

◆ Research paper

DOI: [10.5281/zenodo.10791173](https://doi.org/10.5281/zenodo.10791173)

# Ground Water Quality Assessment of Landhi Industrial Area, Karachi, Pakistan

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**Abstract:** Landhi Industrial Area (LIA) is an industrial zone in Karachi city. It is situated near Landhi Town and Malir River. Groundwater samples (n = 16) were collected from boring wells at various depths (30-150 feet) that have been analyzed for quality assessment. Data revealed that the pH of groundwater is circum-neutral (6.98 to 7.44) and temperature varied between 25 to 28 °C. The turbidity of the groundwater samples varies from 0.08 to 8.12 NTU which is within the permissible limit (< 5 NTU) of WHO. On the other hand, a wide range of hardness (250-1650 mg/L) and TDS content (166-5600 mg/L) is observed. Where about half and a quarter of the total samples show objectionable TDS (> 500 mg/L) and hardness (> 500 mg/L) respectively. Major cations varied in the order of Na<sup>+</sup> > Ca<sup>+2</sup> > Mg<sup>+2</sup> > K<sup>+</sup> while anions show declining trend of Cl<sup>-</sup> > SO<sub>4</sub><sup>-2</sup> > HCO<sub>3</sub><sup>-</sup> > NO<sub>3</sub><sup>-</sup>. It is concluded that the groundwater of the study area is generally fit for drinking purposes and only two sites are found highly polluted.

**Keywords:** Groundwater, quality, industrial zone, Landhi, Karachi.

## Introduction

Water is an important natural resource, that forms the core of the ecological system (Selvam et al. 2013). The demand for groundwater increases with some factors like increasing population and pollution of surface water bodies by agriculture and industrialization. Groundwater pollution originating from municipal, domestic, human, and

animal waste has been a serious problem in Latin America, Asia, and Africa. Groundwater quality is worst in Asian countries where about 70 % of people live without proper sanitation. Exceeding the number of toxic metals and fecal coliform bacteria have been found in Rivers of Asia that exceed the WHO guidelines (Azizullah et al, 2011). Many developing countries like Kenya, Nigeria, and Sudan have suffered from severe groundwater contamination because of the untreated discharge of the effluents from the industries nearby into the water bodies that has resulted from the rapid growth of industrialization (Mondal et al, 2005a). Large numbers of industries are mainly situated along the banks of the canals and the rivers due to which their waste material is directly disposed of into water bodies without proper monitoring. These pollutants entering the water bodies degrade the groundwater quality due to seepage and thus become unfit for human and agricultural use (Tariq et al, 2008). Water quality of the major cities of Pakistan such as Karachi, Faisalabad, Kasur, Sialkot, Gujrat, Lahore, Sheikhpura, and Peshawar is deteriorating due to unchecked disposal of industrial effluents into the water bodies (Ullah et al., 2009). Important Industrial activity known as leather processing is concentrated in three major cities (Karachi, Sialkot, and Kasur) where 600 tanneries are working. Wastewater discharge from leather production industries pollutes air, soil, and water leading to chronic waterborne diseases (Mondal et al, 2005b).

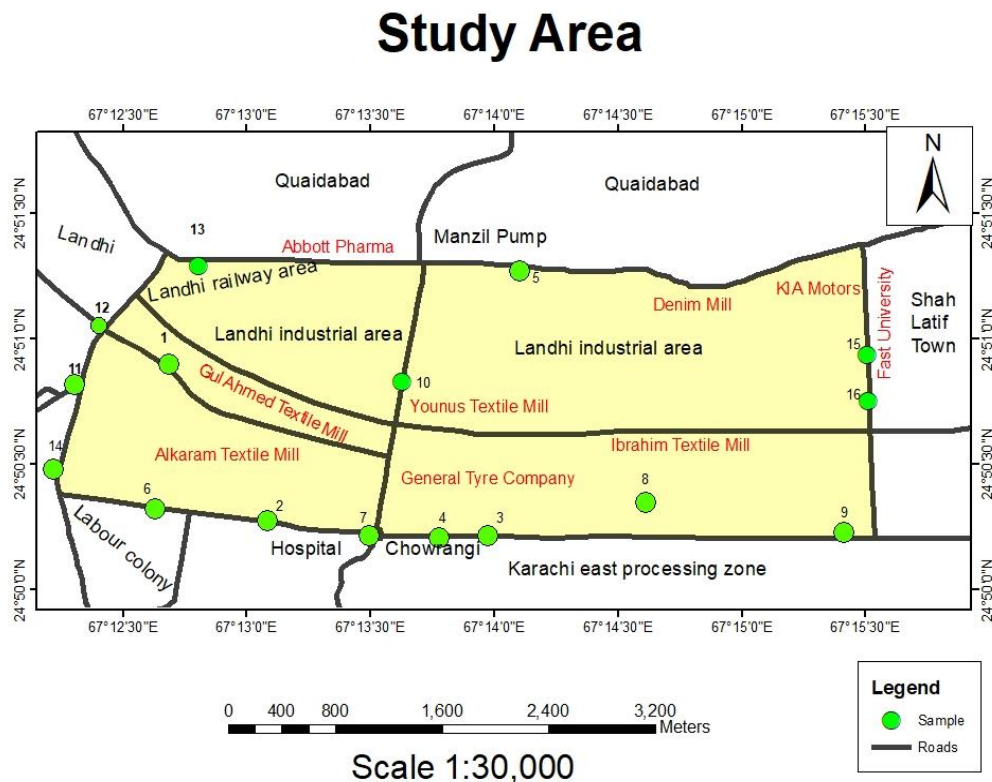
Karachi is an Industrial city in Sindh Province and is characterized to be one of the most severely affected regions in terms of groundwater contamination as it contains various chemical processing industries that discharge huge amounts of contaminated water daily. It is one of the twenty megacities of the world and the largest metropolitan city of Pakistan. It has a population of about 20 million and covers an area of more than 800 Km<sup>2</sup>. The shortage of water supply in Karachi forced the people and the industries to meet their demands from groundwater. Landhi Industrial Area (LIA) lies in the southern part of Karachi. LIA covers an area of about 10 km<sup>2</sup> where more than 300 wells have been drilled to draw groundwater for domestic and industrial uses. Landhi Industrial Trade Estate (LITE), discharges its effluent into the Malir River which is linked to Ibrahim Haideri fish harbors. It discharges about 75,000-80,000, per day into the sea respectively from above rivers. Despite the vulnerability of groundwater pollution from such industrial waste, no work has been carried out so far to

delineate the groundwater water quality in the study area that has been used for many decades by the residents for domestic purposes. Therefore, the present study aims at the assessment of groundwater quality using physicochemical parameters of the Landhi industrial area to determine its suitability for human use.

## Material and Methods

### Sampling

Groundwater samples (n = 16) were collected from various sites through boring wells. To ensure representative samples, groundwater was electrically pumped for a duration of 2-3 minutes. Locations of the boreholes were determined using the Global Positioning System (GPS) that have been plotted on the location map (Fig.1). Plastic bottles with a capacity of 1 liter were utilized for sample collection, while smaller bottles (200 ml) added with boric acid were specifically used for nitrate analysis to prevent further reactions.



**Figure 1** Map showing the sampling locations in Landhi Industrial area, Karachi. Before collection, the bottles were washed thoroughly and rinsed properly with distilled water, and

finally with groundwater from the sampling site. Sample bottles were labeled properly assigning a sample ID number and transported to the laboratory of the Department of Geology, University of Karachi for analysis. All the standard procedures for the calibration of the laboratory and field equipment were followed accordingly.

### ***Groundwater Analysis***

All samples were analyzed for physicochemical parameters. The pH, EC, and total dissolved solids (TDS) of the collected samples were measured using specific instruments i.e. a glass electrode pH meter (ADWA AD 111) for pH measurement and an EC meter (ADWA AD 330) for EC and TDS measurement. Sodium and potassium concentrations were determined using a flame photometer (model: PFP-7, JENWAY, UK). Bicarbonate and chloride ions were measured using argentometric titration. The standard EDTA titration method (1992) was employed to determine calcium and total hardness. Magnesium content was estimated by calculating the difference between hardness and calcium using a standard formula. The sulfate content was determined through a gravimetric method. Nitrate was measured using the Cadmium Reduction Method (HACH-8171) through a spectrophotometer after groundwater samples were preserved in boric acid to stop any reactions that might have reduced the nitrate content.

## **Results and Discussion**

### ***Physic-chemical Parameters***

The results of physicochemical parameters have been summarized in Table 1. The temperature of the investigated groundwater varied in a range of 25 to 28 °C (Table 1). Data reveal that groundwater pH is circum-neutral (Range: 6.98-7.44), which is within the permissible limit (6.5–8.5) of WHO (1997) for drinking water. The pH of natural water is an important factor that is influenced by the chemical and biological parameters of the water as well as the toxicity of many compounds (Haque, 2009). The occurrence of neutral pH in most of the samples indicates the existence of ionic balance in the groundwater of the study area. Ten out of a total of 16 samples are reported to show turbidity that varied in the range of 0.08 to 8.12 which is within the permissible limit (> 5 NTU) set by WHO for drinking

purposes. On the other hand, TDS (total dissolved solid) content shows highly variable distribution (Range: 166-5700 mg/L mean:1167 mg/L). Two samples (LIA 15, 16) showed TDS content above 5000 mg/L. These samples were collected from cattle farms suggesting the leaching of animal waste and mixing with groundwater system (Haider et al., 2023).

Groundwater hardness also varies in a wide range (250-1650 mg/L) where two samples show hardness > 1600 mg/L. The hardness value of these two samples three times higher than the WHO limit (500 mg/L) is attributed to the animal waste mixing from cattle farming sites which is consistent with the high TDS content as discussed earlier. Hardness is commonly expressed as milligrams of calcium carbonate equivalent per liter. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard (Hem, 1970). Hence, all collected samples are found to be unfit (above 180 mg/L) in terms of calcium carbonate equivalent hardness.

The Eh varied in the range of +98 to +188 mv which shows the prevalence of toxic conditions in the groundwater. Only three samples show Eh < 100 mv (Table 1) but all the samples fall in the toxic range suggesting the recent inflow of surface water. The Eh is expressed in terms of ORP (oxidation-reduction potential) that depends on the amount of dissolved oxygen present in the water and the number of other elements that function similarly to oxygen as well. When eh is low, dissolved oxygen is low as a result of which toxicity of certain metals and contaminants can be increased. In healthy waters, eh should read high between 300 and 500 millivolts. On the other hand, low Eh is expected in waters that receive sewage inputs or industrial waste. It is consistent with the present study where He is found to be < 300 mv.

**Table 1** Showing the details of physicochemical parameters of groundwater from LIA

SAMPLE NO	LATITUDE	LONGITUDE	WELL DEPTH(F T)	DESCRIPTION	Turbidity (NTU)	T(°C)	Eh (mv)	pH	TDS (mg/L)	Hardness (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	NO <sub>3</sub> (mg/L)	HCO <sub>3</sub> (mg/L)	SO <sub>4</sub> (mg/L)
LIA1	24.848384	67.211471	120	MASJID	0.08	26.3	104	7.02	570	300	145	10	56	38.88	159.57	4.9	190	300
LIA2	24.837830	67.218116	60	MASJID	1.2	26.3	99	7.06	310	250	120	12	36	38.88	124.11	1.6	160	155
LIA3	24.837049	67.232872	90	BLOCK WORKS	0.33	26.8	111	7.44	166	250	121	12	24	46.17	53.19	0.11	70	150
LIA4	24.836658	67.229452	100	BLOCK WORKS	2.02	28.9	127	6.98	870	500	130	32	96	63.18	319.14	3.535	300	321
LIA5	24.854540	67.235217	110	HOUSE	0.09	26.8	98	7.25	1105	900	160	23	180	109.35	567.36	4.005	190	445
LIA6	24.838807	67.210494	40	MASJID	8.12	27.8	110	7.06	346	300	120	24	64	34.02	35.46	2.21	240	210
LIA7	24.836853	67.225054	30	HOTEL	1.01	27.6	115	7.14	550	400	140	12	80	48.6	106.38	2.43	150	350
LIA8	24.839175	67.243618	150	HOUSE	1.33	28	165	7.12	388	350	120	13	60	48.6	70.92	4.82	140	242
LIA9	24.837202	67.256915	120	CATTLE FARM	2.43	28	177	7.03	725	700	110	7	72	126.36	177.3	24.337 <sub>5</sub>	254	422
LIA10	24.847171	67.227262	80	HOUSE	1.02	28	163	7.07	343	350	180	21	52	53.46	53.1	3.565	130	150
LIA11	24.846825	67.205152	110	MASJID	0	24.3	100	7.33	550	400	110	42	76	51.03	177.3	4.955	200	288
LIA12	24.851052	67.206885	90	MASJID	0.88	25	98	7.21	417	350	130	12	40	60.75	141.84	3.58	150	135
LIA13	24.854864	67.213400	60	RAILWAY ST	0	25	121	7.34	193	350	133	11	32	65.61	106.38	0.22	50	80
LIA14	24.841280	67.203558	100	BLOCK WORK	1.34	28	188	7.2	790	500	120	22	120	48.6	177.3	4.43	240	300
LIA15	24.848834	67.258797	110	CATTLE FARM	0	24.7	145	7.12	5650	1600	1240	31	280	218.7	3758.7 <sub>6</sub>	0.22	160	410
LIA16	24.845924	67.258658	130	CATTLE FARM	0	25.1	151	7.06	5700	1650	1420	32	260	243	3723.3	0.12	170	415

**Solute Chemistry**

Cation’s distribution varied in the order of  $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ .  $Na^+$  is the dominant cation and its concentration varies from 110 to 180 mg/L. extremely high sodium ( $> 1200$  mg/L) is reported in two samples (LIA-15 and 16) exceeding the maximum permissible limits of WHO (1997) for sodium (200 mg/L) in drinking water. These two samples were collected from cattle farms that sewage mixing with groundwater increasing the salt content (Bundschuh, Bhattacharya, and Chandrasekharam, 2005). Potassium ( $K^+$ ) concentration varied in a wide range (Range: 7-42; Mean: 20 mg/L). About half of the total samples exceeded the maximum permissible limit (20 mg/L) set by WHO (1997) for  $K^+$  in drinking water. Naturally K results from the chemical decomposition of sylvite (KCl) and silicates especially clay minerals (Santos et al., 2016). On the other hand, it can be added to groundwater through fertilizer use and the breakdown of animal or waste products (Ali and Khan, 2021; Haider et al., 2023). The occurrence of an exceeding amount of K in the groundwater is attributed to the animal waste as the samples were mostly collected from nearby cattle farming sites.

**Table 2** Statistical descriptive of physicochemical parameters of groundwater from LIA

Parameters		WHO guideline value	Minimum	Maximum	Mean
Physical	Turbidity	1-5	0.08	8.12	1.55
	pH	6.5 – 8.5	6.9	7.4	7.1
	Eh	-----	98	188	131
	Temperature	25-28	24.3	28.9	26.6
	TDS	<1000	166	5700	1363
	Hardness	< 500	250	1650	614
Chemical	$Na^+$	200	110	1420	335
	$K^+$	20	7	42	19.75
	$Ca^{+2}$	100	24	280	102
	$Mg^{+2}$	50	34	243	87.3
	$Cl^-$	250	35	3758	752
	$NO_3^-$	50	0.11	24.33	4.97
	$HCO_3^-$	350	50	300	175
$SO_4^-$	250	80	445	272	

Calcium concentration varied in a wide range (Range:24-280; Mean:102 mg/L). Normal concentration of calcium in groundwater ranges from 10 to 100 mg/L (Ali and Adnan, 2021; Haider et al., 2023). Generally, calcium concentration is within the permissible limit (100

mg/L) of WHO (1997) for drinking water but four samples show exceeding value (120-280 mg/L). The basic sources of calcium are carbonate rocks, i.e., limestone and dolomites, which are dissolved by carbonic acid in groundwater. The chemical breakdown of calcic-plagioclase feldspars and pyroxenes may be responsible for calcium in the groundwater (Ganyaglo et al. 2010). Calcium can also originate as lime from textile industries which are frequently occurring in LIA. Likewise, magnesium also varied in a wide range (Range:34-243; Mean: 87 mg/L) where about half of the total samples exceeded the WHO permissible guideline value (50 mg/L) for drinking purposes. Magnesium in groundwater may be derived from the decomposition of dolomite, ferromagnesian minerals like olivine, pyroxene, amphiboles, and dark colored micas (Ali and Khan, 2021; Haider et al., 2023). The reaction involving the solution of magnesium is influenced by the amount of CO<sub>2</sub> in the groundwater in dissolved condition.

### ***Major Anions***

Chloride (Cl<sup>-</sup>) concentration spans within a wide range (Range:35-3758 mg/L; Mean:752 mg/L). Although the mean value exceeded the WHO permissible limit (250 mg/L) most of the samples are within a safe limit. Normal distribution is disturbed due to the elevated concentration in four samples (Table 1). Chloride in groundwater is attributed to the presence of chlorides from rocks, evaporates, seawater intrusion, or contamination by industrial waste or domestic sewage. The high value of chloride ions is an indication of high salinity in the groundwater of the study area which is associated with the mixing of sewage and animal waste with groundwater.

Sulfate content also varied in a wide range of 80-445 mg/L with a mean of 272 mg/L where about 56% of samples exceeded the WHO guideline value (250 mg/L) for drinking water. Sulfate content in groundwater is attributed to the oxidation of sulphur-bearing minerals and organic matter. Sedimentary rocks, such as organic shale, may play a key role in this connection by the oxidation of marcasite and pyrite (Matthess, 1982). The high sulfate content of groundwater is also associated with industrial input (Mostafa et al., 2017). The concentrations of bicarbonate in the groundwater samples range from 50 to 300 mg/L with a mean of 174 mg/L. Interestingly bicarbonate content is found to be within the permissible



limit (350 mg/L) set by WHO for drinking purposes. Naturally, bicarbonate ions may result from the weathering of silicate minerals (Gastmans et al., 2010). Similarly, other possible sources of bicarbonate include the occurrence of organic matter in the aquifer that is oxidized to produce carbon dioxide, which promotes the dissolution of minerals (Khashoggi and El Maghraby, 2013). On the other hand, fossil carbon of the calcite and dolomite in the aquifer is expected to contribute half of the bicarbonate ions. This weathering enriches the groundwater in calcium, magnesium, and bicarbonate ions. The Nitrate content ranges from 0.11 to 24.3 mg/L with a mean of 4.97 mg/L. normal distribution value of < 5 mg/L in the groundwater of the study area indicates that nitrate is relatively low in the groundwater of the study area which is consistent with the WHO permissible limit (50 mg/L) for drinking purposes.

### **Conclusion**

The present study reveals that parameters like pH and eh of groundwater are within the corresponding permissible limits. According to WHO (500 mg/L), about 56% of samples are objectionable while as per Pakistani guidelines (1000 mg/L), about 81% of samples are safe in terms of TDS content. Among the ions, Na<sup>+</sup> and Cl<sup>-</sup> are the dominant ones whereas K and NO<sub>3</sub> are the minor constituents. Concentrations of calcium, magnesium, and sodium in all the samples are within the permissible limit. Anthropogenic activities are influencing the groundwater chemistry by disturbing the ionic balance. It is concluded that the groundwater of the study area is generally fit for drinking purposes and only two sites are found highly polluted. Further studies are needed to understand the seasonal variation in geochemical parameters of groundwater in the study area.

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This paper DOI: [10.5281/zenodo.10791173](https://doi.org/10.5281/zenodo.10791173)

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