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IMPACT OF COAL ON GROUND WATER CHEMISTRY IN LAKHRA (SINDH)

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Abstract

Lakhra coalfield is the second largest coalfield of Pakistan covering an area of 680 km^2. Water samples were collected from six shallow dug wells in the region and analyzed from environmental geochemistry point of view. Results show that the Electrical Conductivity and Total Dissolved Solids are high i.e. EC = 800-1210µS/cm and TDS = 568-847 mg/l in all the samples and SO_4 is also higher at some places. Heavy metals were analyzed by atomic absorption and it has been observed that Fe is also high (844 µg/l), while Ni, Cu, Pb, and Cd are within the limit set by US-EPA.
Results show that the underground coal is contaminating groundwater and has adverse affected on the health of population using this dug well water.

Keyword: Coal, ground water, chemistry

Introduction

Coal is known to have been deposited in shallow marine and fluviatile (lake) environment. These lakes have also received lithogenic fluxes from mineralized continental shield enriching the coal with heavy metals like Pb, Zn, Cu, Cd, Co, Ni, and Mn. In Pakistan 82% of the mined coal is used in brick kiln industry, while 1.3% is being consumed for power generation. Among the various sources of pollution, coal is the major source producing 41% pollution in the environment.

Lakhra coalfield was discovered in 1853, but active coal mining in this area started from 1959, and has affected the environment of the area. One of the effects of coal is on the groundwater that varies according to location, topography and depth of the natural water table.

The water available for our use is contaminated mainly by three processes as a result of which chemical composition of the groundwater may change drastically. The natural processes such as leaching and evaporation can concentrate salts in the water. Chlorides, sulphates, nitrates, florides and iron may commonly be derived from localized deposits and their concentration in groundwater may therefore exceed the limits set by The United States Environmental Protection Agency's (US-EPA). The second source of contamination of groundwater is the man's waste disposal practice which is very unscientific and unhygienic. The third category of contaminating processes includes accidental spills and leaks, agricultural activity, mining, atmospheric contaminants and acid rain, improperly planned groundwater development schemes and improper well construction and maintenance.

At Lakhra coal field there is scarcity of natural water. A few shallow dug wells exist i. e., two historical Lialian wells named after the Lialiani Baloch tribe, near Habib's rest house at Habibullah coal mining area, two dug wells in Kandeer village and two in Yaro-a-jo khuh villages (Fig. 1). Water from these dug wells is used for domestic and agriculture purposes.

Lakhra coal field is the second largest coal field of Pakistan located 225 km northeast of Karachi in Dadu district of Sindh province, covering an area of 680 km^2. It lies between latitudes 25° 30' E and 25°45' N and longitudes 68° 0' and 68° 15' E (Figure 1). It

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is covered by Survey of Pakistan topographic sheet Nos. 40 C/1 and 40C/2. Khanot is the nearest railway station connected with Lakhra by a 19 km long mettled road upto Indus Coal mines. The Lakhra coalfield is surrounded by a number of villages like Kander, Sher Wala, Yari wala, Issa wala, Murid, Bund Virah, Bahram, Bandi wala, and labour colony at Lakhra.

Geology of the area

The Lakhra coalfield area is underlain by sedimentary rocks. The rocks exposed in the area belong to Ranikot group (Paleocene), Sonhari member (Early Eocene), Laki limestone (Early Eocene) and Manchar Formation (Pliocene). These units are composed of shallow marine and fluviatile sediments.

The oldest exposed rocks in the area belong to the Bara Formation of Early Paleocene. It is conformably underlain by Lakhra Formation of Middle to Late Paleocene age and unconformably overlain by the Laki Formation of Early Eocene age. The unconformity between the Lakhra and Laki formations is marked by a 38 to 63 cm thick laterite bed. Rocks of Middle Eocene to Miocene (intervening the Laki limestone and the Manchar Formation) are absent in the area, hence the Manchar Formation of Pliocene age directly overlies Laki Formation. A very thin cover of alluvium rests over the Manchar Formation. The thickness of the minable coal seam in the area varies between 1.5 to 3.35 meters (Khan *et al.,* 1988).

Siph Nala is the main tributary which flows in monsoon season across the crest of the Lakhra anticline. Lakhra Nala (a rainy stream) flows from northeast to southwest in monsoon season.

Methodology

Samples of water were collected from the six dug wells situated in the study area i.e. (Fig.1). The bottles used for storing the collected water samples were washed/treated with 5% HCl or HNO_3 and then rinsed with deionized water. During sampling two water samples were collected in the clean polythene bottles. One sample was analyzed for the determination of alkalinity, temperature, pH, electrical conductivity, TDS and sulphates on the site. The other was acidified with drops of nitric acid (HNO_3) to a pH below 5.0 for minimizing precipitation and absorption on walls of the bottles. These polythene bottles containing dug well water were capped tightly for heavy metal analyses in geochemistry lab of NCE in Geology, at Pashawar.

COLE-PAMER'S (Model 148-55) conductivity meter was used for the determination of electrical conductivity of water samples. The instrument was first calibrated with a standard KCl solution having conductivity value of 1.45 mS/cm at 25°C. As the temperature coefficient of most waters is only approximately the same as that of standard KCl solution, the electrical conductivity of water samples was determined relative to KCl solution. The alkalinity of water was determined using a special device of Hach Digital Titrator having concentrated titrants in cartridges. Sulfate (SO_4) was determined by Hach DR/2000 spectrometer (a microprocessor-controlled single beam instrument) in the field by "turbidimetric method".

Pye Unicam Flame Atomic Absorption and Electrothermal (graphite furnace) Atomic absorption techniques were used for the detection of trace elements in water samples. The flame atomic absorption technique was used for the determination of Fe in the water samples and electrothermal atomic absorption (Perkin Elmer 3300 model) equipped with HG-600 graphite furnace and

As-60 Auto sampler was used for the determination of Cu, Pb, Ni, Fe and Cd in water samples by inserting hollow cathode lamps of wave length 248.3nm for Fe, 232nm for Ni, 324.5nm for Cu, 283.3.5nm for Pb and 228.8nm for Cd.

Results and Discussions

The geochemical analysis of shallow dug well water obtained during the current investigation is given in Table 1. Generally the quality of dug well water or groundwater depends upon the local geology and mining activity in the area that contaminates groundwater. Following is the description of data analyzed:

Table 1. Water Quality of well water at Lakhra

Sample No.	Location/Name of the dug well	E C µS/cm	T D S mg/l	HCO_3 mg/l	SO_4 mg/l	Fe µg/l	Ni µg/l	Cu µg/l	Pb µg/l	Cd µg/l
US-EPA		300	500	500	250	300	1000	1000	50	10
W1	Lialian-I	910	637	305	52.5	6	0	10	4	1.9
W2	Lialian-II	860	595	115	300	223	7	70	47	2.4
W3	Kandeer-I	830	581	70	40	53	4	68	20	00
W4	Kandeer-II	800	560	202	42.5	45	5	11	00	1.3
W5	Yaro's well-I	1010	707	85	352	844	5	89	24	0.1
W6	Yaro's well-II	1210	847	360	125	0.28	5	79	38	0

In the study area among the six shallow dug wells, it is seen that the measured values of conductivity of the water of these wells range from 800 to 1210 µS/cm. The Lialian-I, Lialian-II, Kandeer-I, Kandeer-II, Yaro´s well-I and Yaro´s well-II are the dug well water samples that have the conductivity values of 910, 860, 830, 800, 1010 and 1210µS/cm respectively which is manifold higher than the permissible limit of 300 given by US-EPA (1979, Fig. 2). Such high values indicate higher content of dissolved solids

The value of Total Dissolved Solids (TDS) of Lakhra dug wells have been calculated from EC values both shown in Tab 1. These values range from 560 to 847mg/l. however, the recommended upper limit of TDS by US-EPA (1979) is 500 mg/l, considering this safety limit, the Lakhra dug well water can not be recommended at least for drinking purpose with the currently obtained values of TDS.

The TDS values of Lakhra ground water are compared with HCO_3, SO_4, and heavy metals (Figure 3). All the plots are showing scattering of data. However, the data in these plots suggest that HCO_3 and SO_4 show positive correlation with TDS. This suggests that the anions (i. e. HCO_3 & SO_4) and other cation bearing phases (except Cd) have been dissolved in water as TDS (Fig. 3).

The bicarbonates of the water of dug wells from Lakhra shown in Fig. 2 indicate that sample collected from Yaro's well-II has the

highest concentration (360 mg/l) while that collected from Kandeer well-I have the lowest (70 mg/l). These observed values are within the permissible limit of 500 mg/l set by US-EPA (1979).

The sulphates of dug well water in Lakhra show that with the exception of two wells i.e., Yaro's well-I (352 mg/l) and Lilian well-II (300 mg/l) the rest of the water samples are below the US-EPA limit (1979), Table.1; Fig. 2.

Comparing with the International Standards (US-EPA) it is interesting to note that except for iron (Fe) in Yaro's well-I all heavy metal content are below the US-EPA maximum contaminating limit (MCL), in all dug wells (Figure 2). Pb is though below the US-EPA limit yet sufficiently high in Lialian-II and Yaro's-II, all others are within standard permissible limit. These observations indicate that the underground water in these wells have received contaminants either directly through air or underground seepage. The lower level of metals in certain wells may be related to the fact that these metals settle down easily and may not be collected during sampling. On the other hand samples showing relatively higher values of heavy metals (e.g. Pb in Lialian-II and Yaro's-II well (Fig. 2) were collected in turbulent conditions.

The higher values of iron (Fe) in Yaro's-I dug well (Fig. 2) is most probably related to the occurrence of this well in the vicinity of coal seam and higher leaching capability of iron from the pyrite bearing host rocks (Tab 2, Simon et al., 1988). As the Lakhra coal itself posses higher amount of iron (Khan *et al.,* 1988).

The higher values of electrical conductivity, Total Dissolve Solids, sulfates and heavy metals (Fe and Pb) in some of the wells (Table 1 and Fig. 2) indicate that water of these wells is not suitable for drinking and agriculture purposes. Due to the above contamination following diseases are expected to affect the general population of the area.

Elementry sulphur may slightly irritate but the noxious effects associated with sulphur are usually due to its oxide or hydride. Sulphuric acid attacks the enamel of the teeth, while sulphate is poorly absorbed by the human intestine; it slowly penetrates the cellular membrane of mammals and is rapidly eliminated through kidneys (Rosum, 1961). The excess of Total Dissolve Solids in water causes unpalatable mineral taste (Anon, 1976). High concentration of TDS may reduce solubility of gases (like oxygen), which in turn reduces the utility of water for drinking and irrigational purposes, as many salts like bicarbonate, sulphates and nitrates get dissolved in water. Pollution zone can be established by measuring the electrical conductivity, though conductivity is a nonspecific parameter but it is related to the concentration of total dissolved solids and major ions (Kumar and Verma, 1986). The high values of iron in water may cause diseases like hemosideroses, liver damage and diabetes (Rosum, 1961). Severe gastrointestinal disturbances and anemia, neuromuscular dysfunction and encephalopathy are the diseases caused by prolonged absorption of lead. Lead in water may also cause weakness, weight loss, hypertension, lassitude and insomnia (NIOSH, 1972).

Table 2. Pyritic Sulphur content in coal (on as received basis), mined around dug wells at Lakhra (Simon *et al.*, 1988).

Name of the coalmine	Pyritic Sulphur
Habib/Gul mine -II	3.05%
Habib/Mumtaz coalmine-44	0.85%
Habib/Taufique coalmine-22	4.80%
Habib/Hamza coalmine-37	1.86%
Habib/Gul coalmine-III	2.90%
Sindh coalmine-5	1.99%
Amine Brother coalmine-5	1.88%
Amin Brothers coalmine-5A	3.05%

Conclusion

The data from dug well water of Lakhra coal field indicate that electrical conductivity is considerably high in relation to the recommended value of US-EPA. These high values are related to high TDS, particularly in Yaro's well No. II. This interpretation is supported by the high SO_4 and HCO_3 in certain dug wells of the area. These data interpretation therefore indicate the following:

The heavy metals from Lakhra coal mines so far noticed in the air of the area (Siddiqui, 1999), have not reached the underground water system.

High electrical conductivity (EC) or total dissolved solids (TDS) and high SO_4 and Fe in certain well water have probably their source in surrounding rocks, including limestone and shale.

It may have taken place due to shallow depth of wells. These wells could have been affected by contamination from coal. However, the coal at greater depth below the limestone, sandstone and shale certainly add heavy metals, sulfur and other contaminants to deep wells. This is supported by the high Pb contents of Lilian-I well which indicate a value (47μg/l) close to the recommended value of US-EPA (50 μg/l).

On the basis of the study performed and the above discussion the following mitigation procedures are recommended for the safe drinking and agricultural water supply: Wells around Lakhra Coalfield be covered to prevent falling of fine coal dust appearing as suspended particulate matter.

Walls of wells should be bricked in order to avoid incoming pollutants from the surrounding coalmines.

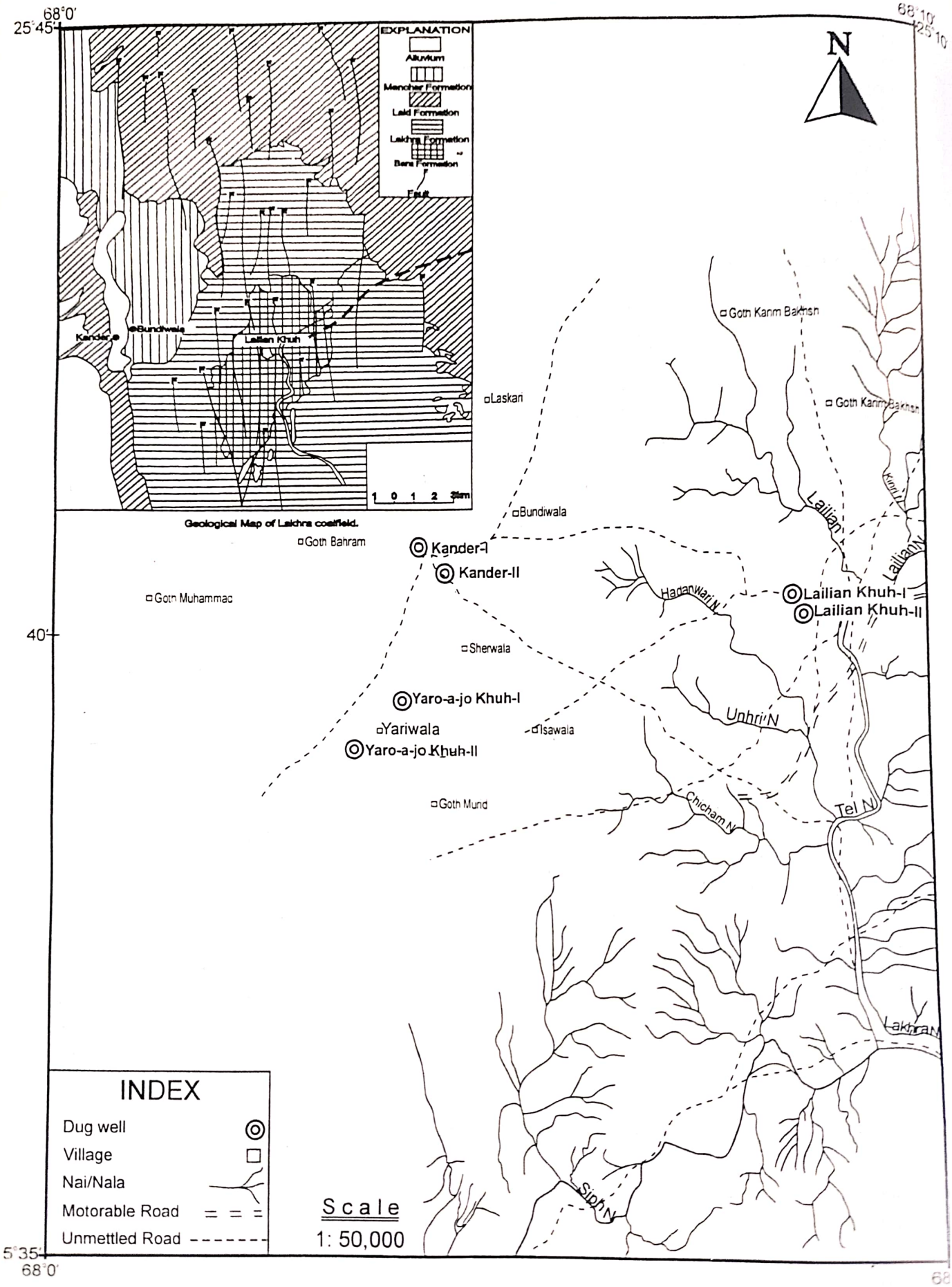


Fig. 1. Showing location and geology of dug wells in Lakhra coalfield

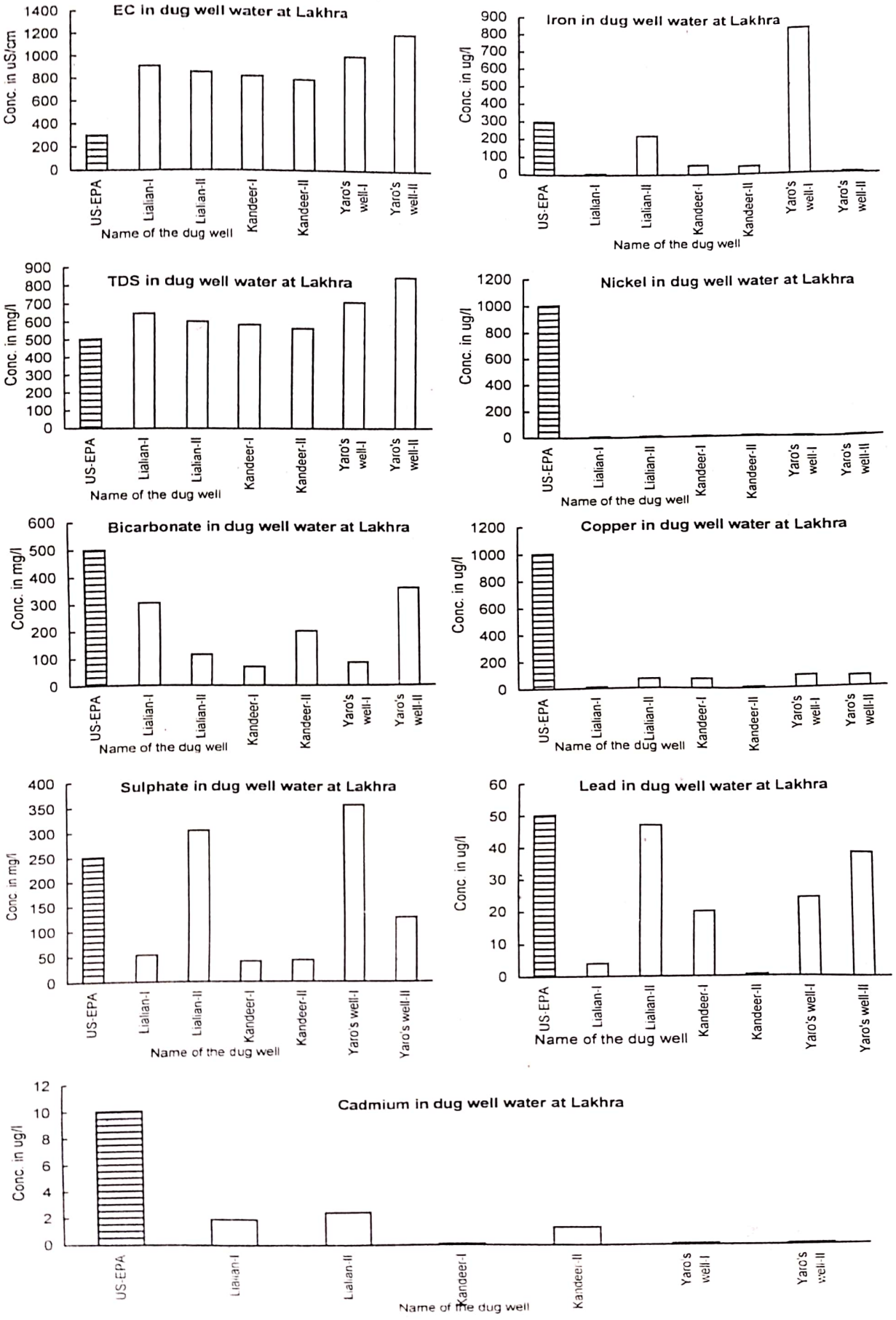
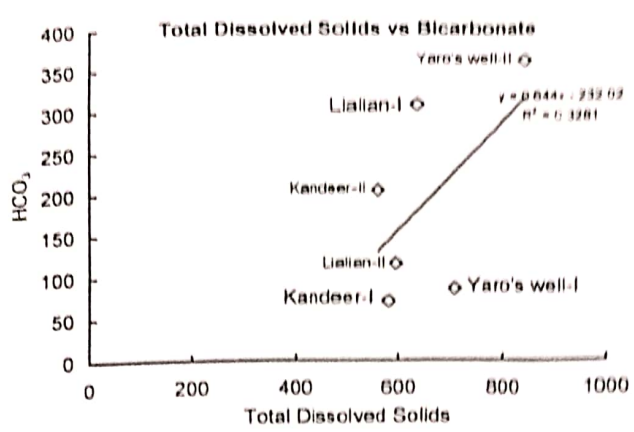
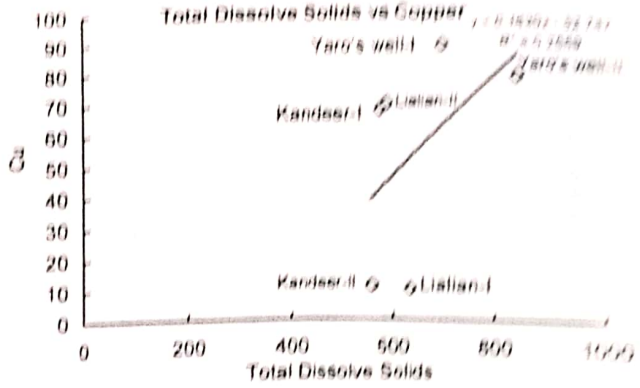
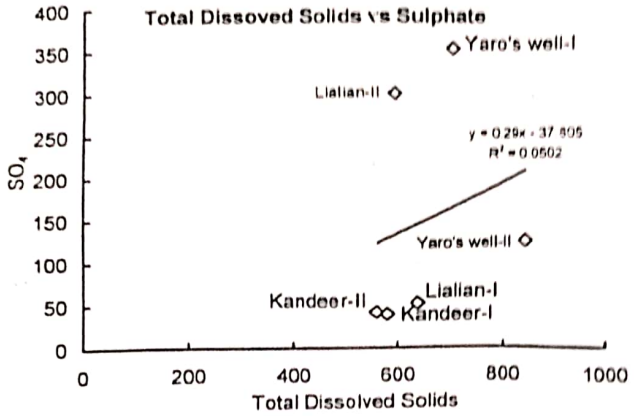
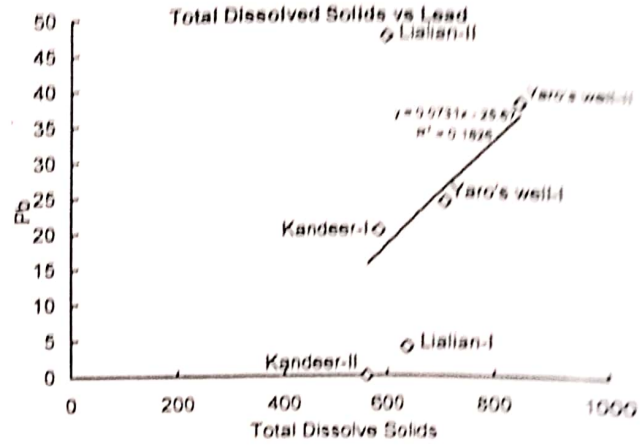


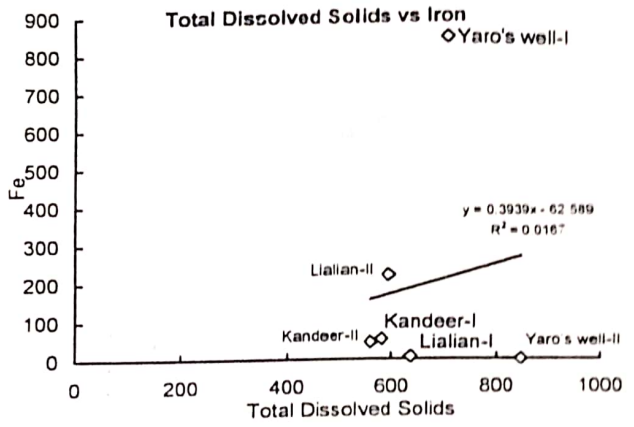
Fig. 2. Comparision of dugwell water sample chemistry of Lakhra with USEPA(19/9)

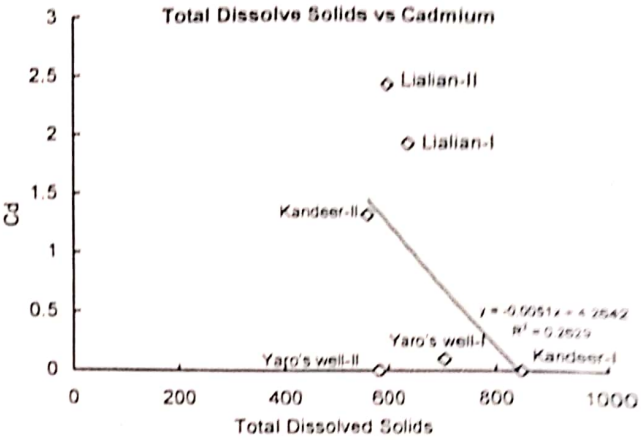












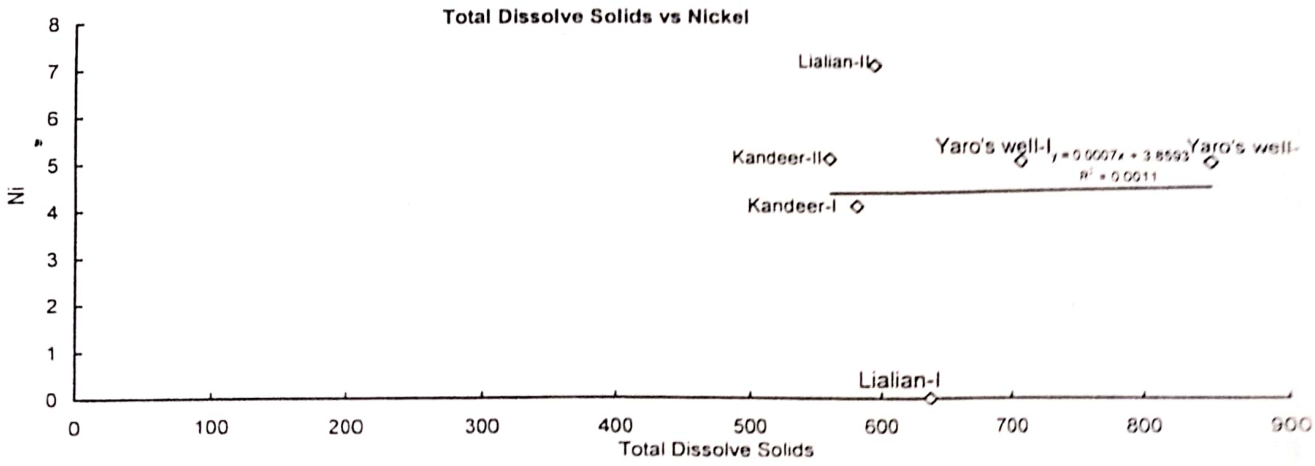


Figure 3. Comparision of TDS with HCO_3, SO_4, and Heavy metals

References

Khan, R. A., S. A. Khan, Z. A. Khan, K. R. Khan and M. J. Qureshi, (1988) Preliminary studies of sub surface extension of coal deposits along flanks of Lakhra anticline in the Lakhra quardrangle, Sindh. Pakistan Geol. Surv. Inf. Release, 369.

Anon, (1976) Quality and criteria of water. United States Environmental Protection Agency, Washington, D. C. 20460.

Kumar, A. and V. Manish, (1986) Environmental pollution and health hazards in India, Ashish Publishing House, New Delhi. p 479.

NIOSH, (1972) National Institute of Occupational Safety and Health. DHEW, US Govt. Printing Press, Washington DC. Pub. 73, 27020.

Rosum, J. R., and Villarruz, P. (1961) Suggested methods for turbidimetric determination of sulphate in water. Jr. Am. Water works Assoc. **55**: p 873.

Siddiqui I., (1999) Heavy metal studies in Lakhra coal, M. Phil thesis, University of Peshawar (unpubl.).

Simon, F.O. and Ahmed, N. (1986) Chemical, Physical, Mineralogical and Petrological characterization of Coal and their Economic and Environmental Significance, Coal Development Potentials in Pakistan , Proceedings of The First Pakistan National Coal Conference, Karachi, pp.190-192,197-198.

US-Environmental Protection Agency (1978) Federal Register, No. 266.

US-Environmental Protection Agency (1979) Methods for Chemical analysis of water and waste. EPA - 600/4 – 79 - 020. National Environmental Research Centre, Cincinnati, Ohio.

US-Environmental Protection Agency (1991) Hand Book of Groundwater. Methodology. Vol. II. Washington D. C. p 980.