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Impact of land use change on water quality of Jhang District Punjab, Pakistan

Abdur Rehman*, **Muhammad Mobeen, Sidra Bashir, Muhammad Rauf, Fahad Ullaha, Tehmina Aziz, Taswar Abbas, Omar Riaz**

Department of Earth Sciences, University of Sargodha, Pakistan

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Key words: Land use, GIS and Remote sensing, Water quality.

Abstract

The study was proposed to examine the land use changes and its impacts on ground water quality in Jhang District, Punjab, Pakistan. The land use change was detected by classifying Landsat TM (Thematic Mapper) from USGS. Satellite images of 1987, 1998 and 2015 with 30m, 15m and 15m resolution were used for classification. The study area was classified into four major categories i.e. barren, residential, vegetation and sites near water. Equal proportion of groundwater samples were collected from each land use class from study area. Groundwater samples were analyzed and their parameters were grouped on the basis of land use classes. The selected groundwater quality parameters of four land use classes were compared and contrasted with each other for calculating land use change impacts on ground water quality. The analyses revealed that from 1987 to 2015 agricultural land has significantly been decreased with the extension of built up areas in and around the urban centers while groundwater quality was found rapidly deteriorating in the urban settlements or around them. It was observed that the vegetative and sites around water have adequate quality of groundwater as compared to the areas near built-up and barren. The extension in built-up areas is responsible for loss in vegetation land use which results in degraded water quality. Land use analysis revealed the present research is a pioneer work in this region. The findings of the study are useful for future land use planning. It can help urban and settlement planner for their decision making.

***Corresponding Author:** Abdur Rehman ✉ cityprince303@gmail.com

Introduction

In the present research an effort was made to disclose the impact of land use change over the water quality of district Jhang by utilizing remote sensing and GIS methods. District Jhang is the 15th biggest city of Pakistan. Results unveiled that there was a 70.16% decrease in vegetation land use from 1987 to 2015 and 47.71% increase in built up land use class besides 51.48% barren land use 7.16% vegetation land use class decrease was found. Water quality and land use are the two intricately linked variables which intensify the importance of each other. GIS and remote sensing (RS) data have been providing us the ability to analyze these intricacies of land surface and groundwater (Mc Vicar *et al.*, 2003). Land use is basically the purpose or cause for which land is being utilized for, while the water quality has three characteristics of water these are physical, chemical and biological. (Goetz *et al.,* 2003). Our earth surface has undergone a rapid change due to the anthropogenic activities. This is because of use of agricultural land for commercialization, industrialization by man thereby affecting the natural landscape resulting in the degraded water quality due to the changes in land use. (Loeb, 1988). We can get useful information by the images obtained through remote sensing on trends and spatial and temporal array of built up land required for perception, displaying and for observing changes in land use (Loveland and Sohi, 1999). Two or more satellite images gained at distinct times tells us about the spectral and temporal reflectance differences those which have happened among them and such kind of the images give us a chance to judge and detect the land use changes (Yuan and Elvidge, 1998). Land use change impacts over water quality have been monitored and traced by remote sensing and GIS mechanisms. Any change in the water quality due to land use change may result in destruction of natural land (Perry, 1996). Great attention has been given to land use change and water quality caused by both man-made and natural sources (Verbyla, 1995). GIS enables us to monitor land use changes. Identifying a terrain and determining its morphological transformations have gained a substantial increase from expansion in geospatial mechanizations namely multispectral satellite images and GIS software. This satellite data was functionally accessible during the early 1970s and leveled the path for the studies of the land use. Land use changes can be efficiently monitored and detected by using the remote sensing tools in and near built up areas since the past a few decades. Researchers can find the highly valuable spectral, terrestrial spatial resolution data through remote sensing (Ayele, 2011). Due to continuous satellite exploration, the speedy advancement in know-how of computers and the combination of satellite images along with geographic information systems (GIS), spatial data and improvement in ecological observing tools and techniques just like change identification methods have become essential (Jensen, 1996). Land use change analysis revolves around the two major factors, reasons of the land use change and socio-economic land use modification impacts (Briassoulis, 2006). Land use is the way in which man engage the land and its possessions such as urban advancement, logging, grazing, mining, and the after uses of man are human infrastructures, roads, buildings water related to surface and ground water (Bottomley, 1998).

Objectives

- To calculate the changes in the land use in the area under study since 1987 to 2015
- To examine the quality of water in various land use kinds of the study area
- To calculate the impact of land use on ground water quality by comparing water quality parameters of diverse land use categories of the study area

Materials and methods

Study area

Jhang is a district in Punjab province. It is located on the eastern bank of the river Chenab about 250km from Lahore and 72KMs from Faisalabad. According to the Government of Punjab (GOP), 1998) census population of 387,418 being 20th in the list of most populous cities. It is located at 31.2680° N, 72.3180° E with an altitude of 285 meters. The city is famous for the tombs of Sufis Sultan Bahu.

Data/Materials and Methods

Research methodology is an essential section of every kind of research. It is an orderly and scientific procedure to attain the objectives. Several steps were incorporated to complete the current research. Primary as well secondary data was used in order to accomplish the research. The following data collection methods were used in the study. The research required collection of water quality samples and collation of existing land use information, conducting filed water sampling, measurements and analysis of water quality samples for selected physicochemical and microbiological parameters. These steps involved field water sampling and measurements: the data collection and GIS analysis for land use mapping data and water quality change detection presentation.

Image Processing

Satellite images were acquired to accomplish the research from the website of United States Geological survey (USGS). Three satellite images were collected for the following years 1987, 1998 and 2015. A total period of 28 years. Erdas Imagine 9.1, ARC GIS 9.2 and MS Excel were used to accomplish the research.

Image Classification

The land use images were classified according to the selected and use classes of the area. So before categorizing an image, it is vital to decide a classification order. Considering in mind the extent of the current research and image resolution the subsequent scheme was chosen in order to fulfill the objectives. The study area was classified into four classes which are barren land use, vegetation land use, built up land use, site near water.

Sample Sites Description

To assess the impacts of land use over water quality, systematic random sampling and convenient sampling was applied for the selection of 60 sampling points, 15 samples from each land use class were collected.

Water Quality Parameters

Analysis

The following parameters have been included in study namely pH, EC, residuals, bi carbonates, carbonates, calcium, sodium, chlorides, sodium absorption ratio, and total dissolved solids. Characteristics of these parameters give us the information either direct or indirect impact of land use change in the water quality of the area under study. (Clesceri *et al.,* 1999). These parameters also give us a general outlook of the health of the quality of water. Parameters which fall in physical category mostly constitute chemical parameters and chemicals in water can affect the pH. High impervious surface areas like residential or urban lands can produce runoff which contains oils that lessens the conductivity of ground water (Tong and Chen, 2006).

pH

pH of water is a standard of whether it is alkaline (basic) or acidic. Water having the pH of 7 is taken as is taken as natural below this amount is considered as acidic and the pH above 7 is considered as basic. WHO limits for the pH range from 6.5 to 8.5.The lower pH value will have more acid in the water and higher the pH values more alkaline the water will be. Huge and excessive amount of pH in water aggravate the taste of the water. pH is a pointer of the presence of the organic or biotic life because many species live in a certain range of PH value.

Electrical Conductivity (EC)

Basically Conductivity is that quality of water which permits an electric current. Biologically they are extremely significant. EC is associated with the transmission of the current by water in a manner to the dissolved solids. It has a substantial influence over the consumer recognition of the water as drinkable. According to WHO standards, maximum tolerable extent of EC is 150 uS/cm. Normally the EC of a ground water is relatively less that is why it is gauged in millisiemen per centimeter (MS / CM). This gives a common thought of chemical conduct and water quality which is chemical (Jain, 1993).

Residuals

It is shown in per liter as mille-equivalents. It is used best as the generally utilized indicator to decide the appropriateness in the water for agricultural intentions. It can best be measured by deducting the accumulations of magnesium and calcium from the gathering of carbonate and bicarbonate shown in mille-equivalents per liter. The elevated residual alkalinity is said to be devastating for the composition of soil makeup and agriculture expansion since calcium and magnesium will be dry out or precipitates from the solution of soil escalating the concerning accumulation of sodium.

Bi Carbonates

The accumulation of bi-carbonates in water depends on pH. Bi-carbonates are customary alkaline ingredient possessed approximately in mostly every one of places and in earth water resources. It is because it impacts alkalinity and rigidity in the water. Bicarbonate substance in water is added by the process of weathering of the rocks strata. Frequently bi-carbonates are dissolved in water for example bi-carbonates of magnesium (MG) and calcium. It is the major reason of stiffness of the water. The stiff water is never apt for drinking uses and is the basis of the illness of gastro. As per WHO standards, permissible limit of the bi carbonates is 500mg /l.

Carbonates

In Chemistry the salt of Carbonic acid is known as carbonate. In naturally circulation of water, carbon CO_2 that dissolved in the water appears as carbonates and bi carbonates. As per WHO standard limit of carbonate is 803 mille gram per liter. The bicarbonate salt is formed only when a charged which is positive in nature and it is appended with the charge which is negative ions of atoms of oxygen, in this way an ionic compound is formed. Water contains numerous dissolved bicarbonates at customary pressure and temperature. It is especially at a normal rate contains sodium bicarbonates is added or mixed to total dissolved solids contributes to total dissolved solids. It is a general factor for ascertaining the quality of water.

Calcium

This is the resource which is more plentifully found over the earth surface. This is the 5^{th}major constituent found in our earth crust. It is extraordinarily significant for individual's physiology cells and for bones. Approximately 95% calcium is available in the body of individual amassed in the teeth and bone, The ultra-insufficiency of calcium in man's body can become the source of rickets, reduced blood coalesce of the bones cracking. In this way the massive edge of the calcium created becomes the source of the cardiovascular illnesses. Calcium is an important constituent of water which is supplied through heterogeneous minerals and rocks to aquifer. Calcite, dolomite and gypsum bearing rocks for instance limestone and gypsum are of greater importance in this regard. Calcium is also present in the shape of dissolved ion in the negatively infused minerals in the surface topsoil and cliffs. The calcium content in the rocks highly relies on dissolve ability of calcium carbonate, sulfate and chlorides. In the terrestrial and loose deposits the primary calcium source exists generally in different minerals and land fractions.

Sodium

The chemical name used for Sodium is NA. Natural waters always possess the sodium in it. It is vital dietary need and the usual intake is equal to the ordinary salt in food. It is a silvery metallic white component available in small quantity in water. Inappropriate amount of the sodium in individuals body put off numerous lethal illnesses for example kidney indemnity, increase in tension, headache. As per WHO guidelines, accumulation of sodium in drinking water is 200mg / l. Sodium exists in the shape of carbonate, bicarbonate and chloride combinations on the exterior of land and also at the sub-surface water at pH of 9 or greater. The sodium chloride absorption increases with the rise in total dissolved solids. Sodium content is comparatively great in the bottomless aquifer when equated with shallow aquifer; this is because of highly extensive ground water pace in the deep-rooted aquifer. The most substantial impact of excessive sodium in water is associated with irrigation water as the sodium ions are exchanged with the calcium concentrations in the centre exchange process thereby creating soil alkalinity which is assumed as deteriorated for the agriculture consumptions. Huge accumulations of sodium absorptions can be a source of disorder in the chemistry of the blood and it asserts profound effects on the health of the human beings which causes the hypertension.

Chlorides (CL)

They occur naturally in all types of water. Chlorides in natural water results from agricultural activities, industries and chlorides – rich rocks. It is the smaller element in the crust of the earth. Chlorides are not more than 1 parts per million (PPM) in the water of rain. Chloride is produced in drinking water through the sources which are natural in nature, manure and the manufacturing affluent, wastewater, sewers of storm and feed of animal built-up overspill composed of salt as a result of melting ice, and salty incursion. The maximum contaminant level (MCL) in chlorides for drinking water is expressed as 250mg/L by the WHO guidelines. It is usually obtained by dissolution of the salts of the hydro choleric acidic as slab salt (NACL). Sodium chloride is mixed via the manufacturing throw away manure ocean water. Lesser accumulation of chlorides is found in exterior or surface water resources as weighed against with the ground water. Chlorides bear the fundamental significance for the activity of metabolism in the body of human beings besides other physiological practices. As per WHO guidelines accumulation of the chlorides must not surpass 250mg/ l Excessive chlorides accumulation may destroy pipes of metals and is deleterious to the growth of the plants also as well. Chlorides are extensively dispersed in environment which exists as salt of sodium (NACL), calcium ($CACl^2$) and potassium (KCl).

Sodium Absorption Ratio (SAR)

The comparative action of the sodium in ion substitute responses through soil is articulated in terms of proportion is said as Sodium Absorption Ratio. SAR despite a yardstick of alkali sodium vulnerability to the agriculture, it is a significant stricture for ascertaining the appropriateness of the ground water for agriculture and irrigation uses. Sodium absorption ratio (SAR) is a gauge of the appropriateness of water for crops irrigation purposes, as determined through the accumulation of soluble solids in the water. SAR is besides a yardstick of the solidness of earth soil, as resulted through scrutiny of water derived from soil. Sodium absorption ratio quantities and soluble-solids accumulations were gauged values which were based on the laboratory findings for distinct ingredients. The values of the SAR were computed with the analytical outcomes of sodium and calcium also.

Total dissolve solids (TDS)

Total dissolve solids consist of non-living salts for example primarily the calcium, sodium, bicarbonates, chlorides, magnesium, potassium and sulfates and meager quantity of natural substance which can be soluble with water. If groundwater contains TDS value smaller than 300mg/L. It is assumed to be exceptional for drinking uses. Samples of water for TDS were calculated in mg/L. Huge piling up of TDS can change the taste of water into saltiest taste. In drinking water a TDS stems from a number of sources like industrial waste water of the urban areas and or sewage. It is basically a parameter to handle the common water quality. On the basis of (TDS) the drinking water can be classified as fresh, slightly saline, moderately saline, very saline and brine.

Area Coverage by the Land Use Classes

Pie graph used in the research show the area covered by the four land use classes of the study area i.e built up, vegetation, site near water and barren land.

Results and discussion

The study assessed the current status of water quality in relation to spatial land use of selected class on temporal basis; the selected water quality variables and distribution of the selected land use classes of the area under study. The assessment was made through collection and analysis of water samples and satellite images of 1987, 1998, and 2015.

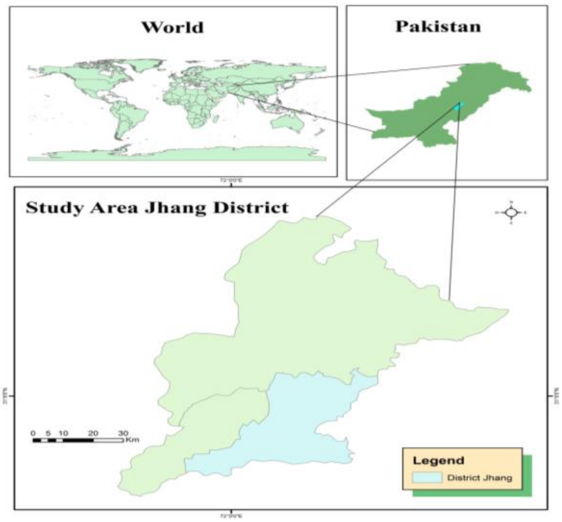

Fig. 1. Map of the Study area.

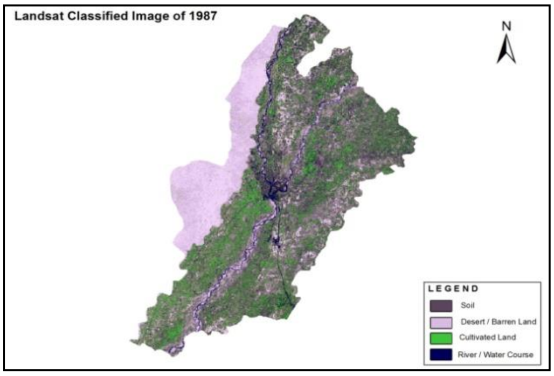

Fig. 2. Image Classification of 1987.

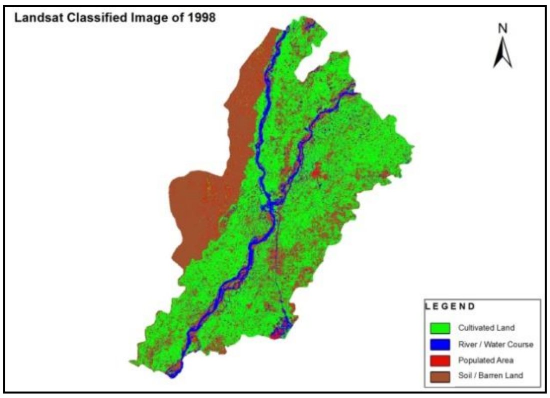

Fig. 3. Image Classification of 1998.

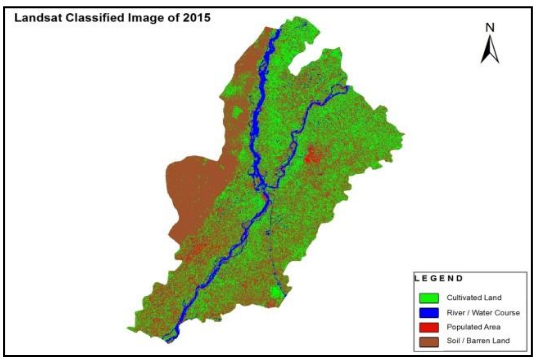

Fig. 4. Image Classification of 2015.

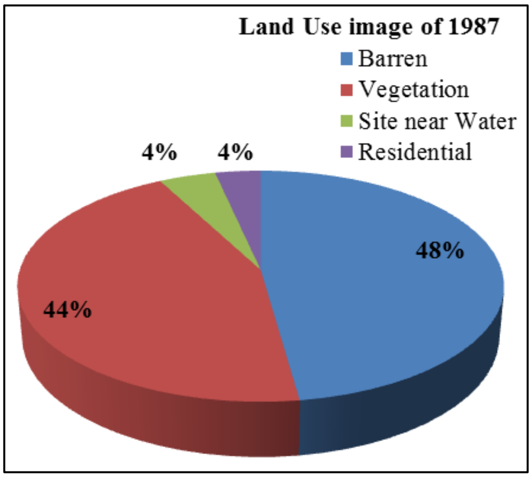

Fig. 4. Land Use in 1987.

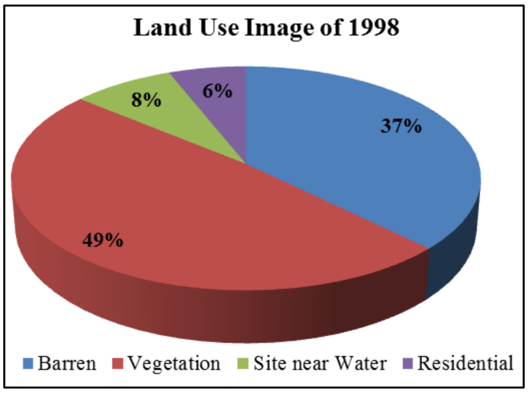

Fig. 5. Land Use in 1998.

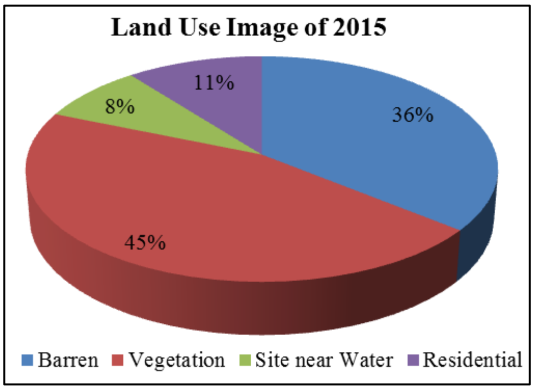

Fig. 6. Land Use in 2015.

The land use classes showed a significant change in area. With the increase in built-up area there was a decrease in the agricultural area. The residential areas as well as built up areas do not possess the infiltration properties so water quality is generally degraded in these areas as compared to rural areas where water can percolate deep into soil pores. Ph, E.C, Bi-Carbonates, Carbonates, Sodium and TDS were found highest in barren land use followed by other selected land use classes in the study area. By sampling and quantifying the effects that land use has on water quality, we can develop recommendations for better land use management to ensure the quality of our ground water. Our research focused on finding out how human land use interactions affect water quality in urban and agricultural developments. The land use was divided into four classes, urban and agricultural areas barren site near water. Comparing and contrasting the change in water quality was the main focus in our research. We thought it would be very beneficial to know which land use had the higher impact on land use class. The research hypothesized there to be no significant difference between urban and agricultural developments. This led us to look at how different water quality and land use variables such as urban and agricultural developments can affect water quality. Barren land use was found greatest affected land use class in respect to water quality. The relation between the land use and water quality has been studied in various studies. Water quality has a strong correlation with the land use. The effect of the land use change on water quality depends very much on type of the changes happened on the land use. If the change in the residential land use class increases the area of the agricultural land use class decreases so the water quality is also affected.

Our present research also found the profound impact of land use change on water quality which showed the highest change in land use followed by residential, vegetation and site near water land use in the study area of District Jhang.

Table No.1

Year	Barren land (Sq Kms)	Vegetation (Sq Kms)	Site near water (Sq Kms)	Residential (Sq Kms)
1987	3391.3	3155.6	306.6	245.6
1998	2357.6	3072	502.4	381.8
2015	1745.8	2213.6	400.5	514.8

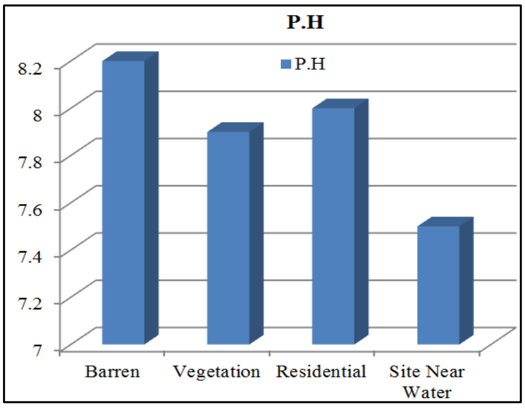

Fig. 7. Graph of PH.

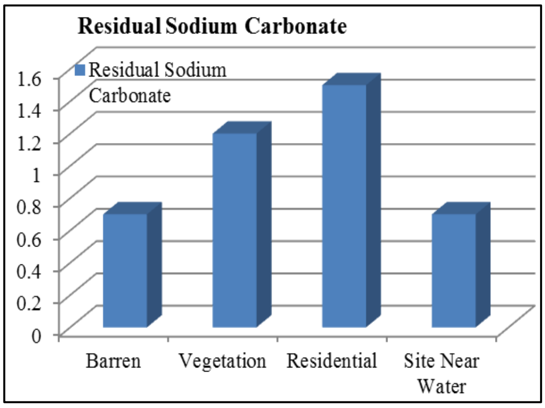

Fig. 9. Graph of Residual Sodium Carbonate.

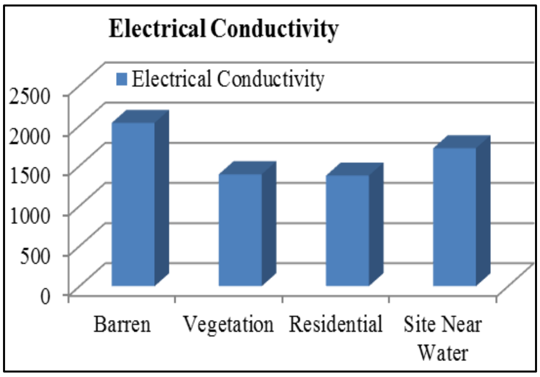

Fig. 8. Graph of Electrical Conductivity

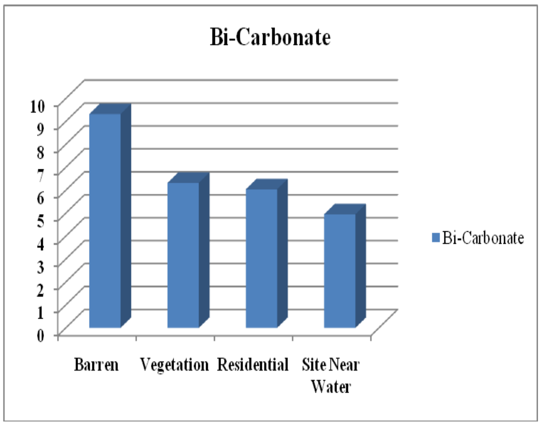

Fig. 10. Graph of Bi-Carbonate.

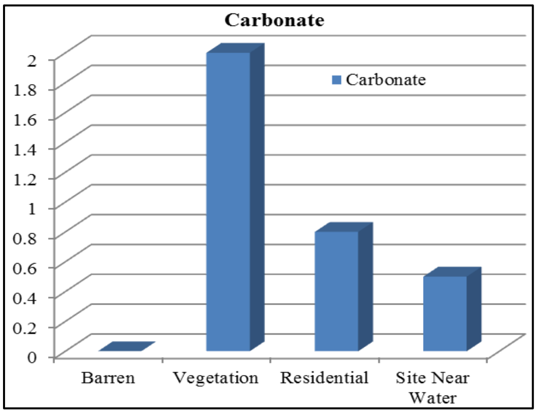

Fig. 11. Graph of Carbonate.

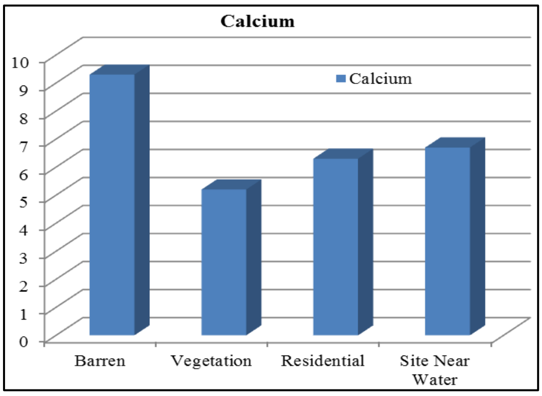

Fig. 12. Graph of Calcium.

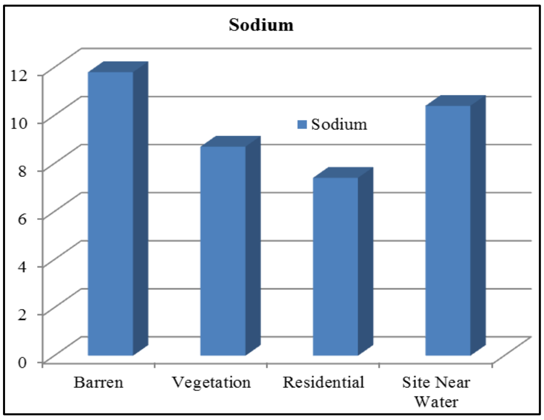

Fig. 13. Graph of Sodium.

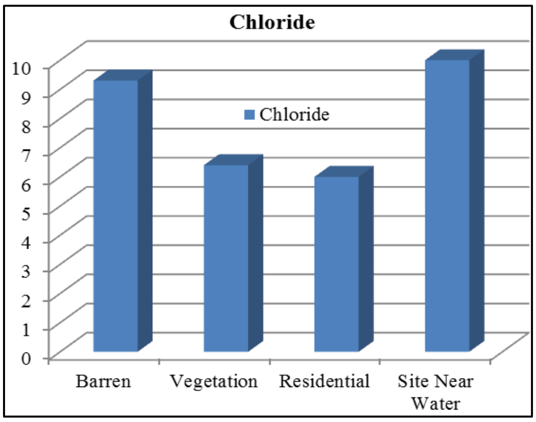

Fig. 14. Graph of Chloride.

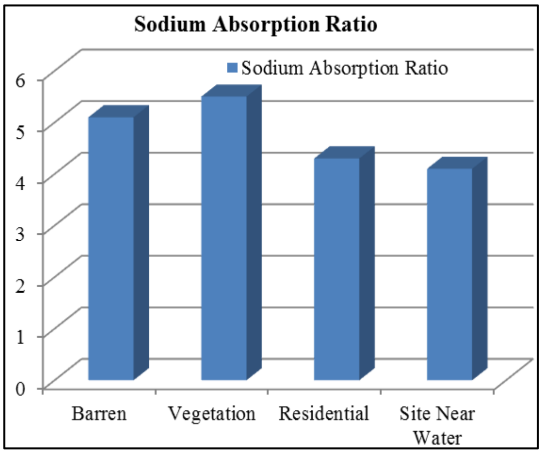

Fig. 15. Graph of Sodium Absorption Ratio.

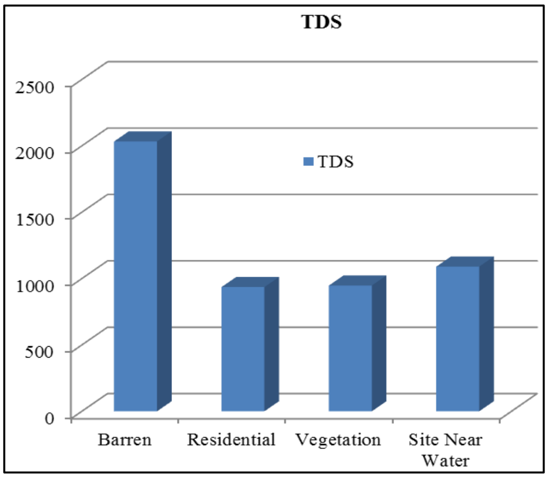

Fig. 16. Graph of TDS.

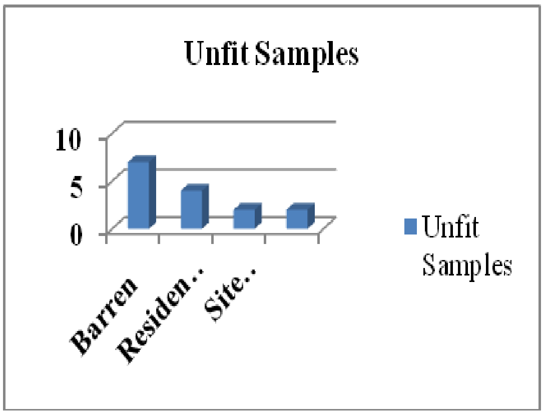

Fig. 17. Graph of Unfit Samples.

Selected indicators including calcium and chloride and sodium absorption ratio (SAR) had no specified upper limit recommendation value as per WHO limits. However, this study also found a higher concentration of pH, EC, and TDS in barren land and built up land use categories. Vegetation to site near water land use class had minimal effects over water quality.

Conclusion

Land use is becoming the major source of the water quality deterioration in the area due to urban expansion and decrease in vegetative area. However it can be said that the two land use classes namely barren land preceded by the built up land can be said having the most worsen water quality due to land use changes resulting from urban expansion and industrial activities. The investigations of the water quality of the selected study area showed that the water quality of vegetation and site near water land use class was comparatively less degraded as compared to barren land and area of built up land use class. Water quality in other land use classes has been found to have greatly affected by it but barren land use class is the most affected by it. So it can be perspicuously resulted that the land use changes are becoming the greatest cause and contributors of ground water deterioration that is why it becomes unfit for agricultural, drinking, industrial use. This loss or change in water quality attributed to the built-up expansion and increase in industrial activities in the Jhang.

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