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# Distribution of Trace Elements in Groundwater around Beris Lalang Landfill Bachok, Kelantan, Malaysia

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**Abstract:** The present study was conducted in the vicinity of Beris Lalang landfill, part of state Kelantan, Malaysia to determine the distribution of trace elements concentration in groundwater. A total of eleven groundwater samples and two surface water samples were analyzed for lead (Pb), manganese (Mn), copper (Cu), zinc (Zn), iron (Fe), chromium (Cr) and aluminium (Al) using Atomic Absorption Spectrophotometer (AAS). These probe elements were further categorized as toxic metals (i.e. Pb), transition metals (i.e. Mn), metallic elements (i.e. Cu, Fe, Zn, Cr), and non-metallic elements (i.e. Al). This study shows that few groundwater samples have marginally high concentration of Mn, Pb, Fe and Cr as per W.H.O. standard for potable water. The high concentration of metal ions in groundwater is likely due to untreated effluents from landfill site, municipal wastewater, fertilizers and other activities. To help identifying the contamination sources, the study recommends that regular monitoring of the groundwater quality should be undertaken both temporally and spatially that can contribute in public health and as well agricultural uses.

**Key words:** Trace elements, groundwater, landfill site, untreated effluent, Bachok.

## Introduction

Water is an important natural resource and is one of the basic requirements for the survival of the mankind. The Earth has the privilege to store this precious commodity. Water is required for increasing agricultural production and also in great demand for domestic and industrial uses. Water is a precious resource which, therefore, requires planned utilization and conservation. It has to be planned for a country at macro level and for a basin at micro level. Water is used to perform varieties of socio-economic activities such as agriculture, industries like iron, steel, paper, thermal power station as well as to meet domestic needs (Khan, 2010).

Most of the freshwater in the Earth is found not in lakes and rivers but is stored underground as aquifers. Certainly, during periods of no rainfall, these aquifers provide a valuable baseflow supplying water to rivers. The contribution from groundwater is very important; perhaps as many as two billion people depend directly upon aquifers for drinking water, and 40% of the world's food relies largely on groundwater for irrigated agriculture. In the future, aquifer development will continue to be fundamental to economic development and reliable water supplies will be needed for domestic, industrial and irrigation purposes (Morris et al., 2003).

Study of trace elements is of wide application in varied branches of scientific discipline. Generally, trace

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elements are contributed to groundwater from a variety of natural and anthropogenic sources (Ramessur, 2000; Newcomba et al., 2002; Abollino et al., 2004; Leung and Jiao, 2006). Various anthropogenic activities under the shadow of urbanization and the industrial development result in effluent disposal and introduce the groundwater system to high concentration of trace metals.

Trace metals like Fe, Mn, Cu, Zn, Co and Ni are micronutrients for living system; their deficiency or excess can lead to a number of disorders in human body (Jinwal et al., 2009). Some trace metals like Cd, Pb and Cr can be lethal to human being even at low concentration because of their tendency to accumulate in the body system (Domenico and Schwartz, 1998). Even though many trace elements are essential nutrients, certain trace elements such as As, Cd and Hg are known to be persistent environment contaminants and toxic to most form of life (Jinwal et al., 2009).

## Location

The study area is located at Kampung Beris Lalang; one big landfill site is located around study area which is approximately 1 km to the Jelawat town Bachok. The area lies approximately between latitude 5° 55′ 30″ N to 5° 57′ 00″ N and longitude 102° 24′ 0″ E to 102° 25′ 30″ E (Figure 1). The area covers 46 hectares in the village and is used as landfill from three districts: Kota Bharu, Bachok and Pasir Puteh in Kelantan. There is a village near the landfill with few houses, known as Kampong Gong Nibong Hulu, using the groundwater for domestic purposes. All the wells are confined from shallow aquifer in the study area. The climate of the study area is much influenced by monsoon wind with high rainfall during the northeast monsoon, followed by a distinct dry period. The topography of study area is almost flat.

## Materials and Methods

A total of eleven groundwater samples from housing's wells were collected in February 2013 and were put in 1.5 litre sterilized polyethylene bottles. The bottles were sealed with aluminium foil and acidified in the field by $HNO_3$ for trace elements to keep the samples below pH 2. The samples were labelled with the well code and stored at 4˚C. Prior to collecting the samples, the wells were duly pumped so that the stagnant water, if any, is completely removed from storage in the well assembly.

Some of the parameters were taken in situ after samples were collected because of the instability of the water characteristics. Values of pH, electrical conductivity (EC) and TDS were measured by a portable digital water analysis kit with electrodes.

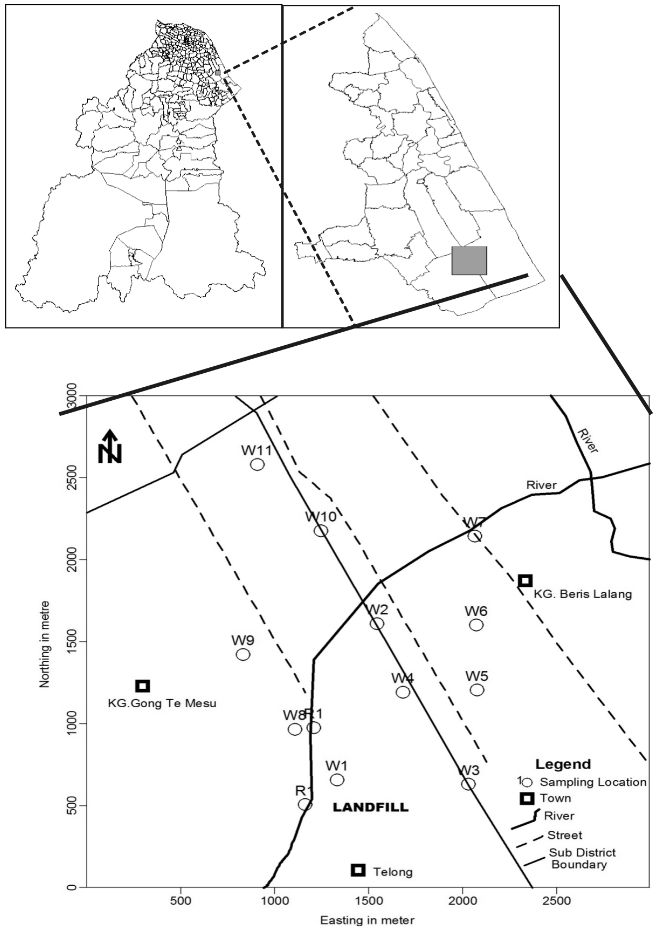


**Figure 1: Location map of groundwater samples.**

Before analyses, the samples were filtered by using filter paper to make the samples clean from any substances that can disturb the process of AAS. In AAS, the water sample is aspirated, aerosolized, and mixed with combustion gases (e.g. acetylene air, nitrous oxide), then vapourized and atomized in a flame at temperature of 2100˚C to 2800˚C. The results indicate the degree of contamination it possessed. The result will be compared with World Health Organization (WHO) and National Standard for Drinking Water Quality, Malaysia.

## Result and Discussion

Eleven groundwater samples were collected from representative sampling stations established over entire study area and were analyzed for their trace elements content and in situ parameters listed in Table 1.

**Table 1: Result of physico-chemical parameters and trace elements analysis**

| *Sample Code* | *Pb (mg/L)* | *Mn (mg/L)* | *Cu (mg/L)* | *Cr (mg/L)* | *Fe (mg/L)* | *Zn (mg/L)* | *Al (mg/L)* | *TDS (mg/L)* | *EC (µS/cm)* | *pH* |
|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 0.08 | 0.018 | 0.016 | 0.077 | 3.167 | 0.038 | 0.743 | 73.5 | 103.5 | 6.3 |
| W2 | 0.1 | 0.023 | 0.011 | 0.073 | 0.102 | 0.048 | 0.185 | 113.0 | 159.1 | 5.9 |
| W3 | 0.076 | 0.009 | 0.011 | 0.091 | 6.408 | 0.406 | 0.153 | 44.7 | 63 | 5.2 |
| W4 | 0.107 | 0.193 | 0.022 | 0.081 | 0.81 | 0.049 | 0.808 | 42.2 | 59.4 | 5.2 |
| W5 | 0.016 | 0.023 | 0.014 | 0.073 | 3.218 | 0.037 | 0.084 | 242.1 | 341 | 5.3 |
| W6 | 0.048 | 0.01 | 0.01 | 0.064 | 1.101 | 0.022 | 0.054 | 51.9 | 73.1 | 5.1 |
| W7 | 0.048 | 0.143 | 0.005 | 0.076 | 5.101 | 0.223 | 3.896 | 298.6 | 420.6 | 3.8 |
| W8 | 0.101 | 0.03 | 0.008 | 0.079 | 14.09 | 0.506 | 0.296 | 89.2 | 125.7 | 6 |
| W9 | 0.105 | 0.018 | 0.01 | 0.08 | 1.454 | 0.015 | 0.009 | 34.6 | 48.7 | 5.6 |
| W10 | 0.085 | 0.008 | 0.003 | 0.079 | 0 | 0.014 | 0 | 161.7 | 227.8 | 5.9 |
| W11 | 0.057 | 0.04 | 0.029 | 0.058 | 0.226 | 0.006 | 0 | 43.0 | 60.5 | 6.2 |
| R1* | 0.072 | 0.093 | 0.012 | 0.088 | 72.18 | 0.711 | 6.418 | 360.0 | 507 | 3.5 |
| R1* | 0.078 | 0.148 | 0.009 | 0.083 | 51.71 | 0.055 | 4.681 | 350.0 | 493 | 3.2 |

*W1 to W11 are groundwater samples and R1 and R2 are river samples.

**Depth to Water Level Map**

A perusal of the water level map exhibits shallow water levels ranging from 0.9 to 1.7 metre which makes the aquifer more vulnerable to near-surface activities (Figure 2). Inspite of very small and low range variations in groundwater levels, a significant inverse relationship between these variations and TDS distribution pattern were observed. A comparative study of water level and TDS distribution map shows (Figure 3) that areas with deep water level conditions in north-east show higher TDS values. Shallow water level conditions in south and south-west were found to be associated with comparatively low TDS values. Moreover, an overall increase in water levels from SW to NE coincides with a subsequent increase in TDS values in the same direction along most of the area.

**Water Table Contour Map**

From water table contour map (Figure 4) two significant mounds can be observed, one in the central part and other in the south-west of the study area. The area exhibits very diversified flow directions with frequent local diversions. Overall, the northern half shows south to north flow direction, whereas southern half exhibits north-south trend.

A comparison of water table contour map and TDS distribution map clearly indicates that the areas in north-east, towards which groundwater flow is more, exhibit higher TDS values. Two mounds were found to be associated with comparatively low TDS values, which indicate their close proximity to the recharge areas in the study area.

## Physico-chemical Characteristics of Water Samples

In natural waters, dissolved solids consist mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. The concentration of TDS in water is a general indication of its suitability for any particular use. The results of physicochemical parameters show that the TDS values range from 34.6 to 360 mg/l with an average of 117 mg/l including river samples. The groundwaters of the area, therefore, are ‘fresh water’ in general. High TDS values can be observed in north-eastern and a small patch in south-east of the study area. Low TDS values can be observed in extreme south, west and a small part in north-west of the study area (Figure 3).

The pH was measured at sample collection sites, to avoid pH changes caused by escape of $CO_2$ and it ranges between 3.8 and 6.3 for the groundwater samples. All the samples show acidic in nature and consumption point of view may not be considered.

The electrical conductivity with 400 µmhos/cm at $25^o$ C is considered suitable for human consumption (WHO, 1984), while more than 1500 µmhos/cm at $25^o$ C may cause corrosion of iron structures. The values

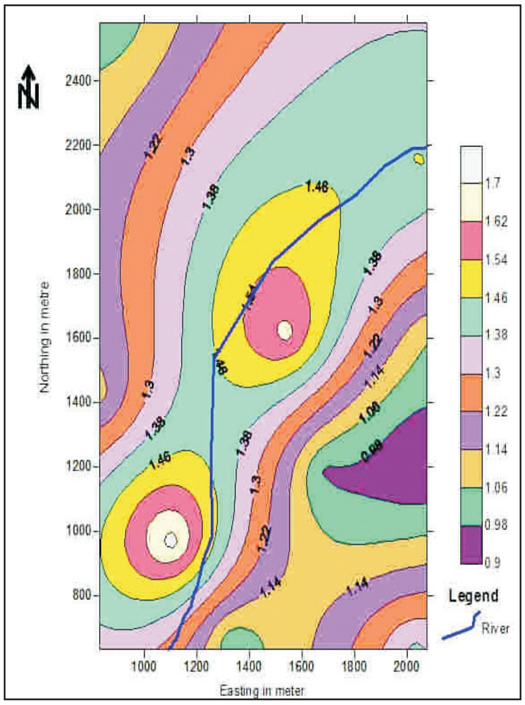


**Figure 2: Depth to water level map.**

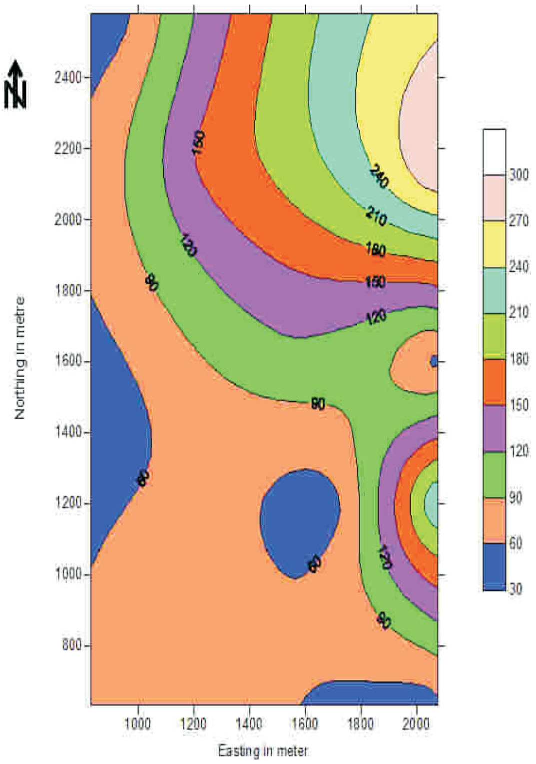


**Figure 3: Distribution map of TDS.**

of the samples ranged between 48.7 and 507 μS/cm in the study area. Thus, the water samples exceed the maximum permissible limit.

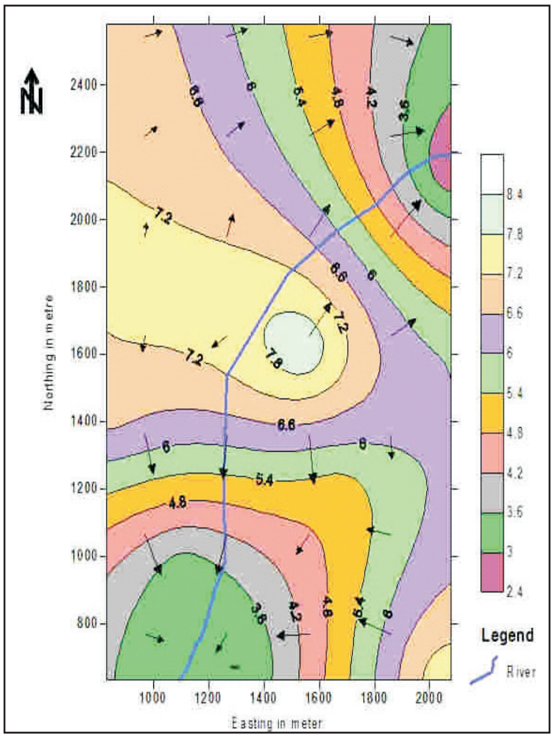


**Figure 4: Water table contour map.**

The trace elements found in the groundwater of the study area had been classified in different groups like toxic element (i.e. Pb), transition metals (i.e. Mn), metallic elements (i.e. Cu, Fe, Zn, Cr), and non-metallic elements (i.e. Al). Range of concentration of trace elements in groundwater samples and their comparison with WHO (2003a-f) and MOH (2004) is given in Table 2.

**Toxic Eletment (Pb)**

Lead concentration in drinking water is permissible up to 0.01 mg/L according to MOH (2004) and 0.1 mg/L (WHO, 2003a). Concentration of Pb found in the study area ranged between 0.016 and 0.107 mg/L. All the samples analysed have concentration levels higher than the permissible limit of 0.01 mg/L. From the Pb distribution map, it shows that high Pb values can be observed in the west part of study area. The lower Pb values prevail in the east of the study area (Figures 5a and 5b).

The possible cause of lead concentrations in these wells and rivers may be attributed to increased use of chemical fertilizers on farm and used in some pesticides such as lead arsenate (Khan, 2010). Agricultural run off may have found their way into water sources. Olade (1987) and Nriagu (1998) noted that phosphate

**Table 2: Range of concentration of trace elements in groundwater samples and their comparison with WHO (2003) and MOH (2004)**

| *Constituents* | *WHO (2003)* | | *MOH (2004)* | *Concentration in study area (mg/L)* |
|---|---|---|---|---|
| | *Highest desirable level* | *Max. desirable level* | *Max. desirable level* | |
| pH | 7-8.5 | 6.5-9.2 | 6-9 | 3.5-6.3 |
| TDS | - | - | 1000 | 34.6-360 |
| Copper | 0.05 | 2.0 | 1.0 | 0.003-0.029 |
| Iron | 0.1 | 1.0 | 0.3 | 0.226-14.09 |
| Lead | - | 0.1 | 0.01 | 0.016-0.107 |
| Manganese | 0.05 | 0.4 | 0.1 | 0.008-0.193 |
| Chromium | - | 0.05 | 0.05 | 0.058-0.091 |
| Zinc | 0.5 | 3 | 3 | 0.006-0.711 |
| Aluminium | - | 0.2 | 0.2 | 0.009-6.418 |

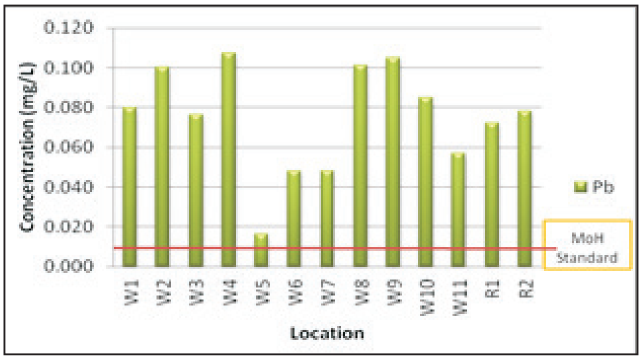


**Figure 5a: Bar chart of lead (Pb).**

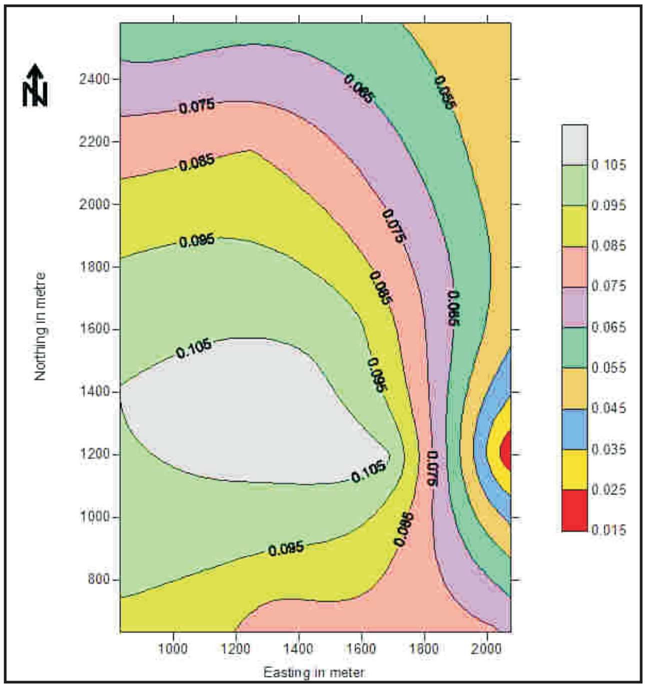


**Figure 5b: Distribution map of Pb.**

fertilizer contains lead that can contaminate the soil and groundwater. The other source of lead in groundwater is from the rocks containing lead sulphide and oxides. The household plumbing fixture made up of lead may contribute lead in the drinking water.

**Transition Metal (Mn)**

Manganese concentration in drinking water ranged between 0.05 and 0.1 mg/L (MOH, 2004) and 0.4 mg/L (WHO, 2003b). In collected groundwater samples, Mn concentration was found in the range of 0.008 to 0.193 mg/L. Out of 11 groundwater samples, only two samples had exceeded the permissible limit of 0.1 mg/L which are W4 and W7. From the Mn distribution map, the south east of the study area shows highest values of Mn while lower Mn values can be observed in north west (Figures 6a and 6b).

Naturally, Mn occurs in many surface and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for

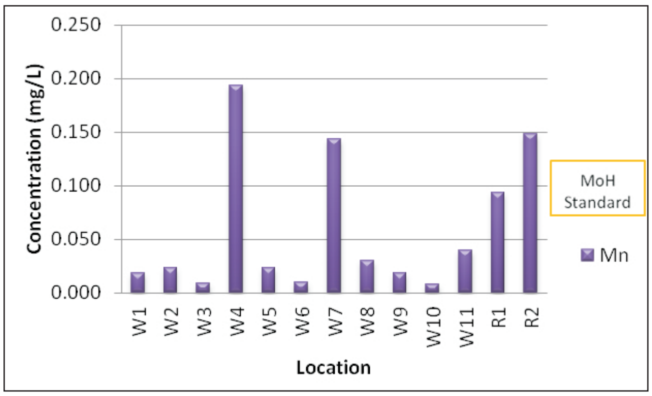


**Figure 6a: Bar chart of manganese (Mn).**

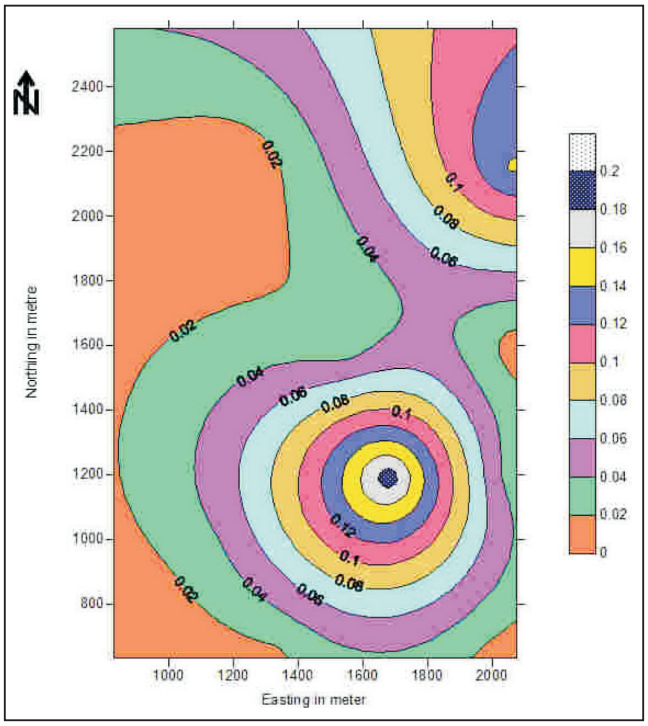


Figure 6b: Distribution map of Mn.

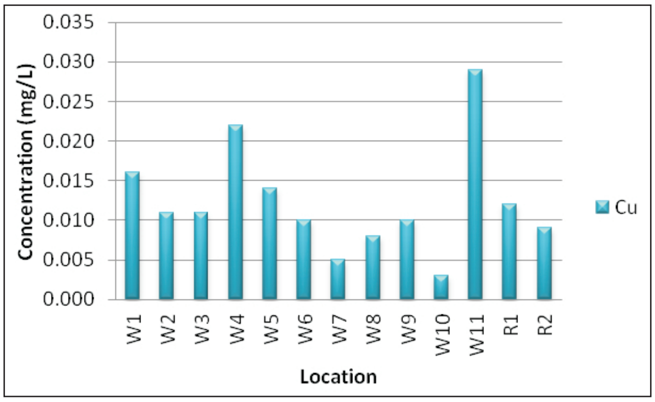


**Figure 7a: Bar chart of copper (Cu).**

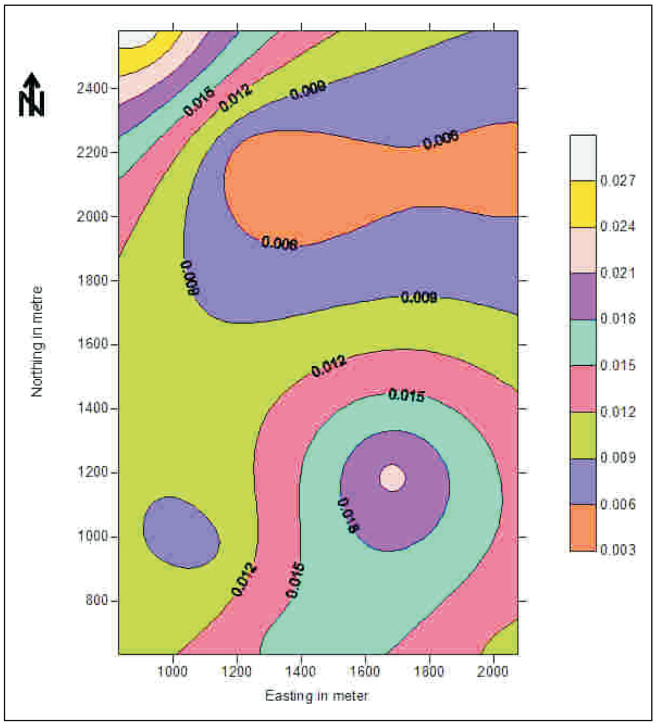


**Figure 7b: Distribution map of Cu.**

much of the manganese contamination in water in some areas. In the present study, slight rise in its level at certain location may be attributed to the combined influence of domestic waste, natural geological rocks and industrial effluents.

**Metallic Elements (Cu, Zn, Fe, Cr)**

Copper (Cu) is an essential element in human metabolism and is considered to be non-toxic up to 1.0 mg/L concentration in drinking water (MOH, 2004; WHO, 2003b). The concentrations of Cu in the present study ranges from 0.003 to 0.029 mg/L. The groundwater is more enriched in Cu than in natural waters (rainwater), probably suggesting possible enrichment from aquifer materials such as feldspar, biotite and muscovite minerals. However, all samples show concentration under permissible limit of 1.0 mg/L. Distribution map shows clearly that Cu concentration increases towards north-west and south-east. The lowest Cu concentrations were observed in the extreme north-east of the study area (Figures 7a and 7b).

Zinc (Zn) is also an essential trace element found virtually in all kinds of food and potable water in the form of either salt or organic complexes (Khan, 2010). Zinc concentration is found in range of 0.006 to 0.711 mg/L and the maximum permissible limit is 3 mg/l (MOH, 2004; WHO, 2003c). The distribution map of Zn shows the higher concentrations of Zn observed in south-west whereas the lower concentrations in north-west of the study area. High Zn content of these groundwater is likely to originate from pollution sources such as domestic effluents, septic tanks and landfill in study area (Figures 8a and 8b).

Iron (Fe) is a trace element found in significant concentrations in drinking water because of its abundance in Earth's crust. It is observed that concentration of Fe in groundwater in the study area varies from 0.226 to 14.09 mg/l, while for river water the range is too high which is 51.71 to 72.18 mg/l. Out of eleven samples of groundwater, six samples showed concentration of iron more than the provisional

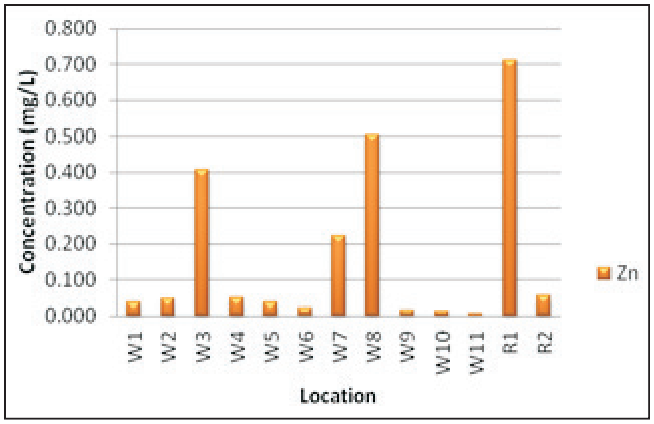


**Figure 8a: Bar chart of zinc (Zn).**

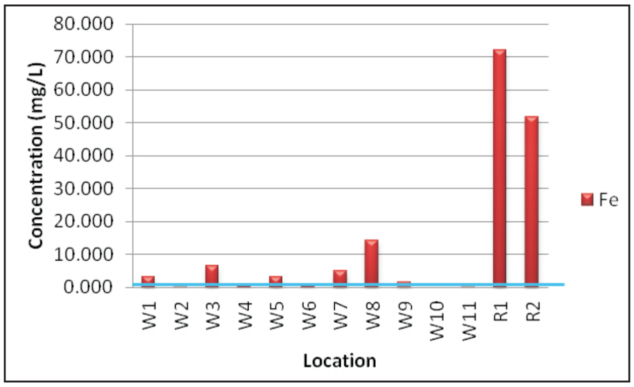


**Figure 9a: Bar chart of iron (Fe).**

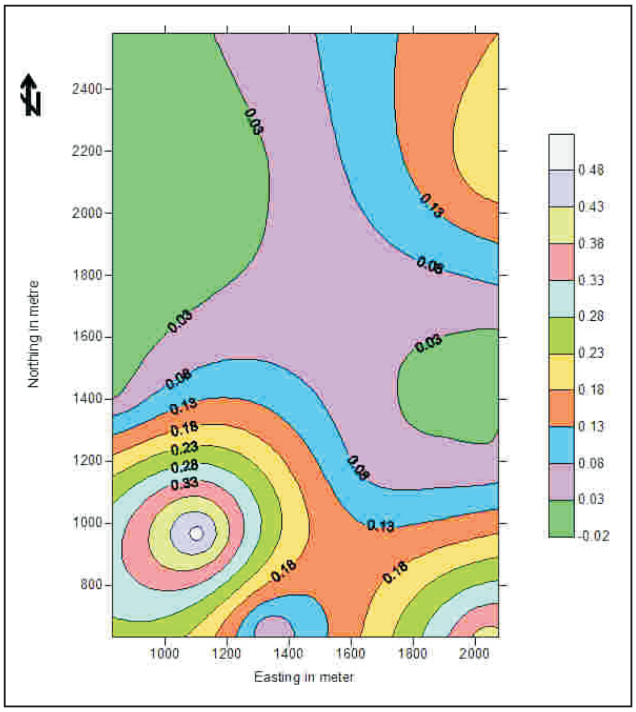


**Figure 8b: Distribution map of Zn.**

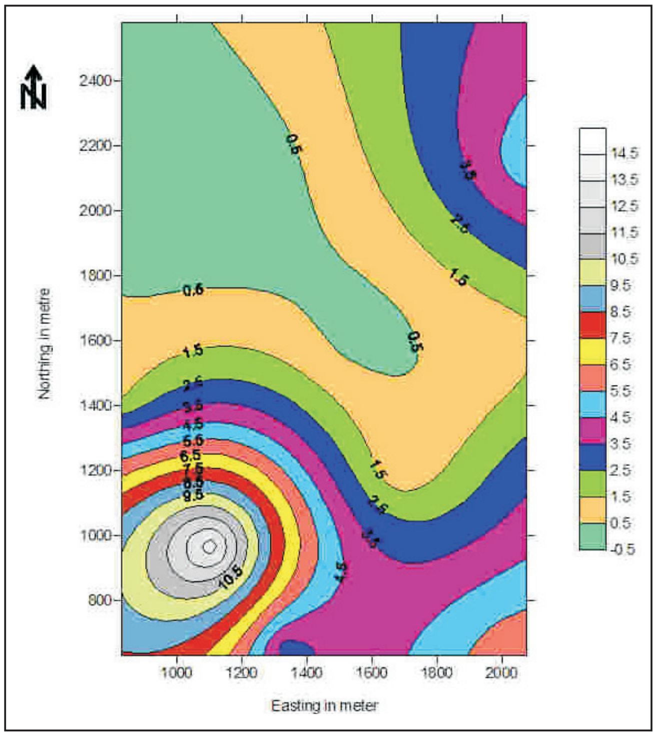


**Figure 9b: Distribution map of Fe.**

guideline value of 0.3 mg/l prescribed by MOH (2004) and WHO (2003d). From the Fe distribution map, the south-west of the study area shows the highest values of Fe. The lower Fe values can be observed in north west (Figures 9a and 9b). Higher Fe concentrations of surface water might have resulted from interaction of oxidized Fe minerals and organic matter and subsequent dissolution of $Fe_2CO_3$ at a comparatively lower pH (Mondal et al., 2010). This type of water is clear when drawn from the well, but shortly changes into cloudy and then turns brown due to precipitation of $Fe(OH)_3$. Another reason for high Fe concentration is due to the removal of dissolved oxygen by organic matter, leading to reduced conditions (Khan, 2010).

The chromium (Cr) concentration in study area is found between 0.058 and 0.091 mg/L and thus, all the samples had concentration level approaching the highest desirable limit which is 0.05 mg/L (WHO, 2003e; MOH, 2004). From distribution map, south-east of the study area shows the higher values of Cr while north-west of the map shows the lower values of Cr (Figures 10a and 10b). The cause of these relatively high Cr concentrations in study area is not known. Normally, higher Cr values may be expected in terrains

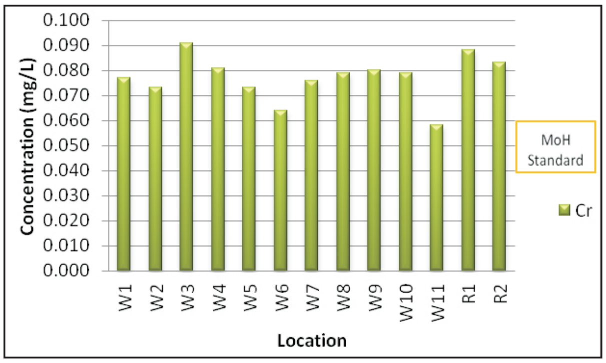


**Figure 10a: Bar chart of chromium (Cr).**

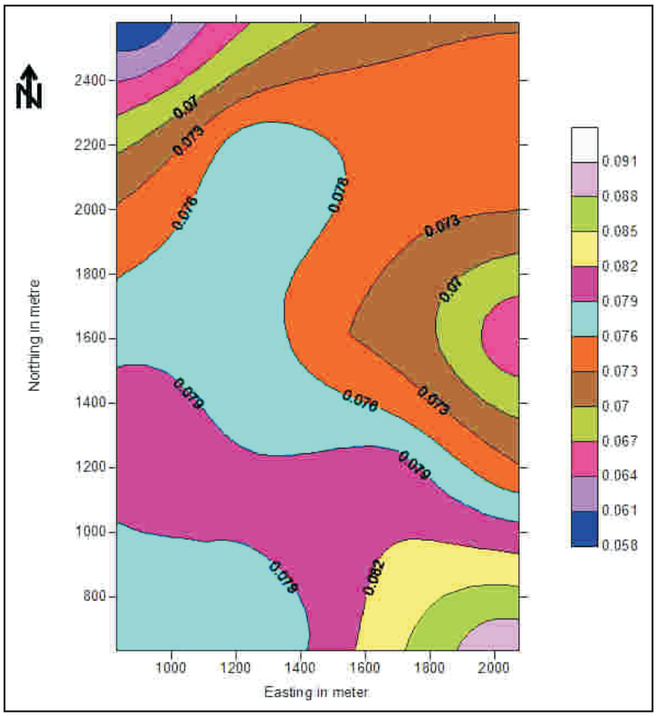


**Figure 10b: Distribution map of Cr.**

characterized by the presence of basic rocks (Khan, 2010) but there are no basic rocks in study area. In the area of study the only point that may be made is that Cr in groundwater is of anthropogenic origin probably from landfill or any other unknown source.

### Non-metallic Element (Al)

Aluminium (Al) concentrations in groundwater samples were found between 0.009 and 3.896 mg/L while surface water values are 4.681 to 6.418 mg/L. The maximum permissible limit of Al in drinking water in the absence of aluminum source is 0.2 mg/L (WHO, 2003f). Out of 13 samples, six of them show Al concentration higher than permissible limit. From distribution map, the higher values of Al is observed in north-east of the study area (Figures 11a and 11b). It also proved that the surface

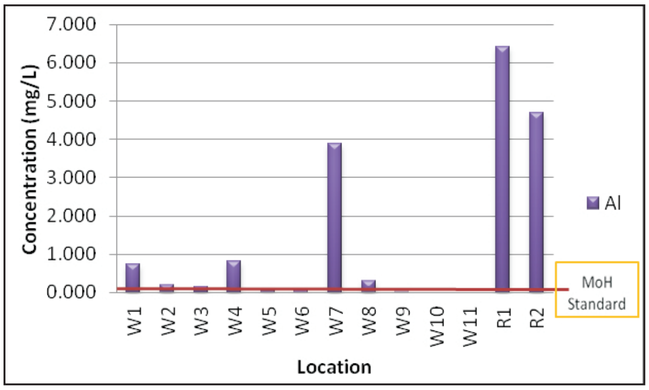


**Figure 11a: Bar chart of aluminium (Al).**

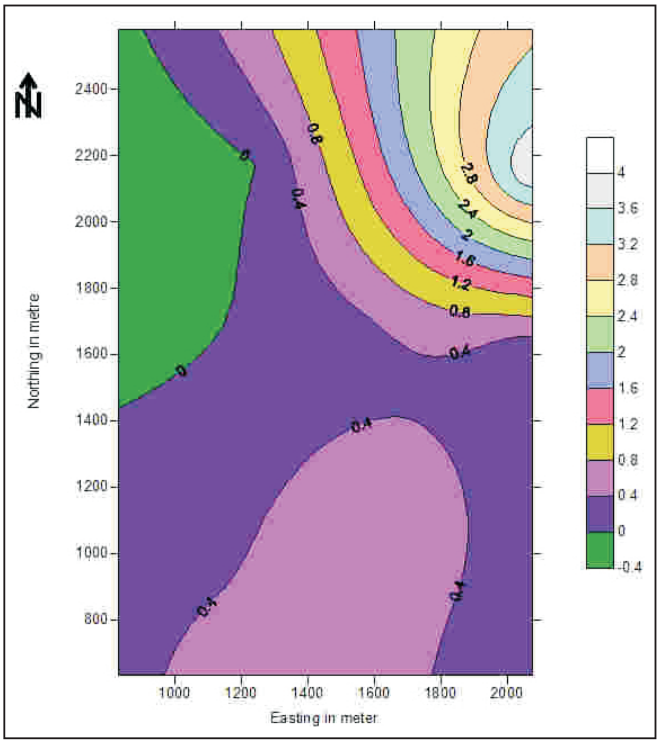


**Figure 11b: Distribution map of Al.**

water have high concentration of Al and deteriorate the quality of groundwater while interacting with it. The source of Al in the water samples may be through weathering of bedrock and soil and leachate from the landfill area which introduces Al into surface water and groundwater (Khan, 2010). Healthwise, there had been a considerable debate on the possible link between Al in drinking water with Alzheimer's disease in humans (Craun, 1990; Epstein, 1990; Flaten, 1990).

## Conclusion and Recommendation

The present study indicates that a perusal of the water level map exhibits shallow water level in north-east and south-west of the study area, therefore, the vulnerability of the groundwater to be contaminated with trace elements is possibly high. From water table contour map the area exhibits very diversified flow directions with frequent local diversions.

So far as physico-chemical parameters are concerned, TDS ranges from 34.6 to 298.6 mg/l and the groundwater can be classified as fresh water. The pH values range between 3.8 and 6.3; these values show groundwater is acidic in nature and not suitable for consumption. The EC values of the samples ranged between 48.7 and 420.6 µS/cm in the study area. It showed that the groundwater samples are of low conductivity and safe to consume.

All the samples analysed have higher concentration levels for Pb and Cr which range between 0.016 and 0.107 mg/L and 0.058 to 0.091 mg/L respectively. The concentration of Mn is found in the range of 0.008 to 0.193 mg/L. Out of the 11 analysed samples, only two samples have exceeded the permissible limit of 0.1 mg/L which are W4 and W7. Besides that, it is observed that concentration of Fe in groundwater in the study area vary from 0.226 to 14.09 mg/L while for river water the range is too high which is 51.71 to 72.18 mg/L. Out of eleven groundwater samples, six samples show concentration more than 0.3 mg/l. For Al concentrations in groundwater, out of 13 analysed samples, six of them show Al concentration higher than permissible limit with values ranging between 0.009 and 3.896 mg/L while surface water values are in the range of 4.681 to 6.418 mg/L.

The increasing concentration of these elements in the groundwater of the study area is mainly influenced by the leachate generated from landfill area. The leachate also affected the surface water near the landfill site through percolation. Thus, the surface waters are contaminated and deteriorate the groundwater quality. The other possible sources are from domestic waste, agriculture, and natural geological rocks. The increased levels of these elements in groundwater may also be contributed by some nearby activity such as cattle and poultry farming near the community wells.

Most of the trace elements that have been analyzed were under the permissible limit except few samples. Therefore, a few wells of groundwater samples in the study area are suitable for drinking and other household purposes. On the basis of the present study, the following recommendations have been made for protection and sustainable management of groundwater of the study area:

i. Since development, environment and public health are interlinked, it is necessary for all concerned to adopt sustainable utilization of the available water resources.
ii. Regular monitoring is required over a large period, in order to verify the influence of seasonal variations on the contaminant concentrations with time and to identify the sources of toxic contaminants and other inhibitory compounds that affect the potability of water.
iii. In agriculture indiscriminate use of lead arsenate as a pesticide should be minimized so that it does not leach down to groundwater and deteriorate its quality.
iv. Industries should set up their effluent treatment plants (EFT) independent or jointly as per norms and should remain effectively operational in order to safeguard the groundwater for future generations.
v. Mass awareness should be developed about the over-use of pesticide, its harmful effects on quality of water and human health.
vi. There is a need to monitoring regularly the quality of effluent released from landfill.

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