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Management Policy regarding Water Quality in an Industrial Area: A case of Sindh Industrial Trading Estate

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Abstract

The rapid pace of population growth and continuous expansion of urban area is moving us towards economic prosperity but causes limited water resources across the globe. Water quality issues are prevailing due to the meteoric urban development and knocking the doors of legislators, city planners and development specialist for the efficient management of groundwater by adopting sustainable approaches. To address this alarming situation, current study examines the quality of groundwater in industrial and trading zone, Pakistan, as well as its influences on human fitness and ecological environment. Suitability and quality of 24 boring wells are examined at different depth ranges between (100-150 feet). The study involves substantial field work for collection of water sample, laboratory testing further, correlation matrix in the study figure out water excellence by computing physical parameters i-e pH, temperature, electrical conductivity, turbidity, hardness), chemical parameters including significant ions (sodium, potassium, , magnesium, chloride, calcium, bicarbonate, nitrate), few minor elements (iron, manganese) and trace elements (zinc, nickel, cobalt, chromium and copper) and comparing it with World Health Organization standards. The findings have reported the substandard water quality in the S.I.T.E (Sindh Industrial and Trading Estate) town. However, issues-oriented groundwater protection and management policies can help to promote sustainable development especially taking all stakeholders on board for the smooth implementation and fruitful results. This research will benefit the engineers, planners, concerned authorities for the establishment of public responsiveness and awareness plans about the quality of groundwater.

Keywords: Water quality; development; industrial zone, planning

Introduction

Water is considered a significant constituent in determining the use of land and regulating the climate. Water is one of the utmost imperative compounds that importantly influence the life of a living being (Gorde and Jadhav, 2013). Groundwater is substantially used for irrigation, domestic and industrial usage all over the world. Due to the rapid growth of population and enhanced pace of industrialization, a tremendous upsurge in demand for fresh water is observed. Around 80% of all the ailments in living beings are due to an inadequate supply of clean water (WHO, 2008) moreover, they reported that quality of groundwater cannot be restored easily once it gets contaminated.

Approximately, 50% of water used in urban areas, in most of the developing countries, is obtained through wells, springs and boreholes. The people living in such regions are mainly relying on these water resources (Kavitha and Elangovan, 2010). Recent increase in urbanization has drastically altered both the quantity and quality of water resources through different channels; firstly, urbanization and industrialization have positive and bi-directional relationship which mentions that higher urbanization is caused by industrialization and industrial infrastructure also strengthen through urbanization, as urbanization provides diversified employees and labors to the industry that may use to enhance the productivity (Lv et al., 2018). Such industrialization produces waste materials (sodium, iron, zinc, cobalt, chromium and copper etc.) and gases that pollute the water quality and environment. Secondly, it turns to be difficult to manage the waste water and sanitation system in higher dense population areas that also harms the water quality.

Quality of water is the expression of its conformation and configuration which is mainly affected by natural happenings regarding its calculable amounts (Kumar, 1999; Daud et al., 2017). Two primary sources of acquiring water are groundwater and surface water which are frequently used by creatures as it is accessible and essential to human life. The scarcity of surface water, contamination, higher evaporation rate has ultimately increased the dependency on groundwater in most of the areas of the world.

Pakistan is blessed with groundwater sources that contains annual recharge to the ground water system of Indus plain is projected around 55-million-acre of which 39-million-acre is being extracted annually. Despite of numerous natural resources and opportunities, Pakistan is facing massive shortage of quality water, especially near industrial zones such as Karachi, Lahore, Faisalabad. Furthermore, 60 per cent of an urban population of Pakistan is consuming ground waters for various purposes without upholding the prescribed standards of World Health Organization (WHO, 2014) In our case, we emphasize on Karachi as it faces extreme water shortage and concentration of dangerous materials in water. The main cause for such alarming situation is the increased population, bad sewerage condition, sanitation system and industrial activities etc.

The first key objective of current study is to examine the water quality standard of Karachi, which ascertain whether groundwater quality is appropriate for its intended use. Secondly, on the basis of research findings, we discuss on the solutions to reduce this alarming situation that is harmful for human health. Our main contribution is to examine the water sample of highly dense area of Pakistan that has been neglected previously. As most of the residents of this area belongs to lower class, for this reason, they are unable to purchase pure water. In light of these reasons, we choose this area to highlight its water quality substandardness that causes human health. The results provide substantial information about water quality which may use by Pakistan Council of Research in Water Resources (PCRWR) to take some preemptive actions, before the situation turns to be worse.

Literature review

Urban Planning and Ground Water Quality

Meteoric urban development coupled with swelling industrialization in metropolitan regions of the globe demands high water supply to impart urban functions. Water is a prerequisite, and essential human need for urban settlements and water is needed in several combinations, i.e. civic purpose, commercial use, use for various industrial process and many more. Urbanization process and rapid population growth have hugely affected the natural quality and quantity of water sources in several forms. (Wichelns,2010). It is universally recognized that the unprecedented pace of urbanization and industrialization is causing the reduction in groundwater due to the development of waterproof concrete structures across the huge chunk of urban land. Aquafers are paramount water sources for human settlements and their contribution in performing allied urban functions is significant (Jakobsen and Høgh Jensen, 1993). Several studies have revealed that prevailing urbanization across the globe and inimical forms of development hampering recharge of aquifers (Howard and Gerber, 2018). Urban settlements supplied with the massive amount of water with high pressure, so any contamination has the devastating impact on the human health (Morris, 2001). Urbanization has four substantial repercussions on the natural water cycle: urban flash flooding because of concrete and asphalt sealing, water shortage as consequence of increased water consumption, water pollution due to industrial development and changing patterns of rivers and water bodies (Strohschon et al., 2013). Aquafers are paramount water sources for human settlements and their contribution in performing allied urban functions is significant. A central concern for the urban managers is how to combat over abstraction and contamination of groundwater sources and hence increase groundwater refurbishment for the sustainable use of groundwater.

Inferences on Groundwater Quality and Quantity

Aquifers have three main functions in our natural environment: maintain and provide the absolute level of flow in the rivers, sustain the quality of water in the rivers by adulterating the sewage and other chemical effluents and an extraordinary source of potable water supply to more than 75 percent of the world's regions (Lerner and Harris, 2009). Conversely, ill-planned development in the epoch of rapid urbanization is dramatically affecting the groundwater quality. It mentions that instantaneous urbanization lessens infiltration of aquifers because of the impermeability of the water sources by the development of carpeted roods, concrete buildings, and industrial development on prime agricultural land and causing proliferation of urban landscape. Studies show that modern agriculture practices and industrial wastewater are the significant contributors to ground water deterioration (Lerner and Harris, 2009). Consequently, colossal amount and extent of pollutants exist in ground water sources. There are various ground water pollutants, which have the direct impact on human health are bacteriological instigating diseases. Urban planners argued that natural quality and quantity of water is affected mainly due to the changing land use trends and chaotic development. Further, changing land uses due to the modernized and urbanized socio-economic system has severe repercussions on ground water quality, magnitude and extent of water level (Uma, Karthiyayini, and Vaardini,2016). Urban socio-economic activities are altering natural land cover of this planet rapidly and causing environmental changes. Modifications and alterations in land use such as urban expansion on green covers, industrial development along water channels, urban infrastructure and commercial activities drastically affecting water sources. The present pace of inauspicious growth at the cost of environment causes drastic changes in the quality of groundwater sources, i.e. the intensification of salinity, nitrogen composites, microbiological and petroleum mixtures adulterations (Ibe and Njemanze, 1999).

Methodology

Location of Study Area

Karachi is the principal and most populous region in Pakistan. S.I.T.E (Sindh Industrial and Trading Estate) town is in the west of Karachi shown in (fig 1). To the north, it is surrounded by Gadap town, Liaquatabad and North Nazimabad to the east, Lyari and Saddar to the south across the Lyari River and Kemari to the west which is originated as worker’s colony. This town is further segmented into nine union councils and we have selected it for this study, as it is the chief manufacturing and industrial zone of Pakistan with more than 2,000 industrial units on 4,500 acres of land, a population is about 467,560 according to 1998 census. If it is assumed that the population grew at 1.9% quoted by the (Economic Survey of Pakistan) its current population would be over 530,000. (Dawn, 2005)

Sample Collection

Twenty-four samples were gathered from boring and dug wells to inspect the quality of groundwater at a depth range of 100-150 feet. Boring wells were electrically pumped to run water for 1-2 minutes to get respective samples of the water. Samples were collected in plastic containers of 1-litre capacity for physicochemical examination. Bottles were appropriately washed and rinsed carefully with distilled water, and then groundwater was taken as a sample. Physical properties including color, taste, odor, temperature, turbidity was observed immediately in the field after collecting the samples. A position of the bores was specified with the help of GPS on the google image. Other details are used by the owners of each well.

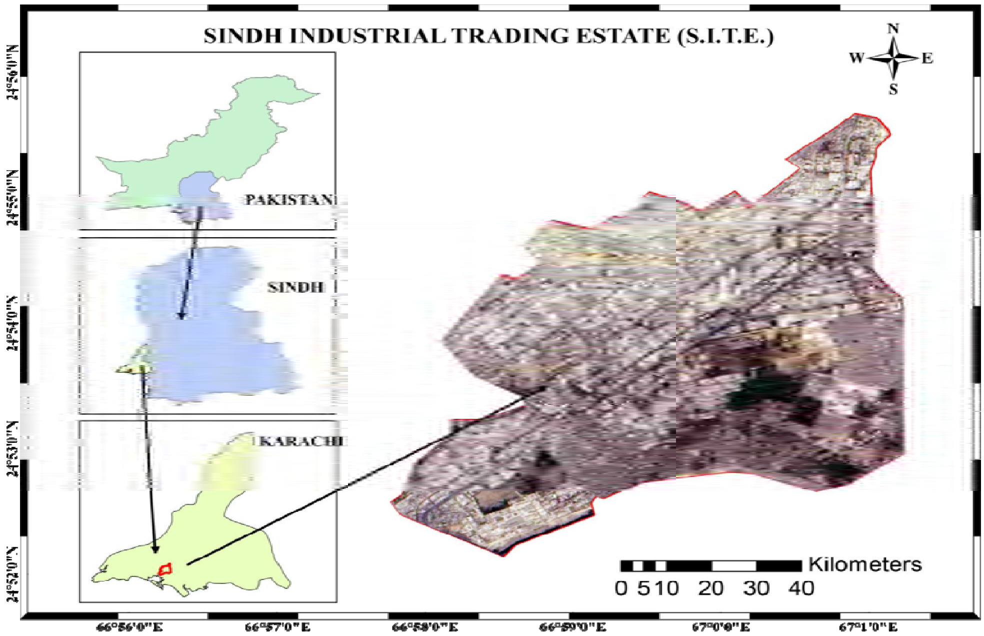

Figure 1. Location map of SITE town Source Developed by researchers

Laboratory Testing

Table 1. Equipment/methods used to analyze groundwater samples collected from S.I.T.E. Area.

Parameter	**Method**
Bicarbonate (mg/Liter)	By Titration and Standard Method, (1992)
Calcium (mg/Liter)	EDTA Titration, Standard Method (1992)
Chloride (mg/Liter)	Titration (Silver Nitrate), Standard Method (1992)
Conductivity (mS/cm)	EC meter, Adwa (AD 330)
Turbidity (NTU)	Turbidity meter, Hanna Instrument Hi 93703-11
Magnesium (mg/liter)	Titration Method, Standard Method (1992)
TDS (mg/liter)	EC meter, Adwa (AD 330)
pH	pH meter (AD 111)
POTASSIUM (mg/liter)	Flame photometer JENWAY EFP7
SODIUM (mg/liter)	Flame photometer JENWAY EFP7
Iron	Atomic Absorption Spectrometer (Analyst 400 Perkin Elmer)
Hardness as $caco_3$	EDTA titration standard method (1992)
NITRATE (mg/Liter)	Spectrophotometer, HACH-8171
Trace Elements	Atomic Absorption Spectrometer (Analyst 400 Perkin Elmer)

Results and Discussion

The quality of groundwater cannot be restored easily whet it get contaminated. 80% of the diseases are due to water contamination according to report of World Health Organization composition of water is the water quality which is overblown by natural and anthropogenic activities in quantities analysis (Kumar, 1999). S.I.T.E town is the industrial hub located at the western part of Karachi near to the sea. For the quality assessment, twenty-four groundwater samples were collected as illustrated by (Cuthbert, 1992). For water quality significance, physicochemical characteristics are analyzed including (color, taste, odor, temperature, pH, TDS, EC, turbidity, hardness, Na, Ca, Cl, K, HCO_3, Mg, SO_4, NO_3 and trace elements) of groundwater samples of S.I.T.E. town. The analytical results thus obtained have been discussed below in detail.

Physical Characteristics

Aesthetic Characters (Color, Taste, Odor), Turbidity

All the collected groundwater samples are colorless with no objectionable smell. Except for few samples whose taste was slightly saline, all the samples were extremely saline, which may be due to the high value of total dissolved solids (TDS) (mean = 6474.167). The well depth of these saline groundwater samples is deep, i.e. ranges between 100-150 feet. Scattering and absorbing of light in water is caused due to the presence of suspended matter, colloidal particles, clay, silt, plankton and other microorganisms are termed as Turbidity (WHO, 1984). Sample collected was also scattering light. Quantitatively all the groundwater samples were clear and qualitative result was 0.0 in Nephelometric Turbidity Unit (NTU) which means there is no turbidity in samples of the study area. Water must have a turbidity value of lesser than 0.1. In this context, the turbidity of groundwater is found to be safe. (Yannopoulos,2017).

pH, Total Dissolved Solids, Electrical Conductivity

pH ranges under the study area are 6.95-7.84 with a mean of 7.445. The pH of all groundwater samples is underneath for drinking purpose assigned by WHO which is (6.5-8.5). It has diverse effects on human health, due to the changes in water quality. The main factor is TDS content, which describes the use of groundwater for any purpose (Nordstrom, 1987). Total dissolved solids in the study area are very high ranging 2020-17800 mg/L. TDS of the collected groundwater samples are above the permissible limit assigned by WHO due to the sea water intrusion. Kidney stones and heart diseases are caused by the huge amount of TDS (Salara and Babu, 2012). The Electrical conductivity ranged from 4050 µS/cm to 35600 µS/cm with a mean value 12802.5 µS/cm. It has a direct and strong relation with total dissolved solids (TDS).

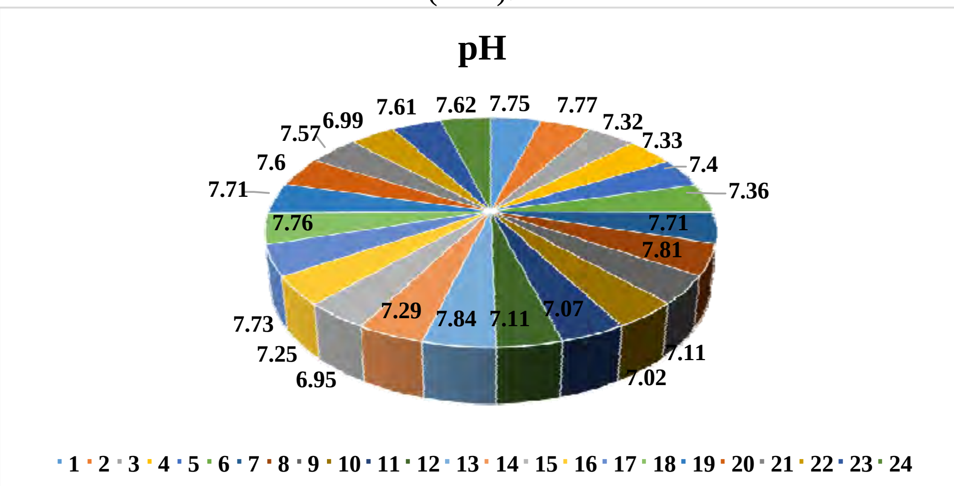

Figure 2. Values of pH obtained after analyzing groundwater samples

Total Hardness

The hardness of the groundwater in S.I.T.E. town is also highly variable which ranges from 890-8100 mg/L. By WHO No prescribed limit of hardness is assigned whereas more than 500 ha mg/l hardness are tolerated by consumers (WHO, 2011). In the collected samples the high amount of hardness in groundwater causes the high amount of Ca and Mg due to the leached minerals from rocks and another seepage of sewage

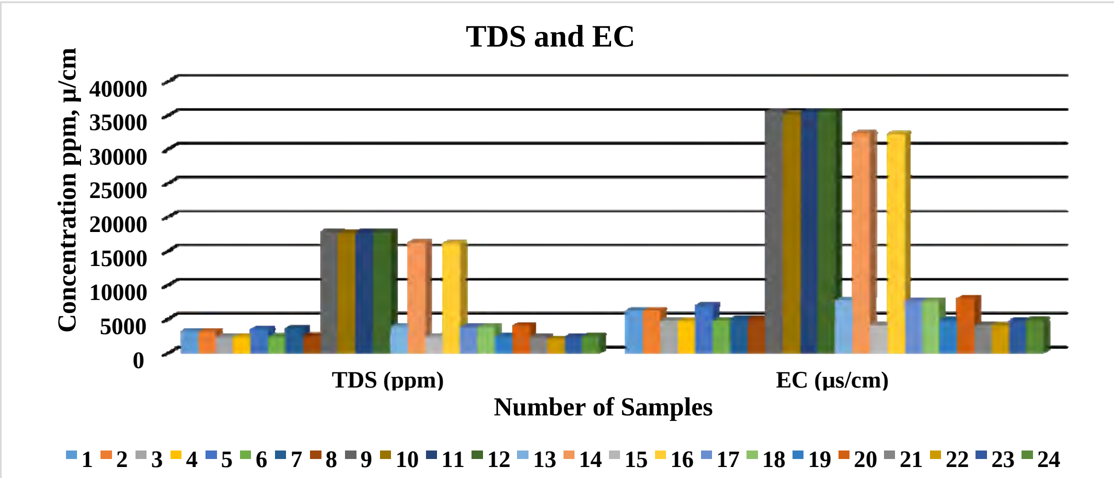

Figure 3. TDS and EC values of groundwater of the study area

Chemical Characteristics

Sodium (Na)

Sodium concentration in the groundwater widely varies between 123-930 mg/L. Except some of the samples (n=4) all the groundwater samples collected were above the assigned permissible limit 200 mg/L by WHO It may be due to sea water intrusion or semiarid climate or high evaporation rate (Bannert, D., Bender,1995). The high values of sodium are due to mistreatment of groundwater resources. Surplus amount of sodium can cause hypertension, kidney disorders and nervous disorders in a human body (Ramesh and Elango, 2011).

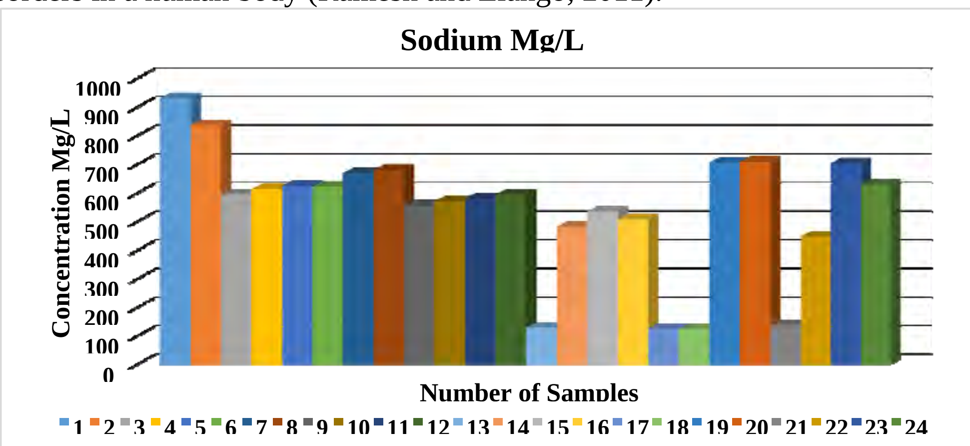

Figure 4. Concentration of Sodium in groundwater

Chloride (Cl)

Chloride content ranges from 1028.05mg/L to 15420.75mg/L with a mean of 4807.168mg/L in the collected samples of groundwater. Samples contain chloride concentration above the permissible limit assigned by WHO which is 250mg/L. Due to high sodium and chloride concentration in most of the groundwater of S.I.T.E town show high salinity which may be due to arid climate or high evaporation rate or may be sea water intrusion that is why it is not suitable for drinking and domestic purposes. High intake of Cl may cause laxative effects (UNESCO, 2000) essential hypertension, a risk for stroke and asthma (Salara and Babu, 2012) in the consumers.

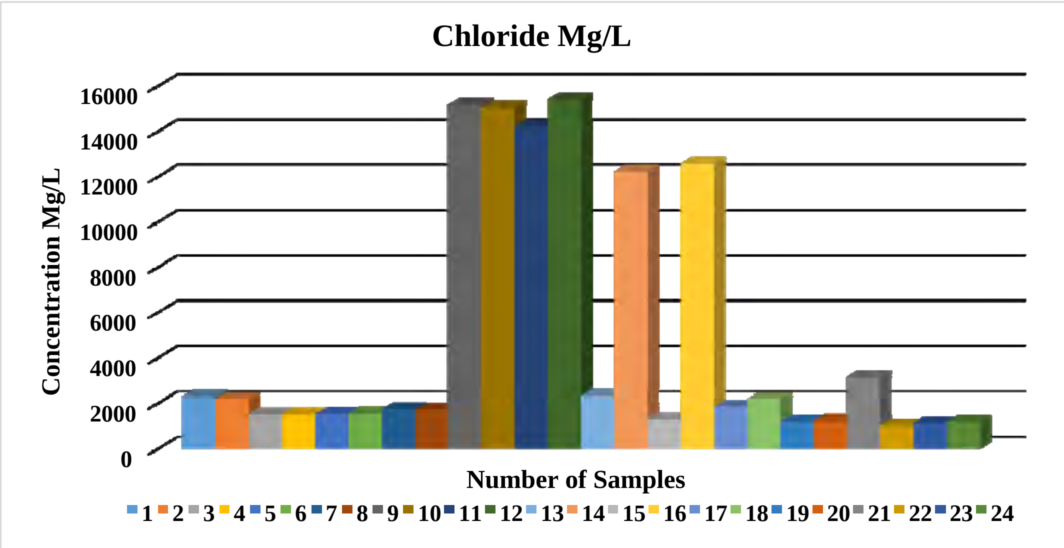

Figure 5. Concentration of Chloride in groundwater

Calcium (Ca) and Magnesium (Mg)

The concentration of calcium in the water sample collected ranges from 340 to 8260 mg/l. For drinking purpose, the defined limit is 75 mg/l (WHO 2011), and all samples are high from the limit. All the samples of S.I.T.E area are not suitable for drinking purpose because they are fluctuating the assigned limit. Mg^{2+} concentration in samples is in range of 176.17 to 1725.9 mg/L. Whereas, the maximum quantified limit is 150 mg/L. according to (WHO, 2011).

Bicarbonate (HCO_3)

Bicarbonate concentration in S.I.T.E town varies widely 1900 mg/L-5025 mg/L with a mean of 3357.29mg/L. Maximum specified concentration for HCO_3^{2-} is found to be 300 mg/l (WHO, 2004). Due to the excess limit, it is not suitable for drinking purpose.

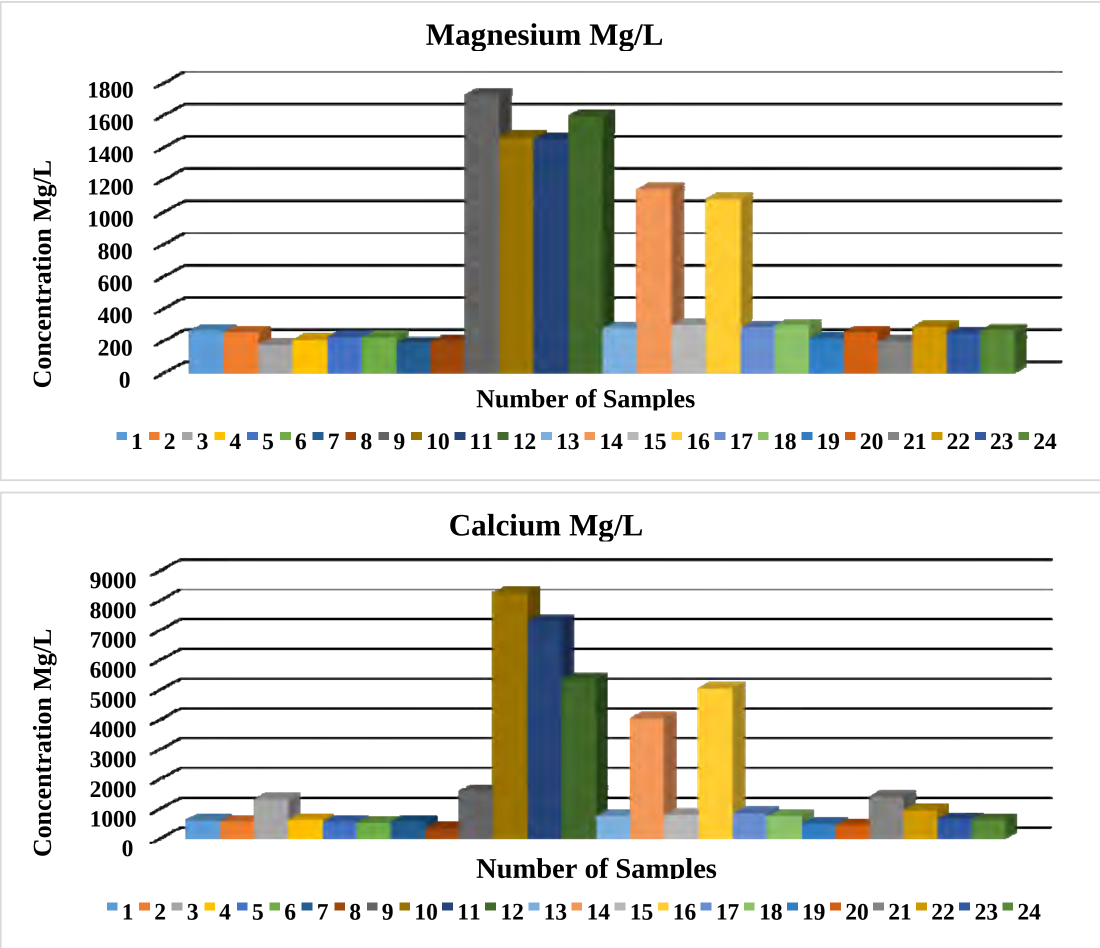

Figure 6. Concentration of Magnesium and Calcium in groundwater

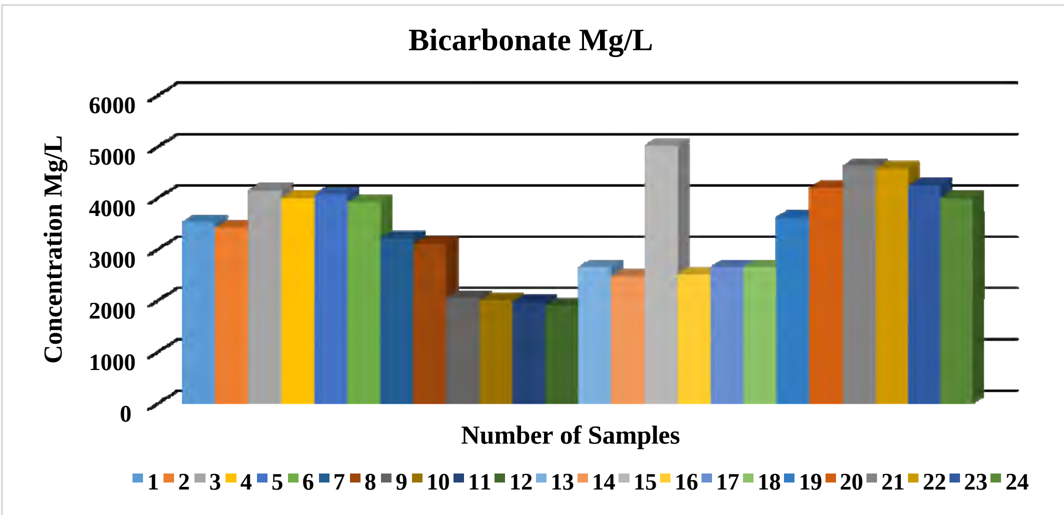

Figure 7. Concentration of Bicarbonate in groundwater of the study area

Potassium (K)

Potassium concentration in ground water samples is from 10.68 mg/L to onwards. Due to the exceeding content of potassium of 12 mg/l for drinking water except for only a few groundwater samples. Potassium sources in groundwater consist of the application of potash fertilizer and weathering of potash silicate minerals Excess of potassium in groundwater can cause the nervous and digestive disorder. (Singh and Tiwari, 2001).

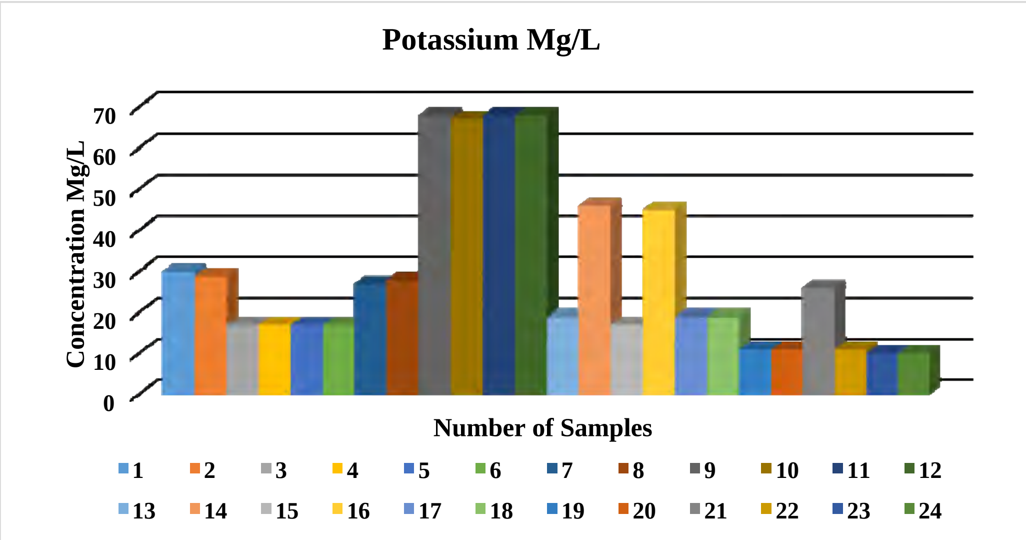

Figure 8. Concentration of potassium in groundwater of the study area

Sulphate (SO_4)

Sulphate ion concentration ranges between 122-960 mg/L. Only a few (n=8) samples are within the prescribed limit of WHO (250 mg/L) others are exceeding. In groundwater Sulphate is obtained from industrial waste discharge and domestic sewage to increase its concentration. (Ratna Reddy et al., 2012).

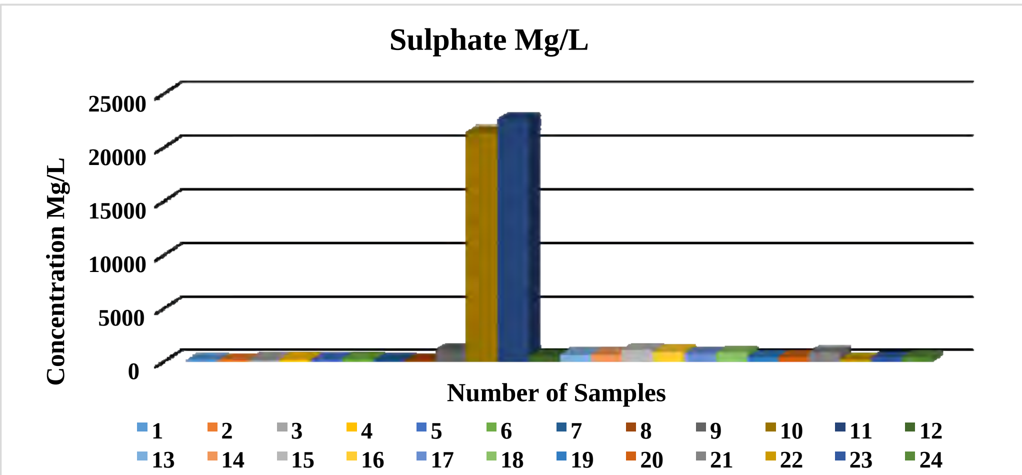

Figure 9. Concentration of Potassium and Sulphate in groundwater of the study area

Nitrate (NO_3)

Nitrate concentration varies between 35.52-227.08 mg/L (Mean 92.24 mg/L) all the samples found to be above the safe limit of WHO except (n=4) samples. Due to human activities, such as agriculture, industrialization, there is an increase in nitrate concentrations. Due to the excessive amounts of nitrate, human body faces number of issues such as, diseases characterized by blood changes (Manivasakam, 2005).

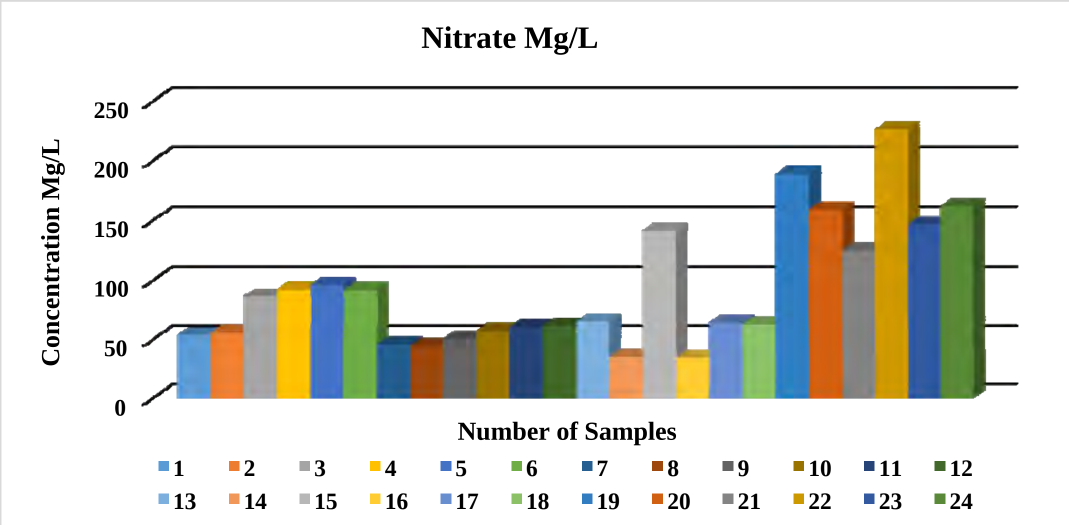

Figure 10. Concentration of Nitrate in groundwater of the study area

Iron (Fe)

A very low concentration of iron (Ranges: 41-79 ppb) is found in (n=8) collected groundwater samples of S.I.T.E. Town. This low concentration may be due to the redox environment. Due to the deficiency of iron may cause of red blood cells, hair loss and headaches pale skin, general weakness, brittle nails, which is complained by the residence of a study area.

Trace Elements (Zn. Cu, Co, Ni, Cr)

Except for zinc, all other trace elements are observed below the detection limit. A concentration of Zinc in groundwater ranges 32-1638 ppb with a mean of 9233 ppb. Only a few (n=3) samples are within the recommended value (50 ppb) set by WHO. for normal body functions Zn is integral, but its least amount distorts immune system, hair loss and depression. Deficiency of other trace elements like Cu may result in anemia in infants (WHO, 2014). Prolong cobalt deficiency causes neurological disorder, nerves damage, memory loss, mood changes, psychosis and may be death. Lack of Manganese (Mn) may cause difficulties in reproductive function, epilepsy, impaired growth and problems in wound healing (Bain and Hossain, 2014). Nickel is an essential trace element used for increasing iron absorption and treating weak bones (osteoporosis). Sufficient amount of chromium (<50 ppb increases in insulin performance and it is mandatory for healthy metabolism. (Soomro and Hussain, 2011).

Ionic Correlation

The is a measure of the linear dependence between two variables X and Y like ions and the sources of contamination is termed as Pearson correlation coefficient. Ions are considered reliable if their correlation is more than 0.7 r >0.7 whereas ions show a moderate correlation when r=0.5-0.7 (Adams et al., 2001). The correlation of TDS and EC is found very strong and imperative with k, Mg, Ca, Cl, and SO_4 which shows that high concentration of these ions is responsible for high TDS in groundwater and strong negative correlation of TDS and EC with HCO_3. The perfect correlation of Mg (r=0.98) and ideal correlation of Ca (r=0.89) with Hardness expose that they are responsible for growing hardness of groundwater. Matrix is shown in the table below.

Table 2. Illustrating Correlation among Physico-Chemical Parameters

CORRELATION MATRIX AMONG PHYSICO-CHEMICAL PARAMETERS											
	pH	**TDS**	**EC**	**Hardness**	**Na**	**K**	**Mg**	**Ca**	**Cl**	**SO_4**	**HCO_3**
pH	1	-0.572	-0.57	-0.629	-0.046	-0.506	-0.62	-0.59	-0.59	-0.43	0.0863
TDS		1	0.999	0.989	-0.011	0.935	0.981	0.869	0.992	0.563	-0.796
EC			1	0.989	-0.012	0.931	0.982	0.869	0.992	0.563	-0.796
Hardness				1	-0.008	0.934	0.984	0.894	0.991	0.599	-0.76
Na					1	0.0501	0.0044	-0.033	-0.019	0.0115	0.15862
K						1	0.944	0.8285	0.957	0.6044	-0.7979
Mg							1	0.8302	0.987	0.5573	0.55731
Ca								1	0.872	0.7999	-0.6558
Cl									1	0.5654	-0.7808
SO_4										1	-0.46
HCO_3											1

Na/Cl is used to detect the source of contamination (Drever, 1997). Na/Cl ratio of all the collected groundwater samples is <1 which is the indicator of seawater intrusion (Yang et al., 2003). Ca and Mg shows the strong correlation (r=0.83) between that verify they are derived from the same source (Annapoorna and Janardhan, 2015).

Table 3. Brief results of water quality of S.I.T.E

Parameter	Method	Findings	Status
Bicarbonate (mg/Liter)	By Titration and Standard Method, (1992)	Above the permissible limit	Substandard
Calcium (mg/Liter)	EDTA Titration, Standard Method (1992)	Above the permissible limit	Substandard
Chloride (mg/Liter)	Titration (Silver Nitrate), Standard Method (1992)	Above the permissible limit	Substandard
Conductivity (mS/cm)	EC meter, Adwa (AD 330)	Lower the permissible limit	Substandard
Turbidity (NTU)	Turbidity meter, Hanna Instrument Hi 93703-11	Lower the permissible limit	Substandard
Magnesium (mg/liter)	Titration Method, Standard Method (1992)	Above the permissible limit	Substandard
TDS (mg/liter)	EC meter, Adwa (AD 330)	Above the permissible limit	Substandard
pH	pH meter (AD 111)	Lower the permissible limit	Substandard
POTASSIUM (mg/liter)	Flame photometer JENWAY EFP7	Above the permissible limit	Substandard

Parameter	Method	Findings	Status
SODIUM (mg/liter)	Flame photometer JENWAY EFP7	Above the permissible limit	Substandard
Iron	Atomic Absorption Spectrometer (Analyst 400 Perkin Elmer)	Lower the permissible limit	Substandard
Hardness as $caco_3$	EDTA titration standard method (1992)	Above the permissible limit	Substandard
NITRATE (mg/Liter)	Spectrophotometer, HACH-8171	Above the permissible limit	Substandard
Trace Elements	Atomic Absorption Spectrometer (Analyst 400 Perkin Elmer)	Lower the permissible limit	Substandard
Sulphate (mg/liter)	By Titration and Standard Method, (1992)	Within the permissible limit	Acceptable

Table 3 summarizes the results of water quality testing; it is not hard to conclude that the water quality in studied region is substandard that points toward an alarming situation. However, there is strong need to focus on such devastating conditions that is harmful for human health.

Conclusions

The studied town (S.I.T.E.) is an industrial hub, this is at south of the Lyari River and draining into the Manora channel. Town residents mainly depend on groundwater for fulfilling their primary need. The study revealed that the groundwater samples are highly saline which associated with high TDS. All the samples have the high concentration of Ca, k, Cl, Na, Mg, SO_4, Zn and NO_3 which is exceeding the prescribed limit of World Health Organization for drinking purpose. The major hydrofacies found in the groundwater of the S.I.T.E area is Ca-HCO_3 and Calcium Chloride. Water quality testing has confirmed the overwhelming status of water, it further mentions that the quality of groundwater contaminated by the disposes of untreated municipal and industrial waste into water bodies which is then adversely affecting the quality of water. This indicates that the groundwater of the S.I.T.E. town is unfit for drinking purpose.

The problems associated with groundwater quality and quantity management are multifaceted and connected to an existing extent of groundwater, portable water supply, distribution mechanism and recycling approaches. Curbing further water exploitation by setting up the mechanism for the water balance and imposing usage charges on industrial and commercial users of groundwater. There are two mostly acceptable strategies, which are used for groundwater quality and quantity management, i.e. optimal yield technique for the controlled and registered groundwater usage and combating over exploitation by regularizing the groundwater usage and constant monitoring of groundwater extraction by giving legal backup at all administrative tiers (Menon, 2007). There is a dire need to bridge two main gaps in in the aquifer water sources management, and these are over abstraction and aquifer resources depletion, which exhibit grave changes in quality of groundwater. Planners and policy makers should focus on water management strategies to manage the multitude of subjects some of them are stated below

- Improve water usage efficiency, sectorial coordination and interaction for the controlled usage of water.
- Develop a planning framework for balancing water demand and strategic planning for the conservation and preservation of water-dependent habitats.

- Sustainable development approaches necessitate concerned institution to penalize industries which dispose of industrial waste water without primary treatment.
- There is a dire need to launch the awareness campaign among all groups and make plans for hotspot areas.
- Prevent and mitigate water pollution sources rather than treating the water after extraction.
- Need to follow precautionary principle for groundwater quality management by monitoring the disposal of hazardous chemical waste without treatment which can deteriorate groundwater.
- Apply groundwater quality management plan at all administrative and human settlement level to combat groundwater pollution.
- Ensure provision of groundwater recharge wells and rainwater harvesting in all commercial and industrial buildings during building plan approval process by local development authorities.

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We are very obliged to Ms. Aisha Khan from City and Regional Planning Department, University of Engineering and Technology, Lahore, Pakistan, who managed the laboratory testing process and made it easy to understand the laboratory results. We pay our foremost recognition to Dr. Suleman Sarwar and our team members from Karachi who helped in collecting and testing samples and enabling us to complete this research project.

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