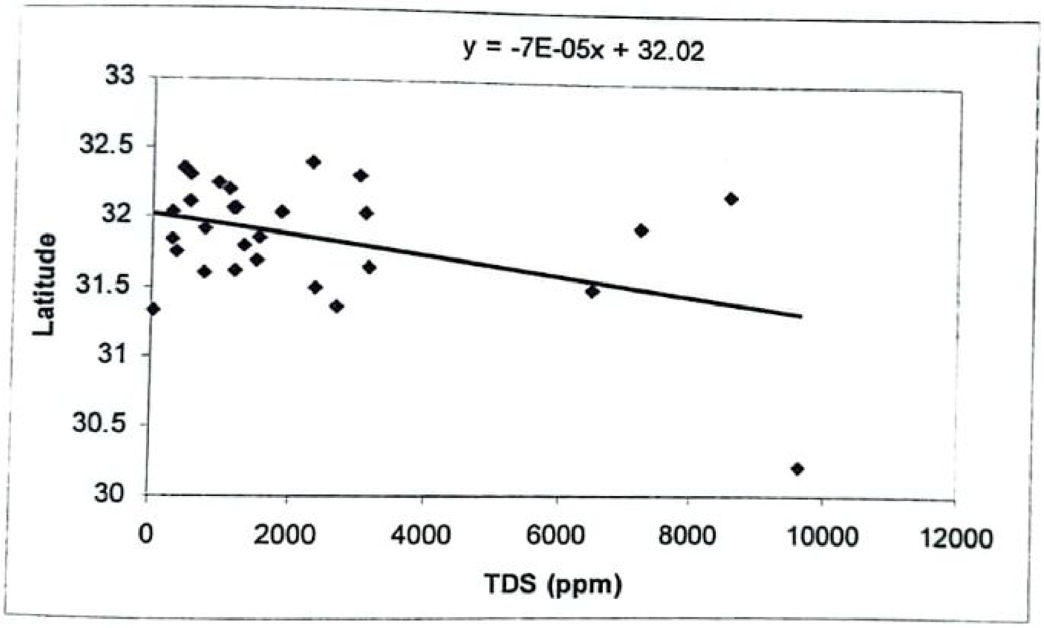

Figure 4.4 TDS variation with respect to latitudes in WASID test holes

Figure 4.4 has shown a variation in TDS value based on latitudes. The trend line is showing an inverse relationship between TDS and latitude. At latitude 30 TDS measured is nearly 1000 ppm but at a greater value of 31 it becomes zero. As the trend line is not very strong so it has shown moderate negative trend line.

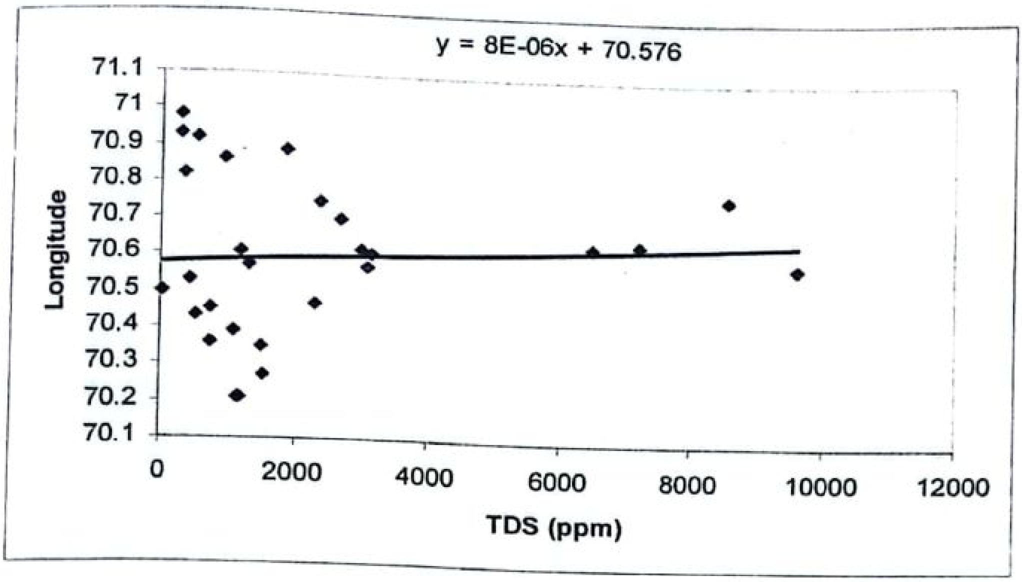

Figure 4.5 TDS variation with respect to longitude in WASID test holes

Figure 4.5 has shown variation in TDS value based on longitudes. The trend line drawn is showing a direct relationship of TDS with longitude. The trend line shown has a positive behavior but not very strong.

TDS also varies by changing depth of test holes as shown in the following comparison between TDS and different depths in Figure 4.6;

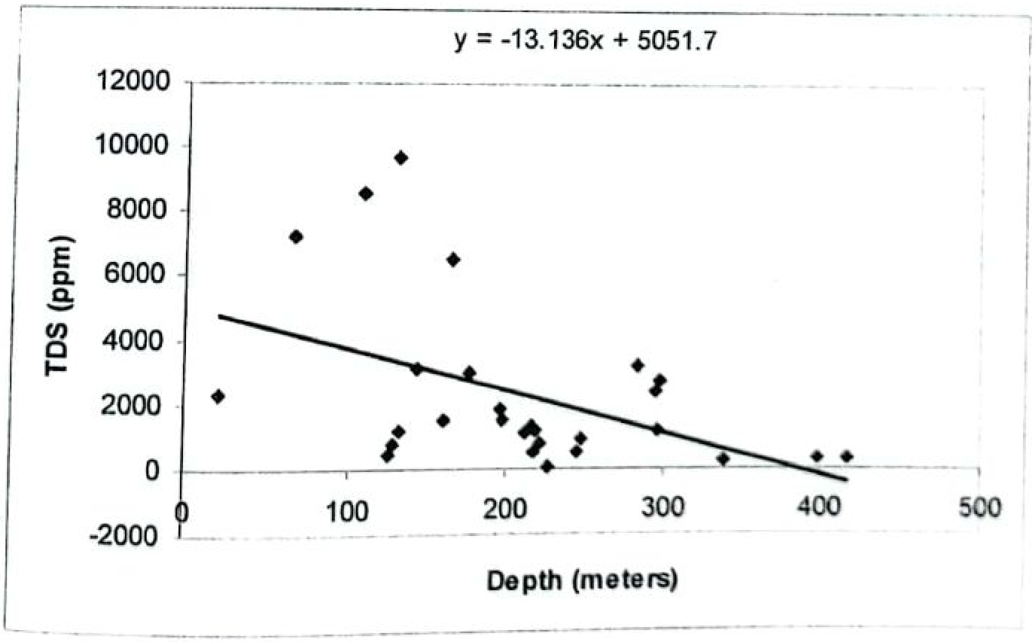

Figure 4.6 Graph showing TDS (ppm) on different depths in WASID test holes

Figure 4.6 has shown that TDS value decreases at greater depths. TDS value measured is approximately 300 ppm which is suitable for drinking on EPA standard. While on lesser depths of 50 to 150 meters, the value of TDS measured is 6000 to 10,000 ppm which is very toxic.

4.1.3 pH

The pH is a measure of the concentration of hydrogen ions. The pH scale ranges from 0 to 14, with 7 being neutral. pH less than 7 are acidic while pH greater than 7 are alkaline (basic).Variation in pH level in WASID test holes with respect to latitude, longitude and depth is shown in the following Figures;

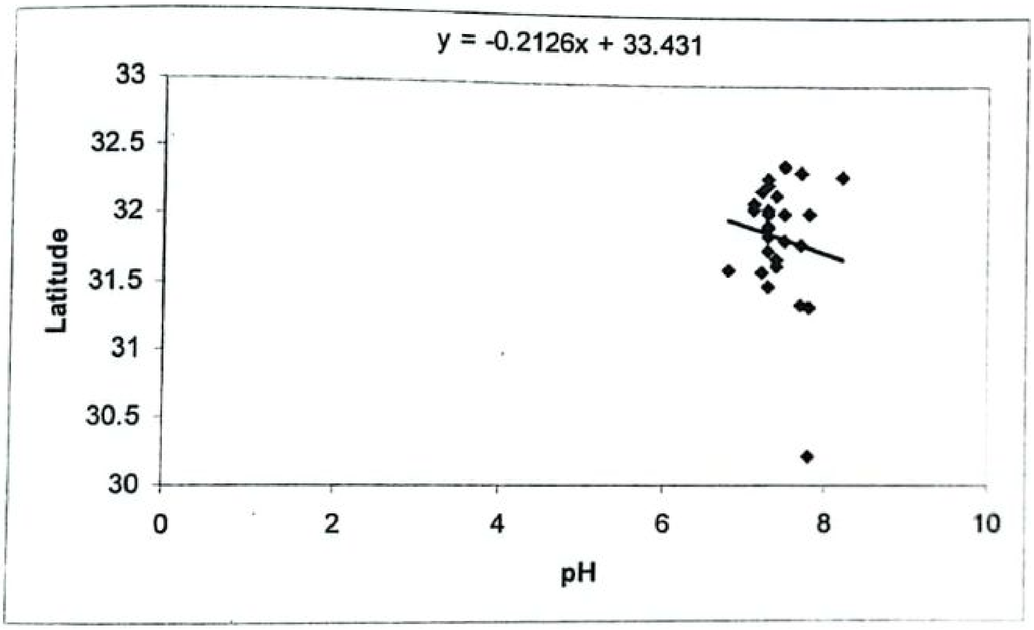

Figure 4.7 pH variation in WASID test holes along latitudes

The trend line has shown in Figure 4.7, an inverse relationship because pH level decreasing 33.4° N but all test holes are showing a value of pH between 7 to 8 which means water in all test holes is fresh to basic in nature. Trend line has shown positive behavior very strongly.

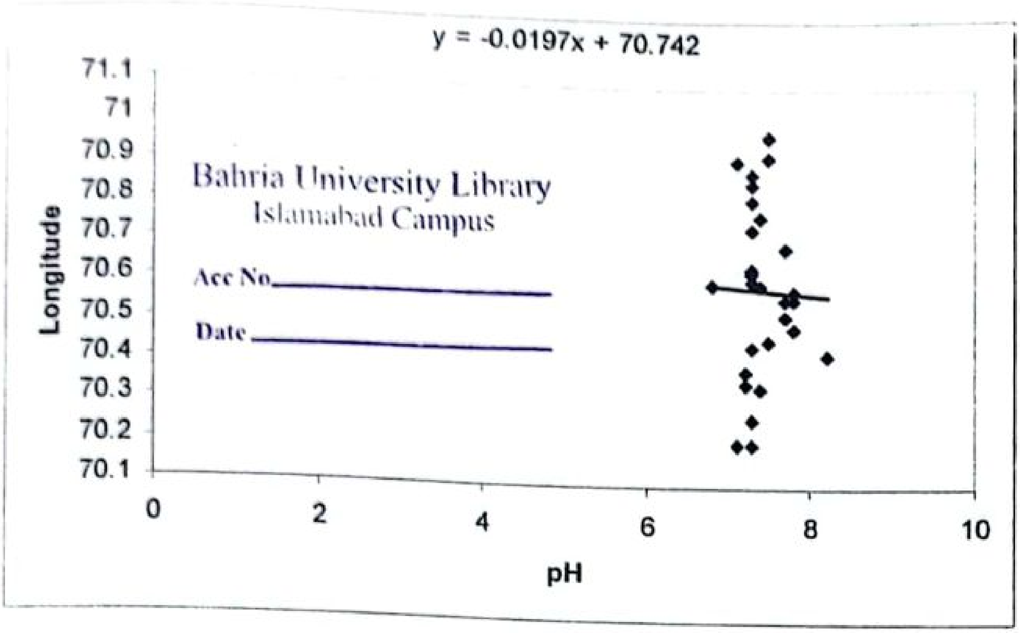

Figure 4.8 pH variation in WASID test holes along longitudes

Figure 4.8, the trend line has shown an inverse relationship between pH level and longitudes. pH level is decreasing after 70.742 E but not very strongly, because there is a minute change and has shown no relationship with longitudes and all values is in range of 7-8 pH. And trend line of depth is moderate negative in nature (Figure 4.9)

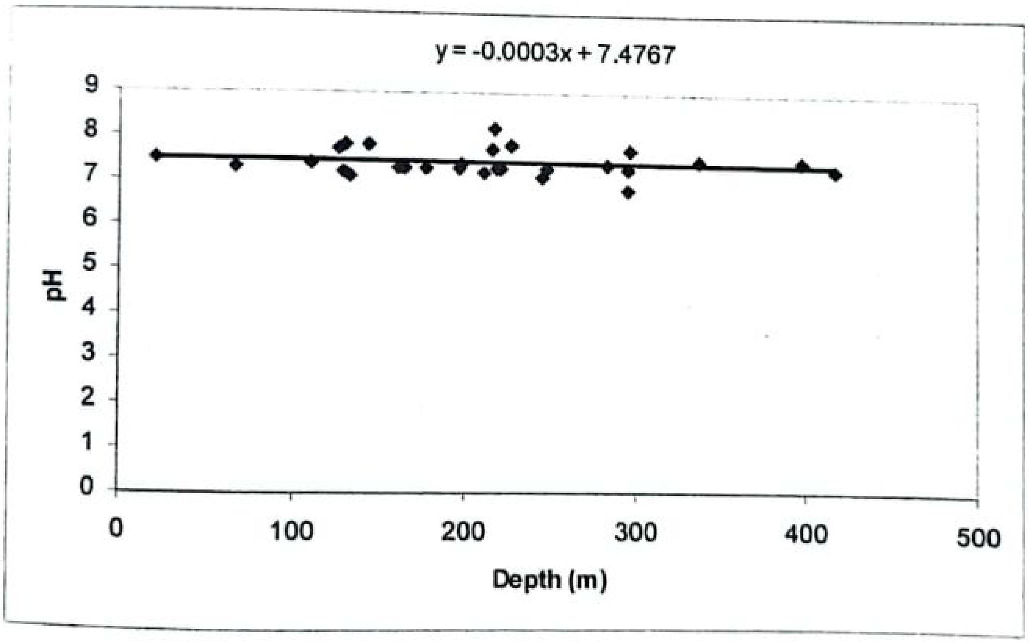

Figure 4.9 Graph pH level on different depth in WASID test holes

There is not any prominent change in pH on different depths. Graph shows that there is no relationship between pH level and depth of the test hole.

All the values range in between 7-8 pH which has shown that in D.I.Khan water at all depth is basic in nature. There is no acidity found in water from all test holes.

4.1.4 **SULFATE (SO_4)**

Sulfates are common soluble salts and anions. Variation in sulfate content in WASID test holes with respect to latitude, longitude and depth as shown in the following Figures;

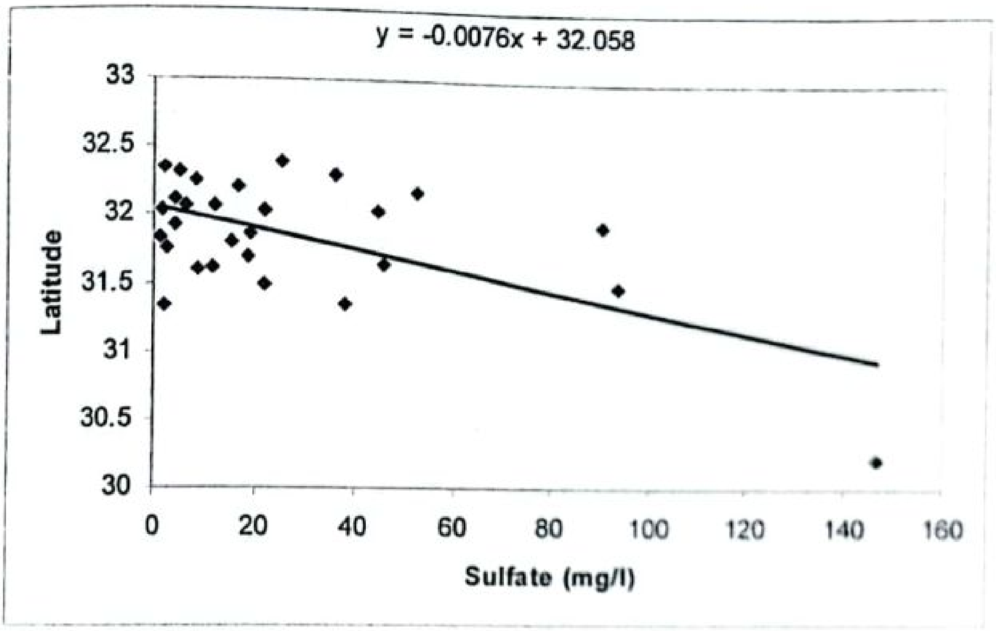

Figure 4.10 Sulfate variations in WASID test holes along latitudes

The trend line has shown an inverse relationship between sulfate and latitude. Sulfate has shown negative behavior towards changing latitude. As trend line is strong, so slope of trend line is strong negative.

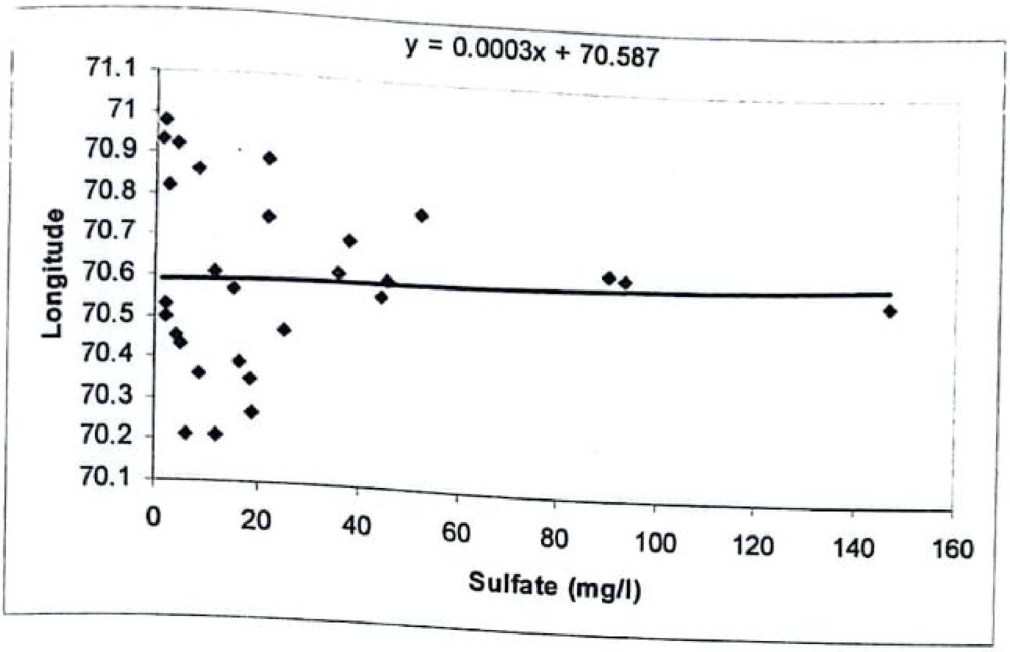

Figure 4.11 Sulfate variation in WASID test holes along longitudes

Figure 4.11 has shown a variation in sulfate value based on longitude value. The trend line drawn has shown a direct relationship of sulfate with longitude. Trend line is not very strong but it has shown a positive behavior. The trend line is moderate positive in nature (Figure 4.12).

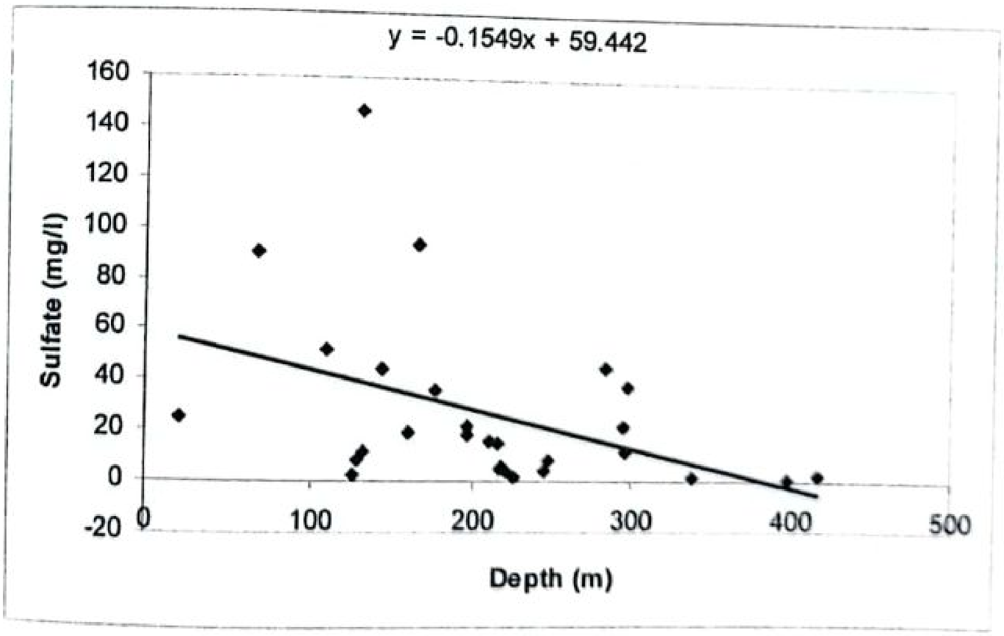

Figure 4.12 Variation in sulfate (mg/l) on different depths in test holes of D.I.Khan

The sulfate content is higher at a depth of 0 to 300 meters. However, the value becomes almost zero at 400 meters. So it was observed that the value of sulfate decreases at greater depth.

4.1.5 CALCIUM (Ca)

Calcium reacts vigorously with water, although not as violently as the Group-I metals such as sodium or potassium, because salts of calcium are generally insoluble. Variation in calcium content in WASID test holes with respect to latitude, longitude and depth is shown in the Figures;

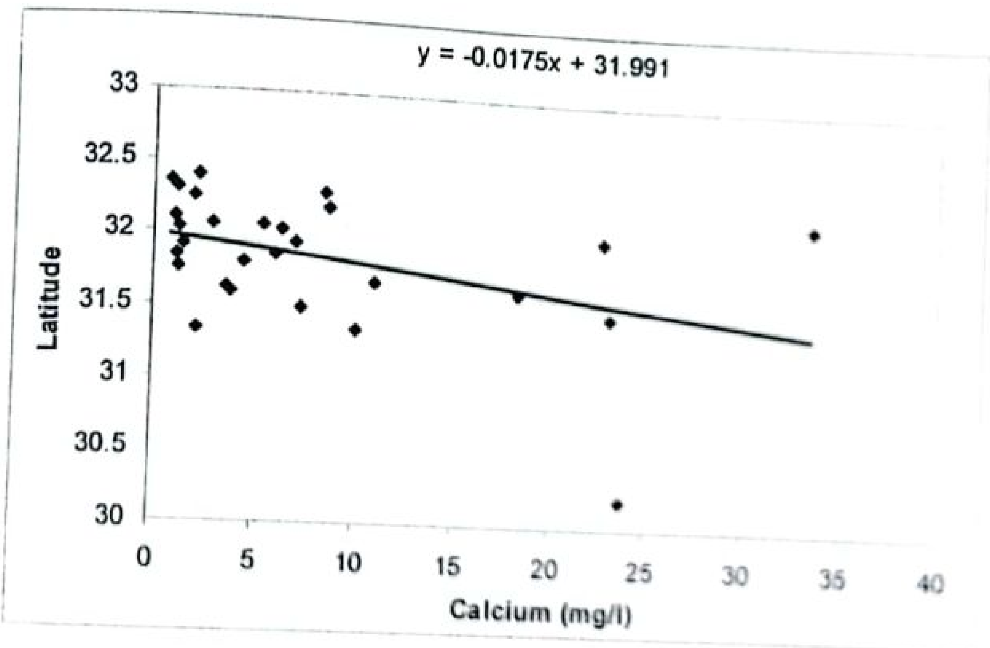

Figure 4.13 Variation in calcium content in WASID test holes along latitude

In Figure 4.13, the calcium trend line has shown an inverse relationship between calcium and latitude, it means at higher latitudes water contains low calcium content. Trend line has shown a negative behavior but not very strong, so it is a moderate negative slope in nature.

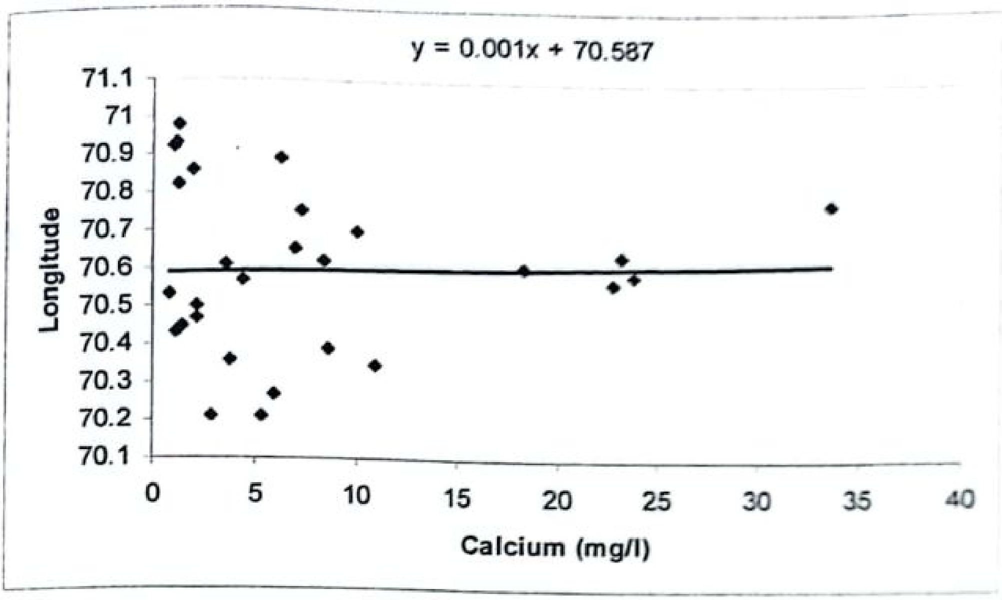

Figure 4.14 Variation in calcium content in WASID test holes along longitude

Figure 4.14, the trend line has shown a direct relationship of calcium content with longitude values of test holes. The calcium content is gently increasing after 70.587° E. The slope of best fitting trend line is moderate positive. Calcium content also varies on different depth in test holes as shown in the Figure 4.15;

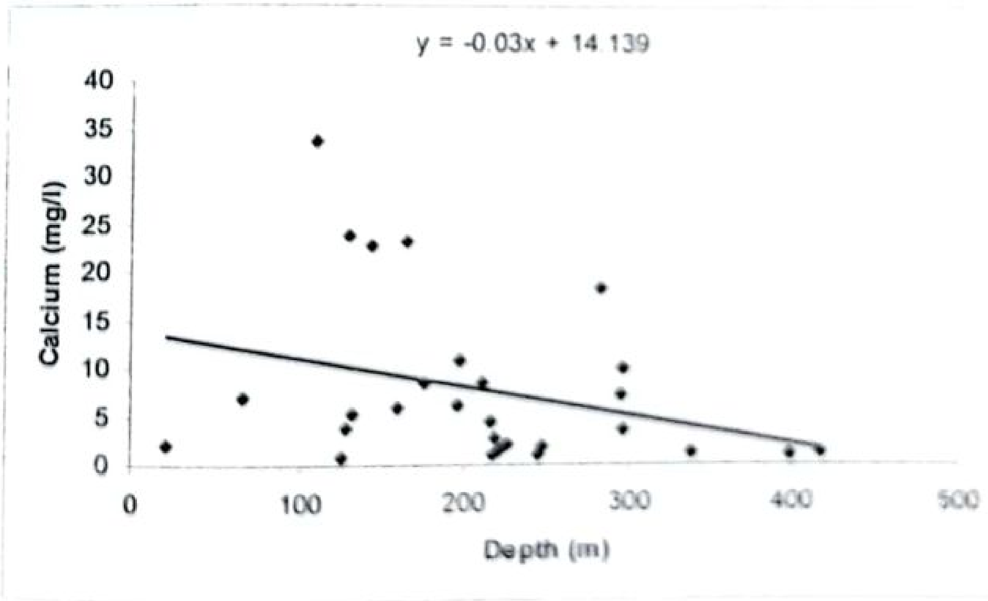

Figure 4.15 Graph showing the calcium content at different depths in WASID test holes

The above figure shows that calcium content is very low at deep level, like at 400 meter depth it remains zero. But test holes with a low depth of about 100-150 meters have high calcium content (Figure 4.15).

4.1.6 MAGNESIUM (Mg)

Magnesium compounds are typically white crystals. Most are soluble in water, providing the sour-tasting magnesium ion. Small amounts of dissolved magnesium ion contribute to the tartness and taste of natural waters. Variation in the magnesium content along latitude, longitude and depth is shown in the Figures 4.16;

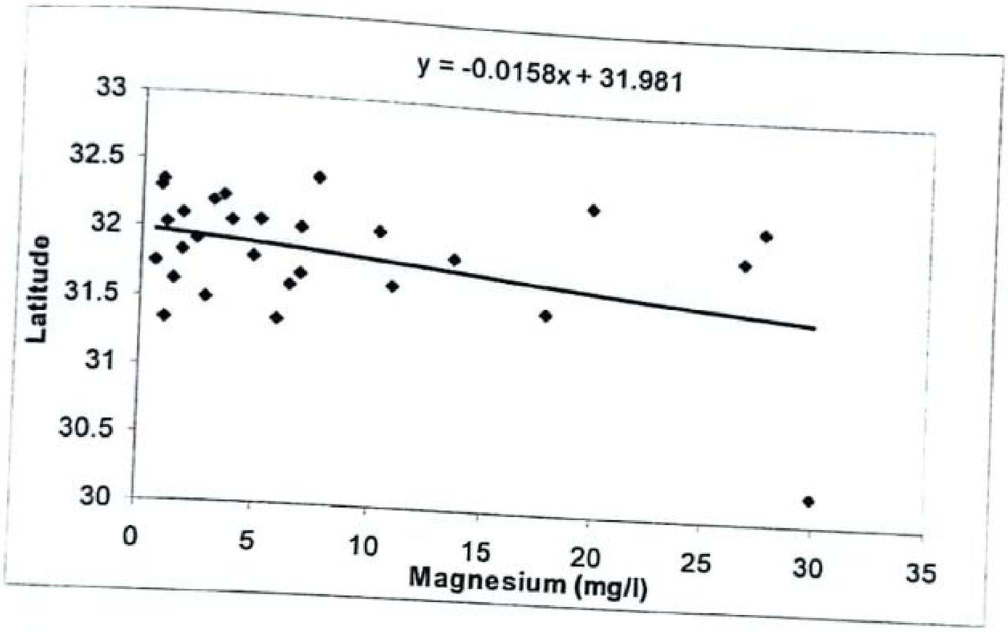

Figure 4.16 Variation in magnesium (mg/l) in WASID test holes along latitudes

In Figure 4.16 a variation in magnesium content in milligrams per liter based on latitude value. The trend line has shown an inverse relationship between magnesium and latitude value, and it has shown a moderate negative trend line.

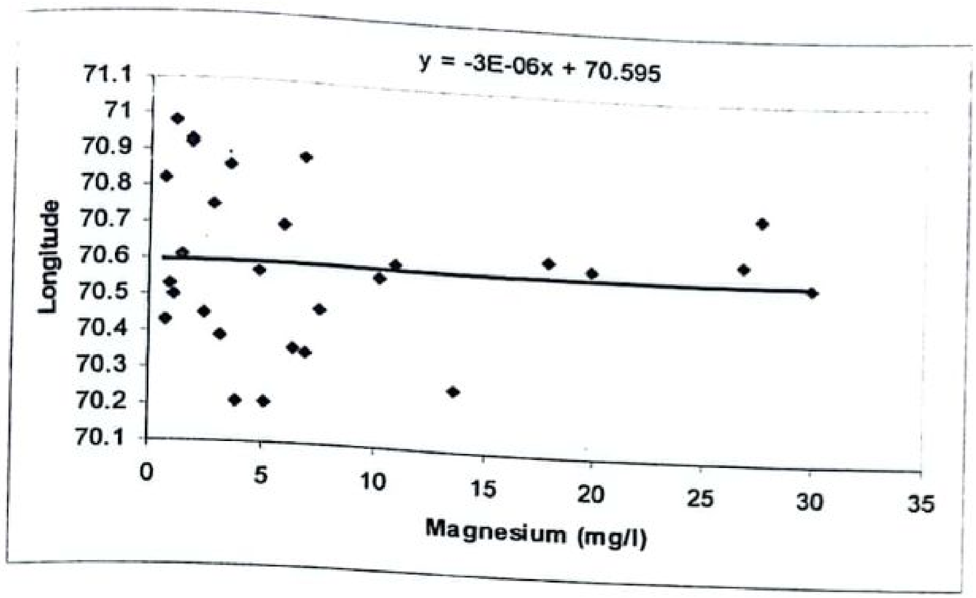

Figure 4.17 Variation in magnesium (mg/l) in WASID test holes along longitudes

In Figure 4.17 the trend line has shown no relationship between magnesium and longitude. The magnesium scattered very minutely so it can be called a weak relationship. The magnesium is mainly scattered from 0 mg/l to 10 mg/l.

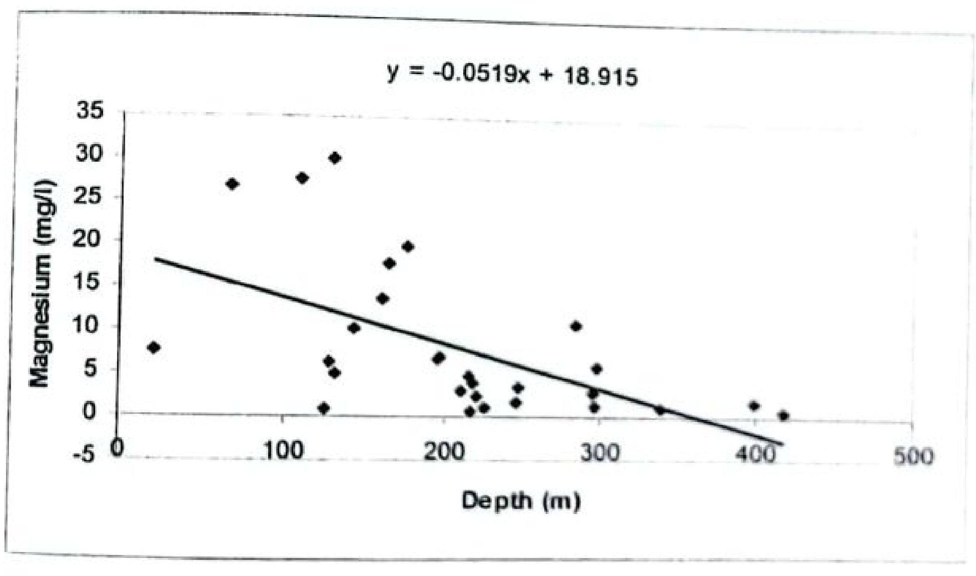

Figure 4.18 Graph showing magnesium (mg/l) content on different depths in WASID test holes

In Figure 4.18 has shown that test holes of D.I.Khan, magnesium value decreases at greater depths, like at a depth of 400 meter. While on lesser depths of 0 to 200 meters, the value of magnesium measured is high.

4.1.7 SODIUM AND POTASIUM (Na+K)

Sodium and potassium are alkali metals and both are common cations. Sodium is generally less reactive than other alkali metals like potassium and more than lithium.

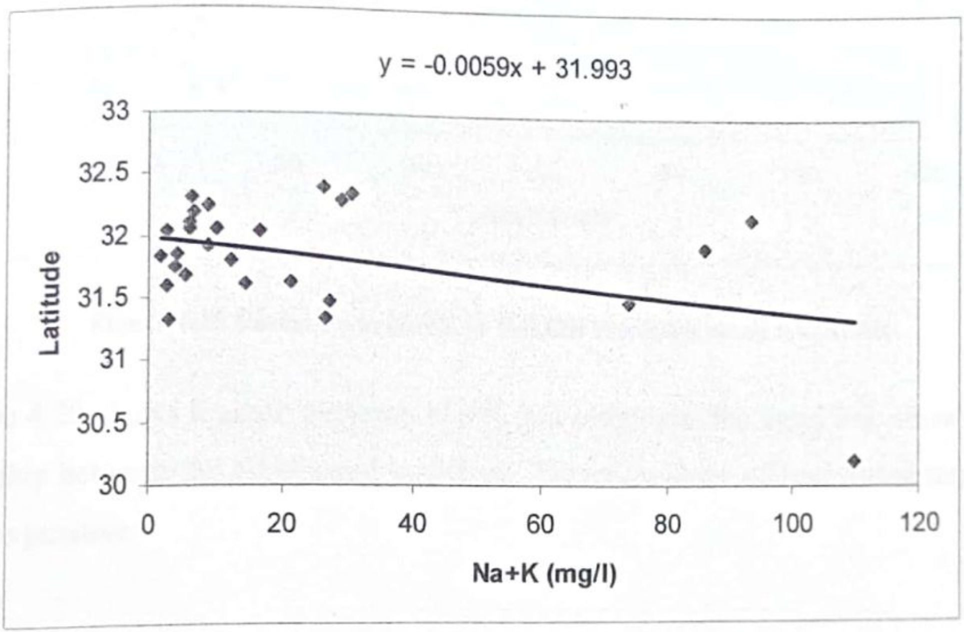

Figure 4.19 Variation in Na+K in WASID test holes along latitudes

In Figure 4.19 has shown a variation in alkalis value based on latitude data. In the figure, the trend line shows an inverse relationship between alkalis and latitude, but their relationships are not very strong. Therefore the best fitting slope of trend line is moderate negative.

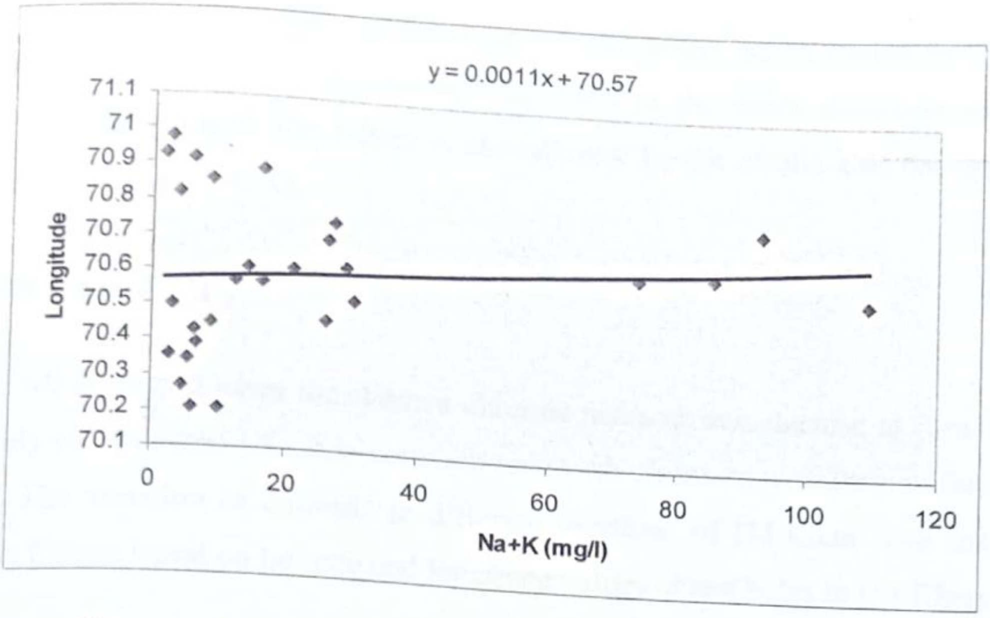

Figure 4.20 Variation in Na+K in WASID test holes along longitudes

In Figure 4.20 shows a graph between Na+K and longitude, the trend line shows a direct relationship between the alkalis and longitude. Therefore slope of best fitting trend line is moderate positive.

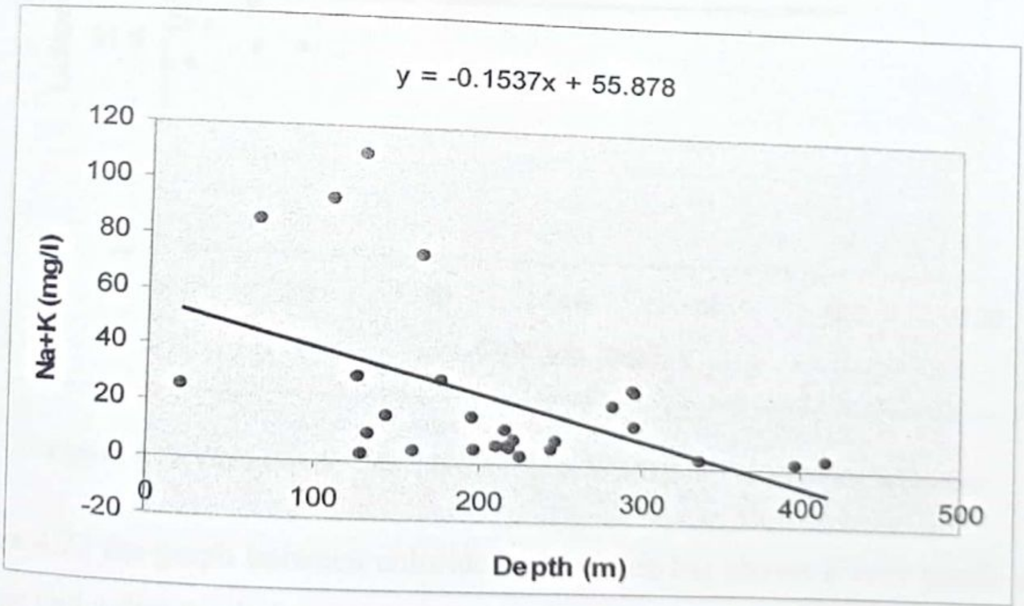

Figure 4.21 Variation in Na+K (mg/l) on different depths in WASID test holes

The maximum value is observed at the depth of 100 meters which shows the content to be approximately 110 mg/l. The content decreases as the depth increases and it was observed that the value at 400 meters is almost zero. So the alkalis also decrease as the depth increases (Figure 4.21).

4.1.8 CHLORIDE (Cl^-)

Chloride ion is formed when the element chlorine picks up one electron to form an anion (negatively-charged ion) Cl^-. It is common anion which reacts with cations for example Sodium. The variation of chloride in different locations of D.I.Khan with the help of following figures based on latitude and longitude values of test holes in D.I.Khan.

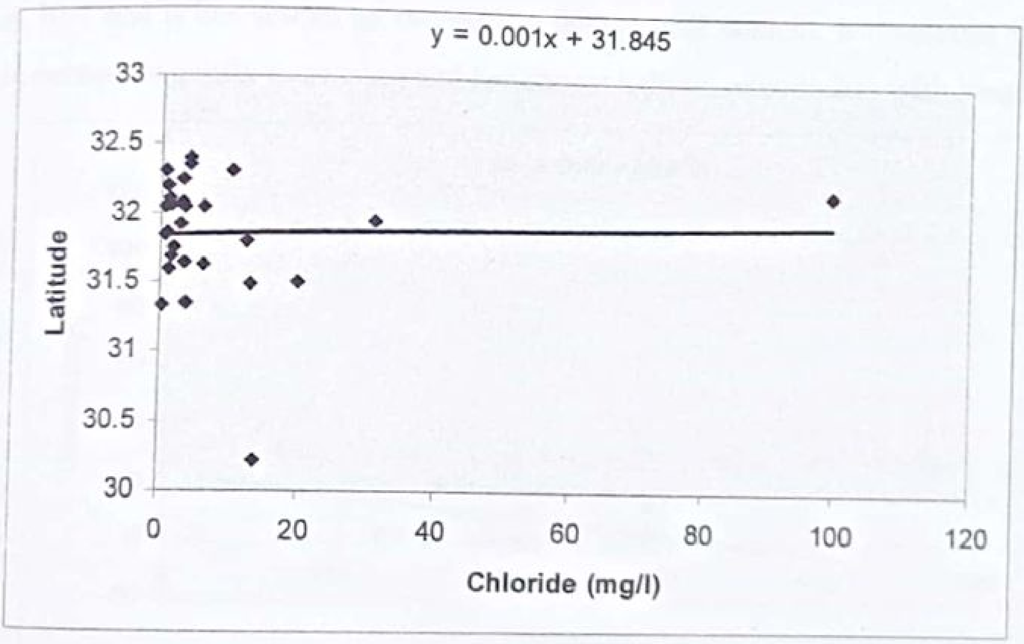

Figure 4.22 Variation in chloride content in WASID test holes along latitudes

In Figure 4.22 the graph between chloride and latitude has shown a very gentle slope of trend line and a direct relationship between chloride and latitude. So slope of best fitting trend line is moderate positive.

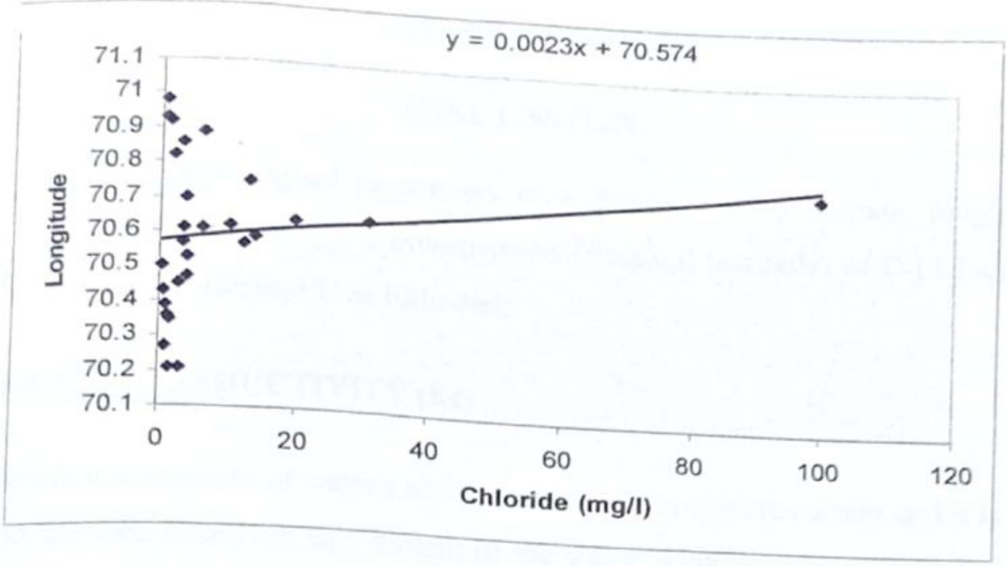

Figure 4.23 Variation in chloride content in WASID test holes along longitudes

Graph shows a moderate positive slop of trend line. There is a bulge in the middle, which starts at 70.4 and it has shown an increase in the chloride content. It continues till 70.8, chloride content is gently increasing and has shown a direct relationship with longitude.

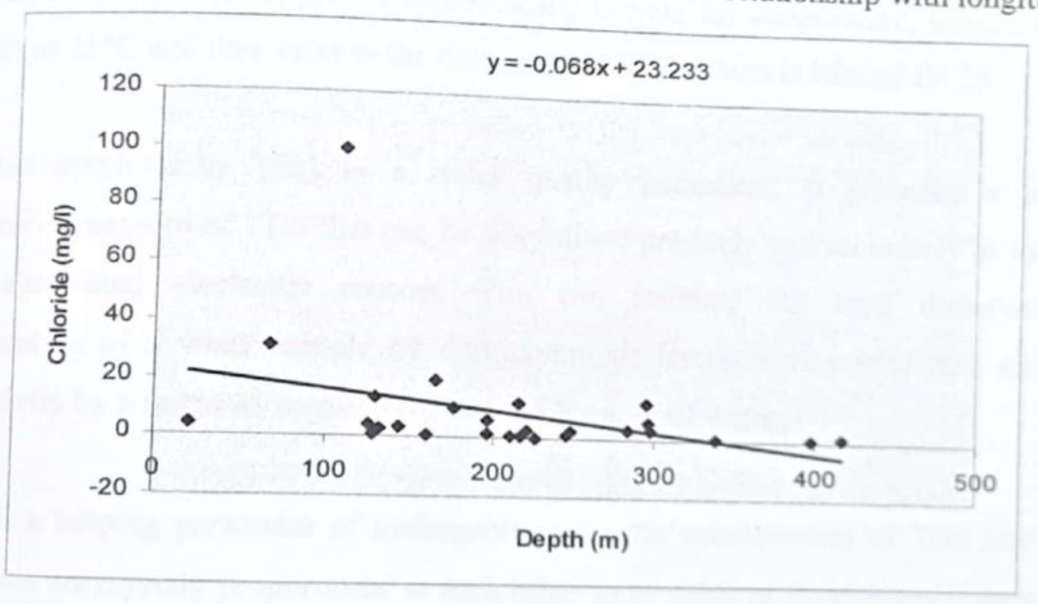

Figure 4.24 Variation in chloride (mg/l) on different depths in WASID test holes

The chloride content decreases at greater depths like at a depth of 400 meter. While on lesser depths of 0 to 100 meters, the value of chloride measured is highest. The value of chloride varies between 100 to 300 meters (Figure 4.24).

CHAPTER NO. 5

DISCUSSION

The different Hydrogeological parameters were interpreted v/s latitude, longitude and depth of WASID (Water and Soil Investigation Division) test holes of D.I.Khan and the discussion on each parameter is as followed;

ELECTRICAL CONDUCTIVITY (Ec)

Conductivity is a measure of water's ability to conduct an electric current and it is directly related to the total dissolved salt content of the water. This is because the salts dissolve into positive and negative ions that can conduct an electrical current proportionately to their concentration. It is called Ec, for electrical conductivity, and is reported in micro-mhos per centimeter (μmhos/cm) which has been recently renamed as μS/cm (Micro-Siemens per centimeter). Ec is temperature sensitive and increases with increasing temperature. Most modern probes automatically correct for temperature, standardize all readings to 25°C and then refer to the data as specific Ec which is labeled Ec 25.

Electrical conductivity (Ec) is a water quality parameter; it provides a simple, inexpensive measure of TDS that can be determined precisely and accurately in the field using automated electronic sensors. You can estimate the total dissolved salt concentration of a water sample by multiplying its temperature normalized electrical conductivity by a factor of between 0.5 and 1.0 for natural waters.

As Ec is a helping parameter of hydrogeology for the measurement of TDS and these parameters are directly proportional to each other so as value of Ec changes in any water well the TDS also changes in the same way. We can easily calculate the TDS value of water with the help of Ec value by using following equation;

TDS (in mg/lor ppm) = **0.67 x Ec** (in μS/cm or micro-mhos/cm)

In D.I.Khan Ec has shown a moderate negative relation with latitude and moderate positive with longitude, so Ec value increases in south-east direction in D.I.Khan and water at greater depth (400 meters) is suitable for drinking.

TOTAL DISSOLED SOLIDS (TDS)

Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/l), also referred to as parts per million (ppm). TDS is directly related to the purity of water and the quality of water purification systems and affects everything that consumes, lives in, or uses water, whether organic or inorganic, whether for better or for worse.

A TDS meter is based on the electrical conductivity (Ec) of water. Pure H_20 has virtually zero conductivity. Conductivity is usually about 100 times the total cations or anions expressed as equivalents. TDS is calculated by converting the Ec by a factor of 0.5 to 1.0 times the Ec, depending upon the levels. EPA standards for TDS that water suitable for drinking is between 0-50 mg/l (0-50 ppm) and a maximum contamination level (MCL) of 500mg/liter (500 parts per million (ppm)) for TDS. As shown in the figure below;

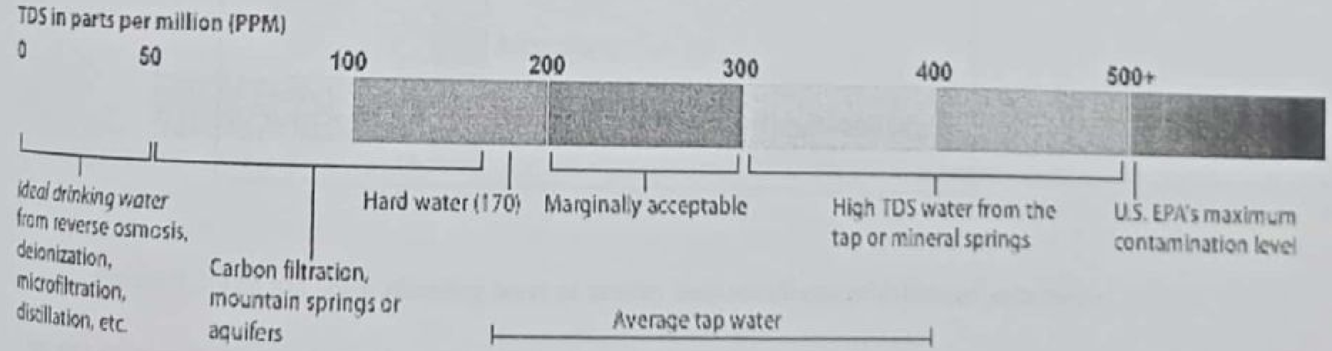

Figure 5.1 Scale of TDS from EPA standards of contamination

In D.I.Khan TDS value does not change very strongly even with both latitude and longitude and all in all it has same results as electrical conductivity.

pH

The pH of a sample of water is a measure of the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated - it is the negative logarithm of the hydrogen ion (H^+) concentration. The pH scale ranges from 0 to 14, with 7 being neutral. pHs less than 7 are acidic while pHs greater than 7 are alkaline (basic).As shown in the figure below. You can see that acid rain can be very acidic, and it can affect the environment in a negative way.

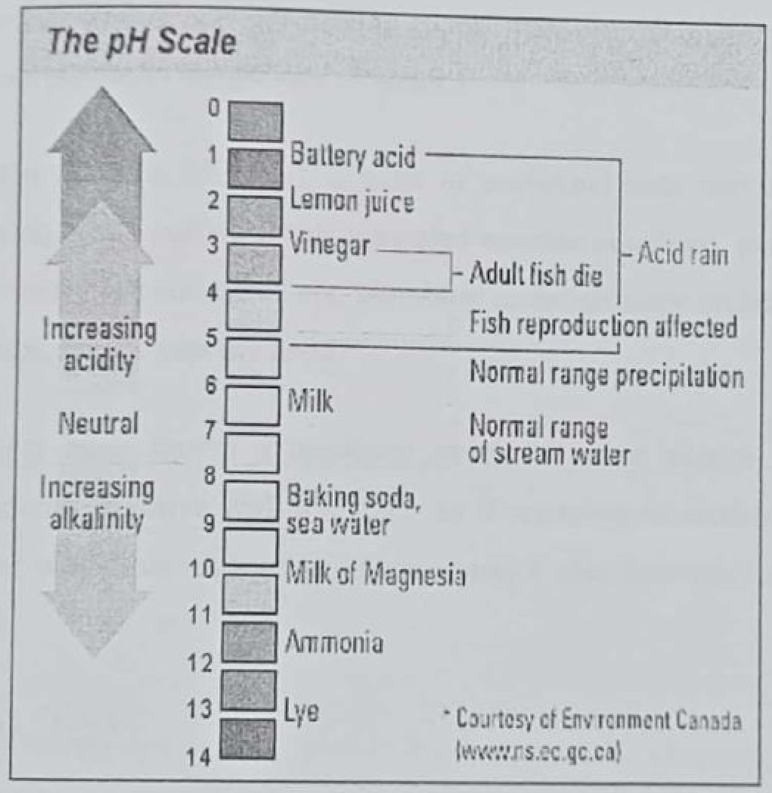

Figure 5.2 The pH scale showing level of acidity and alkalinity of different substance

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.).

pH has shown a strong negative relation with latitude and moderate negative with longitude of D.I.Khan, so pH level gently increases in south-west direction. There is no relationship between pH and depth because test holes of different depth in D.I.Khan shown similar values 7-8 which is suitable for drinking.

SULFATE (SO_4)

As water moves through soil and rock formations that contain sulfate minerals, some of the sulfate dissolves into the groundwater. Minerals that contain sulfate include magnesium sulfate, sodium sulfate, and calcium sulfate (gypsum). Sulfate occur as milligrams per liter (One mg/l is one thousandth of a gram in a liter of water, which is approximately equal to one part per million (ppm). One ppm is approximately equal to one drop of the substance in ten gallons of water.)

If sulfate in water exceeds 250 mg/l, a bitter of medicinal taste may render the water unpleasant to drink. High sulfate levels may also corrode plumbing, particularly copper piping. In areas with high sulfate levels, plumbing materials more resistant to corrosion, such as plastic pipe, are commonly used.

Covariance results have shown a moderate strong negative relation of sulfate with latitude and moderate positive with longitude so if we move in south-east of D.I.Khan then groundwater will show high sulfate content and it also becomes high at a depth of 150 meters.

CALCIUM (Ca)

Calcium is a silvery-white metal; it is relatively soft, but much harder than sodium metal. Calcium is a member of the alkaline-earth metals (Group-II on the periodic table); these metals react vigorously with water, although not as violently as the Group I metals such as sodium or potassium.

Elementary calcium reacts with water. Calcium compounds are more or less water soluble. Calcium carbonate has a solubility of 14 mg/l, which is multiplied by a factor five in presence of carbon dioxide.

Concentration of calcium increases gently in south-east of D.I.Khan because Ca has shown a moderate negative relation with latitude and moderate positive with longitude. Test holes have shown a maximum value of about 35 mg/l at low depth (100 meters) which is lesser than required value of calcium.

MAGNESIUM (Mg)

Magnesium is the eighth most abundant element in the earth's crust. It is found in large deposits of magnetite, dolomite, and other minerals, and in mineral waters, where magnesium ion is soluble. Magnesium compounds are typically white crystals. Most are soluble in water, providing the sour-tasting magnesium ion. Small amounts of dissolved magnesium ion contribute to the tartness and taste of natural waters. Magnesium is found in all natural waters. High levels in groundwater are probably the result of contact with magnesium containing rock formations. Magnesium is a major contributor to water hardness.

Covariance analysis has shown that magnesium content increases in south-west direction because it has shown a moderate negative relation with both latitude and longitude. And it becomes lower at greater depths.

SODIUM AND POTASIUM (Na+K)

Sodium and potassium belong to group of alkali metals. Sodium is generally less reactive than compared with other alkali metals like potassium and more so than lithium, in accordance with periodic law. Like the other alkali metals, potassium reacts violently with water producing hydrogen. The reaction is notably more violent than that of lithium or sodium with water because potassium reacts quickly with even traces of water, and its reaction products are nonvolatile, it is sometimes used alone, or as Na+K (an alloy with sodium which is liquid at room temperature) to dry solvents prior to distillation. In this role, it serves as a potent desiccant.

Sodium and potassium contents change very moderatly in D.I.Khan even with both latitude and longitude but covariance results has shown that Na+K variate negatively with latitude while positively with longitude.

CHLORIDE (Cl^-)

Chloride ion is formed when the element chlorine picks up one electron to form an anion (negatively-charged ion) Cl^-.Concentration of chloride in excess of 250 mg/l may import a salty taste to the water, although there is no evidence of adverse health effects from drinking it. The salty taste is variable and dependent on the chemical composition of the water. High chloride content may harm metallic pipes and structures as well as growing plants. The desirable limit is set at a maximum of 250 mg/l. And concentration of chloride in D.I.Khan ground water has shown a direct relationship with latitudes and longitudes, therefore, its concentration increases in north-east of D.I.Khan area. However, concentration of chloride decreases at greater depths (400 meters) in WASID test holes.

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