



## IMPACT OF WASTEWATER EFFLUENTS ON PHYSICO-CHEMICAL PROPERTIES OF GROUNDWATER

A. Q. Jakhrani, S. R. Samo, I. Nizamani

Energy and Environment Engineering Department, Quaid-e-Awam University of Engineering Science and Technology, Nawabshah.

(Received 11<sup>th</sup> April 2009 and Revised 29<sup>th</sup> May 2009)

### Abstract

A significant number of today's groundwater contamination problems stem from man's activities and can be introduced into groundwater from variety of sources. One of the major source of groundwater contamination are the surface impoundments used by municipalities and industries which dispose off wastewater without treatment to the receiving bodies or used by farmers for agriculture purpose. This research work was carried to investigate the contamination level of groundwater by determination of physical and chemical properties of groundwater and to recommend the preventive measures for the reduction of contamination level of groundwater. It was observed that the groundwater quality is deteriorated because of higher concentration of electrical conductivity ranging from 3348 to 6333  $\mu\text{S}/\text{cm}$  as compared to E. U. guideline value of 4000  $\mu\text{S}/\text{cm}$ , shows the increase of 8 to 18 times, whereas, the total dissolved solids range between 1992 to 4018 mg/l indicates three times increase and hardness ranges from 520 to 977 mg/l indicates two times higher values as compared to WHO standards. It is recommended that only treated wastewater may be used for the growing of vegetable and crops after the complete investigation of physical, chemical and biological characteristics of wastewater effluents. Preventive measures must be taken for reduction of contaminated wastewater intrusion up to the groundwater.

**Keywords:** Contamination, Groundwater, Wastewater effluents

### 1. Introduction

Groundwater contamination can originate on the surface of ground, from the ground above or below water table. If a contaminant is spilled on the surface of the ground or injected into the ground above the water table, it may have to move through numerous layers of soil and underlying materials before it reaches the groundwater (Foppen, 2008). As the contaminants move through these layers, a number of processes come in operation, (e.g. filtration, dilution, oxidation and biological decay), that can lessen the eventual impact of the substances once it finally reaches the groundwater. The distance between the groundwater and place of contamination introduction and length of time affects the effectiveness of these processes (Jakhrani, 2002). In comparison to rivers or streams, groundwater tends to move very slowly and with little

turbulence. Therefore, once the contaminant forms a concentrated plume that can flow along the same path as the groundwater. Among the factors that determine the size, form and rate of movement of the contaminants are; the amount and type of contaminant, and the speed of groundwater movement. Because the groundwater is hidden from view, contamination can go undetected for years until the supply is tapped for use (Chatterjee, 1996).

Substances which contaminate groundwater can be divided into two basic categories; substances that occur naturally and substances produced or introduced by man's activities. Substances that occur naturally included minerals, such as iron, calcium, selenium etc. Substances' resulting from man's activities includes synthetic organic chemicals and hydrocarbons (e.g. solvents,

pesticides, petroleum products etc) and landfill and pond leachates (Mahmood *et al.*, 2006). A significant number of today's groundwater contamination problems stem from man's activities and can be introduced into the groundwater from variety of sources. One of the significant sources of groundwater contamination is the surface impoundments used by municipalities and industries for disposing off variety of liquid wastes and wastewater (Maqbool, 2007).

## 1.2 Objectives of study

Following were the main objectives of this study:

- i) To investigate the contamination level of groundwater by determination of physical and chemical properties of groundwater.
- ii) To recommend the preventive measures for the reduction of contamination level of groundwater.

## 2. Materials and Methods

The study area was chosen for the research work near Hyderabad city, in the vicinity of waste stabilization ponds, for the assessment of physical and chemical properties of groundwater. The waste stabilization ponds were of facultative type constructed in parallel followed by three maturation ponds with a capacity of 6.0 MGD (Laghari *et al.*). The total area of facultative and maturation ponds were 389488 m<sup>2</sup> and 170082 m<sup>2</sup> with a total volume of 1012669 m<sup>3</sup> and 357172 m<sup>3</sup> respectively (Balfours and Sons, 1990). The embankments of these ponds were made up of brick masonry. While the huge wastewater ditches were found around the ponds of study area, which likely contributed the increasing concentration of groundwater contamination. For this purpose, a layout plan was formulated before sampling and observation locations were marked in such a way that the impact of wastewater ditches and waste

stabilization ponds on the groundwater may properly be investigated. Groundwater samples were taken at different distances from the two sides of waste stabilization ponds and ditches as shown in (Fig. 1.) The sampling points were marked at 10, 110, 210, 310 and 1000 meter distance from these ponds, however the ditches were full with wastewater and the local farmers divert most of the untreated wastewater towards agricultural fields. Bores were made for a depth of 15 meter by using Auger of 5cm diameter. There was a single layer of water in that depth. Hence, thirty-nine numbers of groundwater samples were taken from that layer, at the depth of 12 meter in neat and clean plastic bottles. Sampling locations, distance from waste stabilization ponds and date of sampling was marked on bottles for the identification of samples. The groundwater temperature was measured during sampling at the site. Samples were preserved in a refrigerator at a low temperature of about 4° C (WHO, 1996).

## 2.1 Experimental work

The samples were examined in the following laboratories:

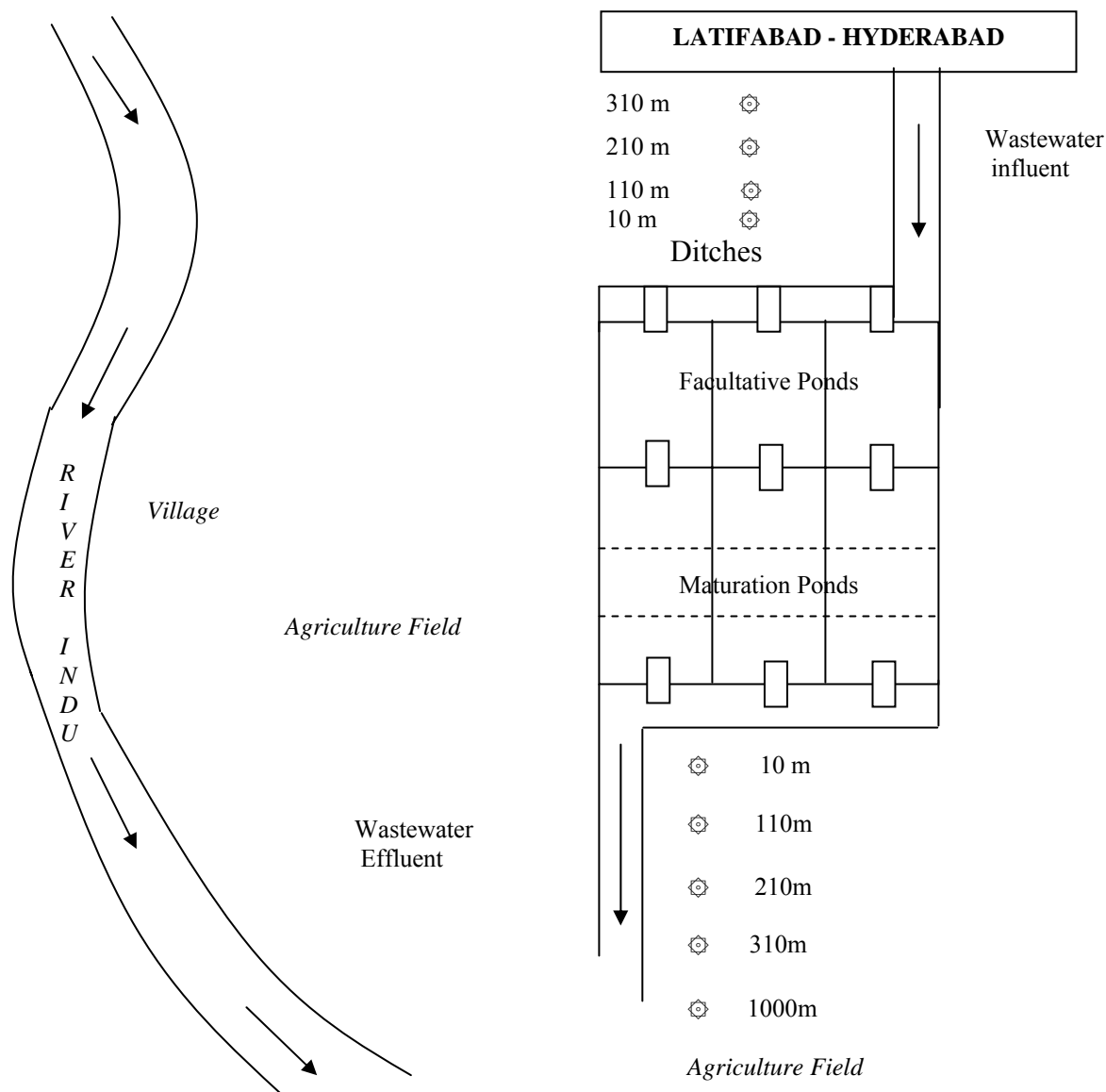
- i) Institute of Environmental Engineering and Management and Public Health Engineering Laboratory, Civil Engineering Department, M.U.E.T, Jamshoro.
- ii) Drainage Reclamation Center, Tando Jam.

The equipments and instruments were calibrated and tested before conducting the research work as per specifications and manual guidelines set by American Public Health Association and Standard methods for the examination of water and wastewater (Mahmood, 2006). The instrument used and methodology adopted for analytical purpose is shown in (Table-1).

**Table-1. Instruments used and Methodology Adopted for Analytical Purpose**

| Parameters                              | Instruments Used          | Methodology  |
|---|---------------------------|--|
| Temperature                             | Thermometer               | Direct measurement method                              |
| pH                                      | pH meter                  | Direct measurement method (Electrode method)           |
| Color                                   | DR/2010 Spectrophotometer | Method No. 8025  |
| Electrical Conductivity                 | EC meter                  | Direct measurement method (Electrode method)           |
| Total Dissolved Solids(TDS)             | TDS meter                 | Direct measurement method (Electrode method)           |
| Total Suspended Solids                  | DR/2000 Spectrophotometer | Photoelectric (Non Filterable Residue) Method No. 8006 |
| Hardness (Total) as CaCO <sub>3</sub>   | -                         | Titration method                                       |
| Alkalinity (Total) as CaCO <sub>3</sub> | -                         | Titration method                                       |
| Ammonia-Nitrogen                        | DR/2010 Spectrophotometer | Method No. 8155  |
| Nitrite-Nitrogen                        | DR/2010 Spectrophotometer | -  |
| Nitrate-Nitrogen                        | ISE meter                 | Electrode method                                       |

**Fig. 1: Location Plan for Experimental work**



### 3. Results and Discussions

#### 3.1 Impacts on physical parameters of ground water

The detailed results of physical parameters of analyzed samples are summarized in (Table-2), and obtained values were compared with the international standards.

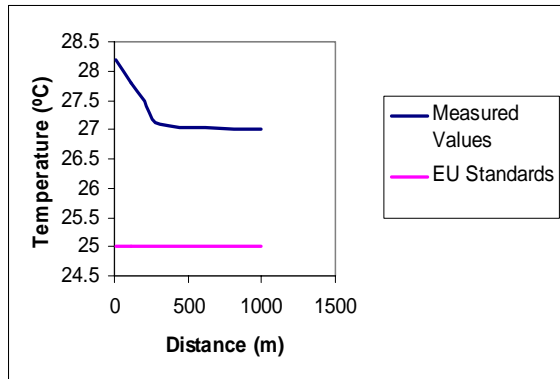
**Table-2: Comparison of physical concentrations of analyzed samples with WHO standards**

| Parameters  |      | Temperature (°C) | Color (TCU) | Electrical conductivity (µS/cm) | Total suspended solids (mg/l) |
|---|------|------------------|-------------|---------------------------------|-------------------------------|
| Distance from waste stabilization ponds in meters | 10   | 28.2             | 32.2        | 6333                            | 4018                          |
|   | 110  | 27.8             | 34.5        | 6248                            | 3681                          |
|   | 210  | 27.5             | 31          | 4934                            | 2937                          |
|   | 310  | 27.1             | 30          | 3492                            | 2163                          |
|   | 1000 | 27.0             | 30          | 3348                            | 1992                          |
| Average   |      | 27.52            | 31.9        | 5251                            | 3199                          |
| WHO Standards                                     |      | 25*              | 15          | 4000*                           | -                             |
| Increase (Times)                                  |      | 1.0              | 2.0         | 8.0-18.0                        | -                             |

\* EU guidelines

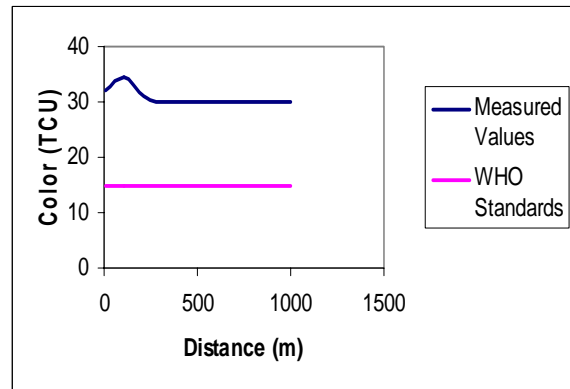
It was observed that the temperature of groundwater samples were in range between 27 °C to 29°C which were slightly greater than European Union guidelines as represented in (Fig. 2). 10°C increase of temperature doubles the rate of biological activities and chemical reactions. The

**Fig. 2. Distance from waste stabilization ponds v/s temperature of groundwater.**



color of investigated samples found higher than WHO standards as shown in (Fig. 3). The high level of color in the samples may be due to presence of high concentration of total dissolved solids in the groundwater.

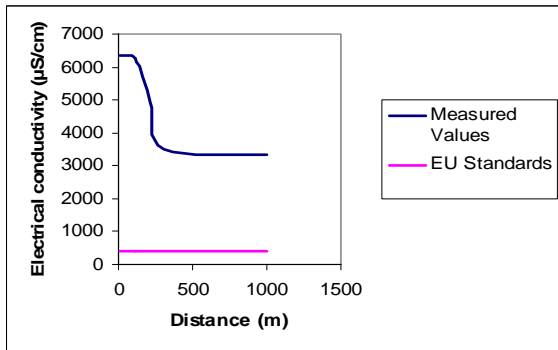
**Fig. 3. Distance from waste stabilization ponds v/s color of groundwater.**



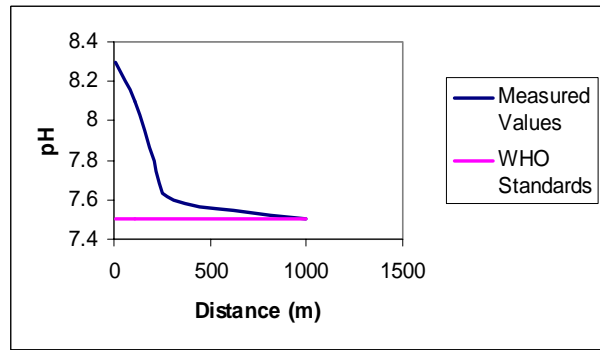
(Fig. 4), gives the electrical conductivity values that were also found very high at all places as compared with WHO standards; whereas, the values of total suspended solids were found

1992-4018 mg/l, as compared to WHO standard value of 1000. The TDS provides the adsorption site for chemical and biological agents, which are objectionable aesthetically.

**Fig. 4. Distance from waste stabilization ponds v/s electrical conductivity of groundwater**



**Fig. 5. Distance from waste stabilization ponds v/s pH of groundwater**



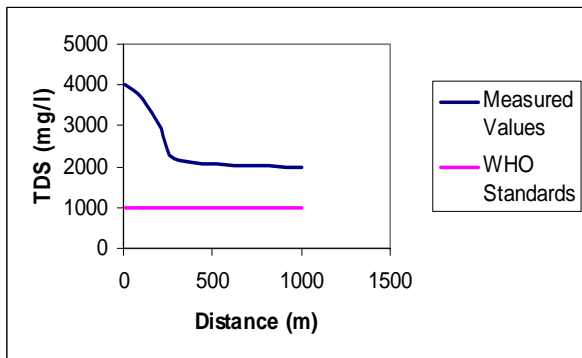
**3.2 Impacts on chemical parameters of groundwater**

The experimental results of chemical parameters of groundwater samples were also calculated and are given in (Table-3), with WHO standards. It was observed that the pH of most water samples were normal as given in (Fig. 5),

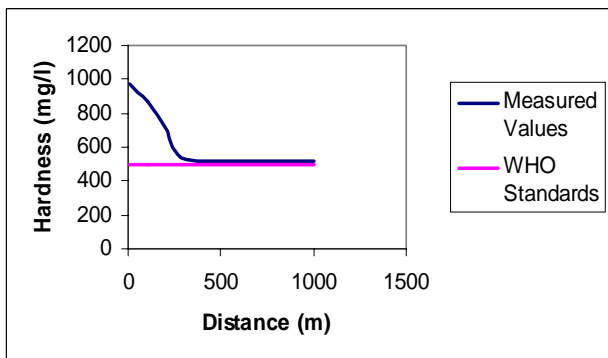
**Table -3 Comparison of chemical concentrations of analyzed samples (mg/l) with WHO standard**

| Parameters  |      | pH     | TDS  | Hardness | Alkalinity | NH <sub>3</sub> -N | NO <sub>2</sub> -N | NO <sub>3</sub> -N |
|---|------|--------|------|----------|------------|--------------------|--------------------|--------------------|
| Distance from waste stabilization ponds in meters | 10   | 8.3    | 4018 | 977.5    | 662        | 0.74               | 0.210              | 14.7               |
|   | 110  | 8.1    | 3681 | 867.5    | 643        | 0.67               | 0.140              | 11.2               |
|   | 210  | 7.8    | 2937 | 689.5    | 620        | 0.49               | 0.057              | 9.2                |
|   | 310  | 7.6    | 2163 | 528.5    | 586        | 0.49               | 0.035              | 6.7                |
|   | 1000 | 7.5    | 1992 | 520      | 561        | 0.39               | 0.018              | 6.5                |
| Average   |      | 7.95   | 3199 | 765      | 627        | 0.59               | 0.111              | 10.45              |
| WHO Standards                                     |      | 7.5 ±1 | 1000 | 500      | -          | 1.5                | 0.010              | 10.0               |
| Increase (Times)                                  |      | -      | 3.0  | 2.0      | -          | -                  | 1.1                | 1.04               |

**Fig. 6. Distance from waste stabilization ponds v/s TDS of groundwater.**

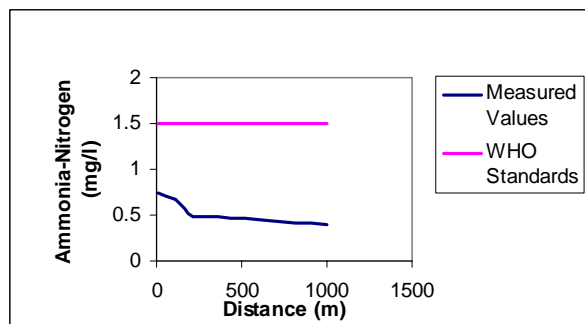


**Fig. 7. Distance from waste stabilization ponds v/s Hardness of groundwater**

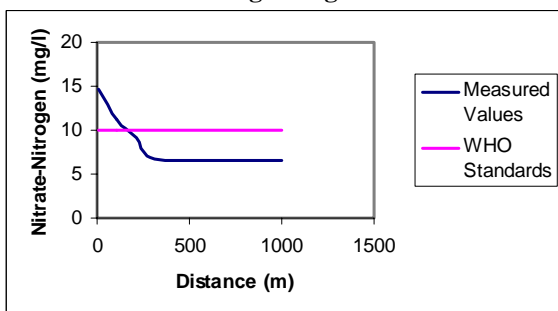


whereas, the observed values of total dissolved solids were found much higher than standard values as represented in (Fig. 6).

Hardness of the samples were found variable due to geology of the area and chemical composition of the earth's crust as shown in (Fig. 7).

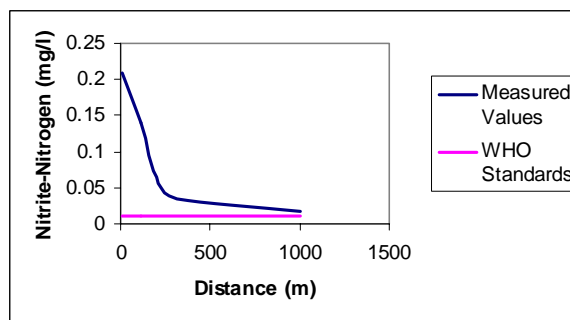
**Fig. 8. Distance from waste stabilization ponds v/s Ammonia-Nitrogen of groundwater**

The results of Ammonia content in the samples were less than standard values as given in (Fig. 8). The concentration of Nitrite-Nitrogen and Nitrate-Nitrogen were observed more than WHO standards as shown in (Fig. 9 and Fig. 10), respectively. High concentration of nitrite presence is indicative to active biological process in water. Nitrite is readily absorbed by blood in digestive tract and attaches to the hemoglobin that interferes with the blood's capacity to carry oxygen to the body cells. Whereas, nitrite is end product of nitrogenous matters and often occurs in the earth's crust in many places.

**Fig. 10. Distance from waste stabilization ponds v/s Nitrate-Nitrogen of groundwater**

#### 4. Conclusions

It was concluded that the groundwater quality is deteriorated because of higher concentration of electrical conductivity ranging from 3348 to 6333  $\mu\text{S}/\text{cm}$  shows 8 to 18 times increase as compared to EU guideline value of 400  $\mu\text{S}/\text{cm}$ . Whereas, the total dissolved solids range between 1992 to 4018 mg/l indicates three times greater value and hardness ranges from 520 to 977 mg/l shows two times higher values as compared to WHO standards, while, the

**Fig. 9. Distance from waste stabilization ponds v/s Nitrite-Nitrogen of groundwater**

concentration of Nitrite-Nitrogen and Nitrate-Nitrogen also indicates slightly higher values than permissible limits. This may be due to the leaching of dissolved impurities of wastewater effluents used by farmers directly without treatment in oxidation ponds, and also from wastewater ditches around the ponds; chemical composition of earth's crust; and/or geology of the study area. Variation found in the observed results was also due to the hydraulic gradient, slope of the area and flow of the River Indus that may dilute the dissolved impurities of groundwater.

#### 5. Recommendations

Preventive measures could save the groundwater from leaching of dissolved impurities of wastewater.

A few suggestions are given below:

- i) Potable water bores must be away from waste stabilization ponds or wastewater ditches.
- ii) Bottom of oxidation ponds should be made lined except around the inlet.
- iii) Wastewater effluents from industries and municipalities must be treated before application to the crops.
- iv) Ban may be imposed on the use of wastewater effluents without treatment.
- v) Treated wastewater effluents as well as groundwater should completely be analyzed at least in the interval of three months.

## 6. Acknowledgment

The authors would like to exchange the words of thanks to all the staff of Institute of Environmental Engineering and Management, and Public Health Engineering, Civil Engineering Department, M.U.E.T. Jamshoro, for providing required facilities.

## References

Abreu, M. M., M. J. Matias, M. Magalhaes, F. Clara and M. J. Bastu (2008) "Impacts on water, soil and plants from the abandoned Miguel Vacas copper mine, Portugal," *Journal of Geochemical Exploration*, V-96, issues 2-3.

Balfours and Sons, (1990) "Sewerage, sewage and solid waste management," Master plan V-2, Hyderabad Development Authority, Hyderabad, Sindh, Pakistan.

Chatterjee, A. K. (1996) "Water supply, waste disposal and Environmental Engineering (Including odor, noise and air pollution and its control)", 5<sup>th</sup> edition, Khana Publishers, New Delhi, 160-173 and 368-379.

David. W., K. Wolfram, C. Laurence, B. Jacky, R. Houda and G. Jean-Luc. (2004) "Nitrate in groundwater: an isotopic multi-tracer approach "Journal of water, air and soil pollution, Springer, Netherland.

Foppen, J. W. A. (2008) "Impact of high strength wastewater infiltration on groundwater quality and drinking water supply: the case of Sana'a, Yemen," *Science Direct-Journal of hydrology*, Elsevier B.V.

Jakhrani, A. Q. (2002) "Impact of oxidation ponds on groundwater quality at Hyderabad" M.E. Thesis, Institute of Environmental Engineering and Management, Mehran University of Engineering and Technology, Jamshoro.

Kulabako, M. R., M. Nalubega and R. Thunvik (2007) "Study of the impact of land use and hydro-geological setting on the shallow ground

water quality in a peri-urban area of Kampala, Uganda" *Science of the Total Environment*, V-381, issues 1-3.

Leghari. A, S. N. Chandio, M. Y. Khuhawar, T. M. Jehangir and S. M. Laghari (2005) "Physico-chemical and Bdgeting study of Wastewater from Latifabad and Qasimabad Talukas of Hyderabad District, Pakistan" *Sindh University Journal (Science Series) Vol. 37(2)* 25-32.

Mahmood. S. and A. Maqbool (2006) "Impact of wastewater irrigation on water quality and on the health of local community in Faisalabad" *Pakistan Journal of water resources*, vol. 10 (2) 42-56.

Maqbool, A. (2007) "Environmental consequences of wastewater irrigation" M.S. thesis, Center of Excellence in Water resources Engineering, Lahore, Pakistan.

Mahmood, S. (2006) "Wastewater irrigation issues and constraint for sustainable irrigated agriculture", *Journal of Italian Agronomy* 234-344.

USEPA, (1999) "Citizen's Guide to groundwater protection", United States Environmental Protection Agency, New York, 01-22.

WHO, (1996) "Guidelines for drinking water quality," 2<sup>nd</sup> edition, V-2, World Health Organization, Geneva.