Ecological Risk Assessment of Ground Water Quality of Two Industrial Zones of Karachi, Pakistan

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Authors’ contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The purpose of this research study is to determine the quality of groundwater in and around the two industrial zones of Karachi such as SITE (Sindh industrial and trading estate) and KITE (Korangi industrial and trading estate) by using EIRA (Environmental Impact and Risk Assessment) method. The environmental researchers find this method easy enough to use for risk assessment and environmental impact. It has estimated the risk and impact associated with measured concentrations of ecological indicators for environmental components examined as a representative in assessment process. There are several mathematical steps being applied in this method. Out of 32 sampling points (18 each) of groundwater analysis, six ecological indicators examined representative for evaluative purpose were assessed. The results of the study indicated that the groundwater quality of both the industrial zones had high pollutant and contaminated due to industrial activities. Therefore, it is certain to implement the plan for remediation to uplift the quality of groundwater and overcome the pollution.

Keywords: Groundwater; Karachi City; industrial zones; effluent; EIRA.
1. INTRODUCTION

Rapidly growing demand for water and shrinking freshwater resources, especially, in developing countries like Pakistan, the application of marginal quality groundwater has posed a serious threat to environmental management.

The groundwater state is usually more stable than surface water and is more preserved against the risk-factors involved such as water contamination than the surface water. However, there are certainly many risks in terms of its quantity and quality facing underground water resources as a result of adverse human activities, for instance, release of chemical wastes from industrial sectors etc. [1-4].

Numbers of reports of groundwater contamination due to industrial effluent penetrations have been reported Worldwide [5-9].

The industrial effluents are discharged indiscriminately in large number of mega cities of developing countries into the soil and water bodies being indifferent to aftermath adverse impact in future; Karachi is not exceptional to this [10].

One of the most populous and largest city, situated in the south of Pakistan on Arabian Sea’s coast is Karachi having 24°51'N 67°02'E geographical view. As of 2013, it has an estimated population of over 23.5 million people, having an area of 3,527 km² approx, resulting in a density of 6000 people per square kilometer. Population within city limit it is the 3rd largest city in the World [11-13].

Karachi is the financial hub and provincial capital of Pakistan generating more than 70% revenue and housing more than 70% of the diverse industries. Multinationals also prefer to locate their industries in Karachi for its deep water seaport and cheap, economical labor in abundance.

Both regulated and unregulated industrial sectors are operating in the city. Most prominently, the largest industrial zones include Korangi Industrial Trading Estate (KITE) and Sindh Industrial Trading Estate (SITE) which have attracted investment from across the country and employed diversified labor force flocked from every corner of Pakistan.

Fig. 1.1. Location map and sampling points
Contamination scenario, due to metal ion pollution of Karachi, is quoted as a problem by the earlier researchers [14-16]. However, a major information gap is noted with respect to ecological risk assessment of groundwater of the city. Ecological risk assessment is considered as a technique to govern ecological issues [17-23]. It is the technique that assays the likelihood that adverse ecological effects are taking place, or may occur, due to exposure to one or more stressor. It has been used broadly to interface environmental stressors and their ecological consequences. Risk assessment employed to ecological problem in modernistic [17,24-26]. Risk assessment could be a useful technique and should be used largely in solving ecological issues.

The outcome of this research study is to furnish an overview of the dormant risks of the shallow groundwater resources of both the industrial zones i.e. SITE and KITE. On the basis of this case study, it is envisaged to create a model of potential risks for groundwater and water supply at this aquifer.

1.1 Location Map

Fig. 1.1 shows the location map of the study areas.

2. MATERIALS AND METHODS

2.1 Sampling

All glassware used was NPLA grade and were appropriate certified. Eighteen (18) representative samples of groundwater of each industrial estate were collected during the examining period in sterile 1500 ml polyethylene bottles, the water quality has been analyzed for transition metals such as (Fe, Zn, Cu, Pb, Cr and Ni). In trace metal analysis 50 ml sample was taken and added 5 ml HNO₃ for digestion. The digested samples were filtered and de-ionized water was used to make the volume up to 50 ml after filtration. Then samples were analyzed on Atomic Absorption Spectrophotometer by using appropriate lamp. Standard solutions of known strength were used for calibrating the instrument first for each heavy metal [27].

Process of dilution was necessary in certain cases where concentration of determinants was exceeded to recommend limit for the method employed for the determination. An Accuracy check for chief ions was accomplished for a considerable interpretation, accuracy and precision of water quality parameters.

2.2 Environmental Impact and Risk Assessment

The method employed herein is an integrated method, which is a combination of significant scale matrix and global pollution index [19,28-30]. The calculation of EIRA (Environmental Impact and Risk Assessment) and significant scale matrix based on method proposed by Robu [28], considering groundwater only in the assessment.

The IM (Impact on environmental component) is the ratio between IU (significant unit) and Q (quality of environmental component), shown in equation 1.

$$ IM = IU/Q $$

(1)

The Q (quality of environmental component) can be calculated as equation 2.

$$ Q = MAC/MC $$

(2)

Here;

- **MAC** = Permissible limit of quality indicator
- **MC** = Measured concentration of quality indicator

If Q value is zero, it shows very poor environmental quality (High contamination); if Q value is equal and higher than 1, then the quality of environmental component is very good [31].

**IM**ₐₐ (Impact on groundwater) can be calculated as

$$ IM_{gw} = \sum I_{(gw)i}/n $$

(3)

Here;

- **IM**ₐₐ = Environmental impact on groundwater due to ecological indicator (i)
- **I**ₐₐᵢ = Ecological indicators (e.g Fe, Co etc)
- **n** = Total number of ecological indicator

$$ IM_{gw} = IU_{gw}Q_{(gw)i} $$

(4)

Here;

- **Q**ₐₐᵢ = Quality of groundwater due to quality indicator i
- **IU**ₐₐ = Significant units obtained by groundwater
The environmental risks are calculated as
\[ RM = IM \cdot P \]  
(5)
Here;
\[ P = \text{Probability of impact.} \]
The probability was calculated by using the same matrix proposed by Robu [28].

3. RESULTS AND DISCUSSION
The purpose of this research work is to establish groundwater quality of study area by using EIRA technique. Groundwater from 36 sampling point was analyzed for six heavy metals during study period and data obtained, presented in Tables 1.2 and 1.4 and graphically showed in Figs. 1.2 and 1.3, were subjected to EIRA technique.

In SITE the Environmental Impact (IM) values ranges from 161.43 to 7198.2 and Environmental Risk (RM) values ranges from 161.08 to 7176.62 (Tables 1.2 and 1.3), while in KITE the IM values ranges from 315.09 to 1125.8 and RM values ranges from 314.15 to 1122.4 (Tables 1.4 and 1.5). High values for IM and RM underlay the presence of pollutants in environment in very high concentration, because impact directly depends upon the measured concentration of pollutants. In this connection, The higher values of IM and RM of SITE show that the groundwater of this industrial estate is moderately polluted as compare to KITE in term of ecological indicator i.e heavy metal. The higher values for impact and risk induced in groundwater from both study areas showed the industrial activity from these areas was working at its maximum capacity.

### Table 1.1. Impact and risk scale [32]

| Range            | Impact                           | Risk                  | Action                          |
|------------------|----------------------------------|-----------------------|---------------------------------|
| 100-500          | Influence of industrial activities| Moderate risk         | Monitoring and prevention measures are required |
| 500-1000         | Influence of industrial activities, life forms are in danger | Major risk            | Remediation and control are required |
| Higher than 1000 | Highly polluted environment      | High risk             | All activities must be stopped  |

### Table 1.2. Risk assessment of S.I.T.E. industrial and trading estate

| Sample stations | Fe  | Zn  | Cu  | Pb  | Cr  | Ni  | Mean IM | Mean RM |
|-----------------|-----|-----|-----|-----|-----|-----|---------|---------|
| GW₁             | 0.089 | 0.098 | 0.01 | 0.004 | 0.01 | 0.002 | 171.79  | 171.27  |
| GW₂             | 0.332 | 0.854 | 0.019 | 0.005 | 0.014 | 0.008 | 429.42  | 428.13  |
| GW₃             | 0.889 | 2.079 | 0.024 | 0.005 | 0.016 | 0.013 | 854.07  | 851.51  |
| GW₄             | 0.129 | 0.476 | 0.035 | 0.001 | 0.009 | 0.009 | 221.9   | 219.57  |
| GW₅             | 11.935 | 1.364 | 0.018 | 0.024 | 0.014 | 0.004 | 7198.2  | 7176.62 |
| GW₆             | 0.078 | 0.312 | 0.016 | 0.002 | 0.010 | 0.004 | 161.43  | 161.08  |
| GW₇             | 0.049 | 0.292 | 0.018 | 0.001 | 0.079 | 0.002 | 325.8   | 324.8   |
| GW₈             | 0.080 | 0.033 | 0.009 | 0.001 | 0.191 | 0.003 | 722.27  | 720.11  |
| GW₉             | 0.032 | 0.048 | 0.001 | 0.001 | 0.017 | 0.003 | 710.64  | 708.49  |
| GW₁₀            | 0.058 | 0.081 | 0.008 | 0.004 | 0.178 | 0.004 | 727.9   | 725.75  |
| GW₁₁            | 0.292 | 2.193 | 0.02 | 0.034 | 0.063 | 0.009 | 1133.58 | 1130.13 |
| GW₁₂            | 0.202 | 0.045 | 0.007 | 0.019 | 0.016 | 0.007 | 541.92  | 540.28  |
| GW₁₃            | 0.310 | 0.529 | 0.034 | 0.053 | 0.014 | 0.014 | 1245.2  | 1241.48 |
| GW₁₄            | 4.334 | 1.292 | 0.044 | 0.22 | 0.008 | 0.007 | 6257.5  | 6238.73 |
| GW₁₅            | 1.76  | 0.081 | 0.022 | 0.086 | 0.008 | 0.007 | 2499.68 | 2492.18 |
| GW₁₆            | 0.286 | 0.174 | 0.031 | 0.044 | 0.018 | 0.007 | 1020    | 1017    |
| GW₁₇            | 0.182 | 4.626 | 0.041 | 0.30 | 0.007 | 0.008 | 5482.88 | 5466.5  |
| GW₁₈            | 0.346 | 0.065 | 0.020 | 0.33 | 0.008 | 0.02  | 5834.13 | 5816.62 |
*WHO (MAC)* 0.3 3 2 0.01 0.05 0.02
Sample No. 5, 14&15 having high Fe Concentration was not including in the graph, similarly sampling point 3,11& 17 having high concentration for Zn. Therefore, these points were excluded from the graph to make the graph presentable.

Table 1.3. Calculation of IM and RM for groundwater sample GW1 of SITE

| Parameters | MAC | Cm   | Q   | IM   | RM   | Mean IM | Mean RM |
|------------|-----|------|-----|------|------|---------|---------|
| Fe         | 0.3 | 0.089| 3.37| 295.69| 294.8| 171.79  | 171.27  |
| Zn         | 3   | 0.098| 20.61| 32.55| 32.45|         |         |
| Cu         | 2   | 0.01 | 200 | 4.98 | 4.96 | 4.98    | 4.96    |
| Pb         | 0.01| 0.004| 2.5 | 398.59| 397.39| 171.79  | 171.27  |
| Cr         | 0.05| 0.01 | 5   | 199.29| 198.69|         |         |
| Ni         | 0.02| 0.002| 10  | 99.65 | 99.35|         |         |
Table 1.4. Risk assessment of Korangi industrial and trading estate

| Sample stations | Fe  | Zn  | Cu  | Pb  | Cr  | Ni  | Mean IM | Mean RM |
|-----------------|-----|-----|-----|-----|-----|-----|---------|---------|
| GW1             | 0.199 | 0.492 | 0.073 | 0.009 | 0.009 | 0.007 | 380.9  | 379.8  |
| GW2             | 0.320 | 0.628 | 0.019 | 0.01 | 0.011 | 0.005 | 446.29  | 444.95  |
| GW3             | 0.187 | 0.407 | 0.016 | 0.026 | 0.011 | 0.007 | 652.7  | 650.8  |
| GW4             | 0.196 | 0.495 | 0.021 | 0.008 | 0.015 | 0.008 | 383.47  | 382.33  |
| GW5             | 0.562 | 0.392 | 0.131 | 0.033 | 0.046 | 0.011 | 1125.8 | 1122.4 |
| GW6             | 0.631 | 1.285 | 0.0006 | 0.008 | 0.011 | 0.013 | 698.2  | 696.1  |
| GW7             | 0.246 | 0.399 | 0.015 | 0.008 | 0.008 | 0.007 | 377.14 | 376  |
| GW8             | 0.77 | 1.023 | 0.141 | 0.026 | 0.007 | 0.006 | 989.24  | 996.8  |
| GW9             | 0.165 | 0.473 | 0.019 | 0.008 | 0.004 | 0.006 | 315.09 | 314.15 |
| GW10            | 0.253 | 0.561 | 0.018 | 0.027 | 0.006 | 0.007 | 699.5  | 697.41 |
| GW11            | 0.209 | 0.396 | 0.035 | 0.008 | 0.004 | 0.006 | 336.54  | 325.03  |
| GW12            | 0.286 | 1.672 | 0.037 | 0.009 | 0.006 | 0.004 | 456.6  | 455.2  |
| GW13            | 0.253 | 1.617 | 0.023 | 0.015 | 0.007 | 0.008 | 570.5  | 568.8  |
| GW14            | 0.358 | 0.385 | 0.032 | 0.007 | 0.004 | 0.002 | 368.35  | 367.24  |
| GW15            | 0.361 | 0.583 | 0.038 | 0.008 | 0.005 | 0.004 | 417.8  | 416.6  |
| GW16            | 0.433 | 0.506 | 0.031 | 0.007 | 0.004 | 0.003 | 424.7  | 423.46  |
| GW17            | 0.308 | 0.638 | 0.043 | 0.008 | 0.006 | 0.003 | 387  | 385.9  |
| GW18            | 0.647 | 0.546 | 0.013 | 0.007 | 0.007 | 0.004 | 562  | 560  |

*WHO (MAC)i

| Parameters | MAC | Cm | Q | IM | RM | Mean IM | Mean RM |
|------------|-----|----|---|----|----|---------|---------|
| Fe         | 0.3 | 0.199 | 1.508 | 660.79 | 658.81 |
| Zn         | 3   | 0.492 | 6.098 | 163.41 | 162.92 |
| Cu         | 2   | 0.073 | 27.397 | 36.26 | 36.37 |
| Pb         | 0.01 | 0.009 | 1.111 | 896.92 | 894.23 |
| Cr         | 0.05 | 0.009 | 5.555 | 179.38 | 178.84 |
| Ni         | 0.02 | 0.007 | 2.857 | 348.78 | 347.73 |

In addition, six heavy metals namely; Fe, Zn, Pb, Cu, Cr and Ni in ground water samples from shallow aquifer in and around Industrial areas were analysed and found to have anomalously high concentration of Fe 1.187 mg/l (0.032-11.93), Zn 0.798 mg/l (0.029-4.626), Cu 0.02 mg/l (0.001-0.044), Pb 0.063 mg/l (0.001-0.33), Cr 0.037 mg/l (0.007-0.191), Ni 0.007 (0.002-0.02) in SITE and Fe 0.354 mg/l (0.165-0.77), Zn 0.694 mg/l (0.385-1.672), Cu 0.039 mg/l (0.0006-0.141), Pb 0.0129 mg/l (0.007-0.033), Cr 0.009 mg/l (0.004-0.046), Ni 0.006 (0.002-0.013) in KITE as compare to the reported by Alvi, et al., 2006 and Mahmood, et al., 1998. The majority samples collected from the SITE area showed higher concentration of Fe, Pb and Cr than permissible limit (Threshold value of WHO), whereas the concentration of Fe and Pb were found significantly higher than WHO permissible limit in KITE area, probable due to:

- The concentration of Fe is particularly high in both the industrial estates. May be due to geological origin as well as number of industries such as steel industry, rusting of iron scraps and corrosion of iron containing metals are responsible for the same.
- The higher value of Pb may be attributed as fuel additive and also present in coal which is used as fuel in industries.
- Significant higher value of Cr is found in the samples which were near to the leather tanneries.

It can be accomplished with the help of experimental result that the ground water of the study areas is moderately polluted due to the presence of heavy metals.

4. CONCLUSION

The data obtained from both the study areas were subjected EIRA technique. According to experimental result the ground water of SITE moderately polluted as compared to heavy
metals observed in KITE, which acts as ecological indicators. These ecological indicators may cause disastrous effects upon public health and environment if consumed directly without any treatment and recommended that possible solution for remedy is combined effluent treatment plant. It is further concluded that to reduce the health risk and the extent of heavy metal contamination, steps must be taken for effluent treatment of industrial effluent. Regular monitoring of heavy metal in and around industrial estates is also necessary.

This study further demonstrates the application of EIRA technique in assessing the ecological risk assessment of the groundwater and also to provide preliminary assessment of the groundwater quality that will serve as a database for future investigations and monitoring of groundwater quality in the study zones.

COMPETING INTERESTS
Authors have declared that no competing interests exist.

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