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Multifaceted ground water quality and recharge mechanism issues in a mega-city (Rawalpindi, Pakistan), and mitigation strategies

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Abstract Pakistan has been blessed with abundance of availability of surface and ground water resources to the tune of 128300 million m^3 and 50579 million m^3per year respectively which comprises of five distinct zones. Rawalpindi city, having population of 1.6 million, relies on surface water from Rawal and Khan Pur Dams (0.073 million m^3 /day) and ground water (0.095 million m^3 /day). Therefore, fast depleting ground water aquifer because of over extraction, contamination levels of ground water is on the increase. Due to the geological sub soil conditions of the sub-surface strata, wastewater (0.545 million m^3/day) flowing in Nullah Lai (main recharge source) easily gets into fissured bed rock and transport contaminants through flow nets into deep aquifer. Another factor of ground water contamination is due to exposure of upper aquifer exposed to contaminants due to over extraction resulting in drastic draw down of water table. Recent analysis of 220 tube wells has revealed that 50% of the tube wells are producing bacteriological contaminated water against 33% in the year 2003. Hence after detailed situational analysis, the only viable solution to protect the ground water source of Rawalpindi is termination of subsoil seepage and infiltration of contaminated water from Lai Nullah and other streams by proper lining of secondary streams and constructing a box channel intercepting the dry weather flow (mainly sewage water) which will act as a dry weather sewer for safe disposal of sewage generated from Rawalpindi and Islamabad. This is an interesting and complex situation which might have numerous environment friendly, cost effective and workable solutions. There can be a big environmental disaster, which warrants immediate mitigation strategies.

Key Words: aquifer, contamination, disposal, extraction, exploited, infiltration, ground water, geological, mitigation,

INTRODUCTION

1. Rawalpindi is Country's forth largest city having population of 2.1 Million. In year 1998, Water and Sanitation Agency (WASA) was established under the Government of Punjab act to meet the requirements of rapid growing population of the city. WASA served population is 1.5 Million and its covered area is 35sqkm. Pakistan has been blessed with abundance of availability of surface and ground water resources to the tune of 128300 million m^3 and 50579 million m^3 per year respectively (The Pakistan National Conservation Strategy, 1992). In spite of this naturally resource enrichment, per capita water availability has

decreased from 5600 to 1000 cum per annum (Water Quality Status, 2003). Beside this appreciable decrease in water availability, the quality of both the sources has crossed the acceptable limits. Both state and non-state actors have overwhelmingly detoriated the water quality due to indiscriminate over extraction of ground water complemented with polluted recharge sources. At the moment the northern part of the country has microbial contamination of 64 % (Diagnostic Survey, 2007). Central part of the country has both chemical and microbial contamination. River Ravi and Chenab receives industrial wastewater of textile, leather and light engineering industries more than 1000 MGD, from both India and Pakistan. This phenomenon is not only polluting surface water but also contaminating ground water aquifer, which is flowing towards southern areas during recharge process. The most prominent contaminants comprises of 50,000 thousands dyes (heavy metals and trace elements), chromium, fluorides, iron which have not only polluted the surface water but has also contaminated potential ground water resources (Major source of drinking water in Pakistan). In addition to the above mentioned contaminants, the central and southern part of the country is also experiencing prevalence of heavy concentration of arsenic ground water contamination ranging up to 1100 ppb (UNICEF, 2005)

2. In Rawalpindi (Twin City of Federal Capital, Islamabad), relies mainly on ground water which is being exploited by more than 240 tube wells. Out of these 240 tube wells, 72 were producing biologically contaminated water (RWASA Water quality report, 2003) which is on the increase. The main reason of this contamination is recharge mechanism of Nullah Lai and Korang River which carries the wastewater of 0.545 million m^3/day of twin cities of Islamabad and Rawalpindi. The Rawal Lake, surface water source (Storage capacity 46.26 Mm^3), has also been contaminated due to massive urban development in the catchments and recharge area. Ground water aquifer has been bounded by these contaminated water sources which is ultimately polluting rather has polluted the entire ground water aquifer. This paper focuses on issues, challenges and mitigation strategies to address the fast depleting ground water aquifer with remedial measures to minimize bacterial contamination.

METHODOLOGY

3. Situational analysis of existing water supply panning and management was carried out which revealed the following statistics;

a. **Water Table Depletion**

Year wise comparison of water table depletion matrix is shown in figure-3.1, below, which is approximately observed @ of 10 ft per year;

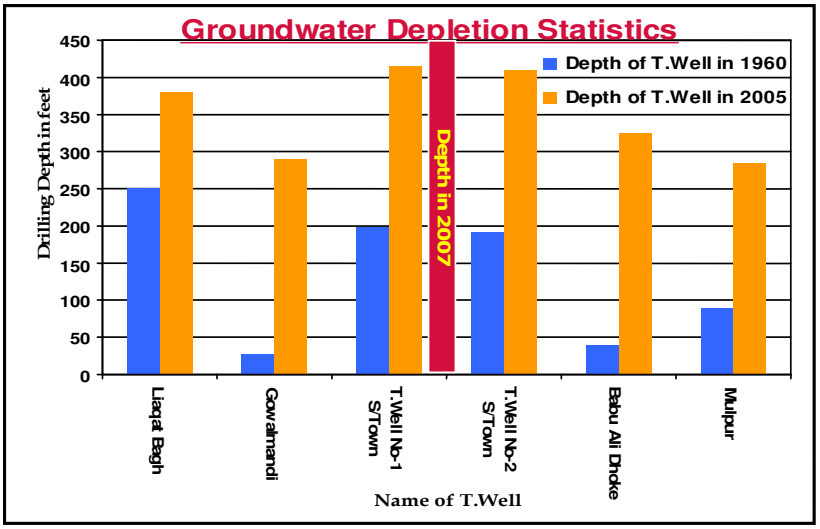

Fig- 3.1 Statistics on Ground Depletion in Rwalpindi- Pakistan

With this fast depletion of aquifer, the contamination level both at source and at consumer's end has increased beyond the acceptable limits. Figure-3.2, below, shows the trend in increase of contaminations;

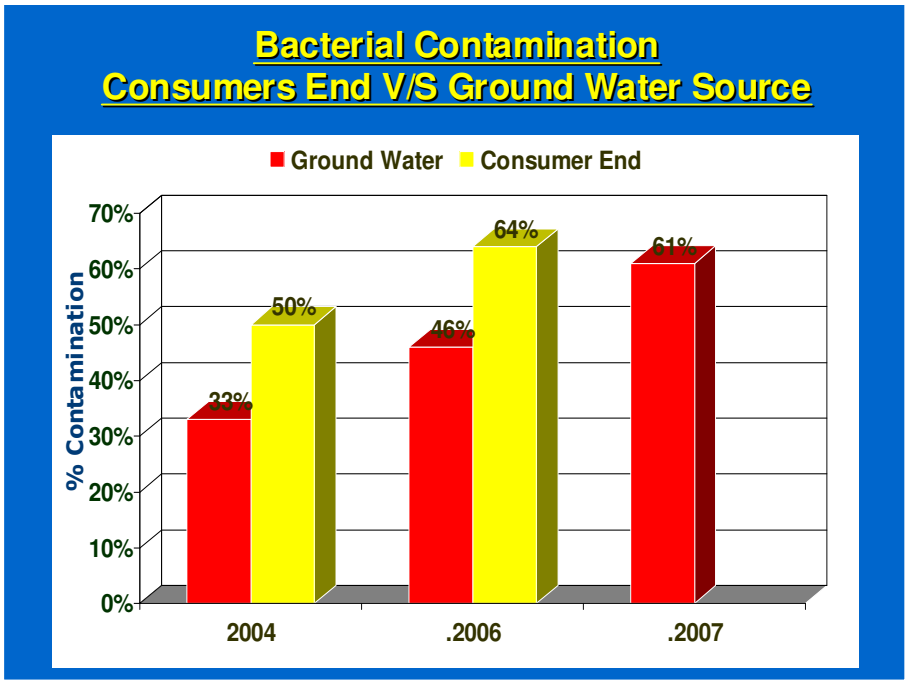

Fig. 3.2 Comparison between bacterial contamination- source v/s consumer's end

4. The major causes of bacterial contamination is due to Nallah Lai which carries 120 MGD wastewater of twin cities of Islamabad and Rawalpindi. Figure-4.1 shows the Recharge mechanism through wastewater drains;

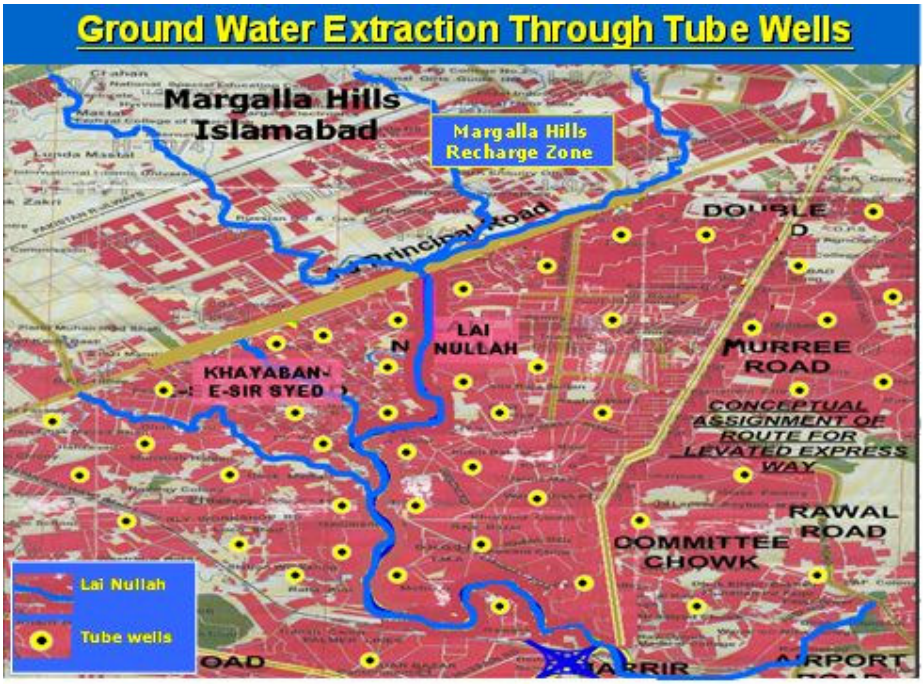

Fig. 4.1 Location map of tube wells installed around Nullah Lai

All the tube wells installed near Nallah Lai, as shown in figure-4.1, are producing contaminated water. The details of water quality are shown in table-4.1, below;

Table 3.1 Latest Water Quality Report - 15 Tube Wells around Nullah Lai

Location	Fecal Coliform Count	Hardness as $CaCO_3$	Conductance	Calcium	Total Dissolved Solids	Chlorides
Arjun Nagar TW # 71A	10/100ml	352	1800	94	522	25
Dhoke Mangtal TW # 84-A	150/100ml	510	955	136	469	27
Dhoke Mangtal TW # 83	36/100ml	510	1112	132	502	24
Dhoke Hassu TW # 88	35/100ml	510	1210	122	429	23
Ratta Amral TW # 74-B	29/100ml	412	879	115	511	27
Dhoke Mangtal TW # 85-A	45/100ml	512	1250	136	422	19
Dhoke Hassu TW # 89	155/100ml	480	1125	116	524	23
Hazara Colony TW # 81	22/100ml	280	1436	93	709	29
Hazara Colony TW # 81A	200/100ml	284	1138	90	750	23
Hazara Colony TW # 82	25/100ml	282	1554	92	781	31
Ratta Amral TW # 74	44/100ml	334	1462	108	732	29
Liaquat Bagh TW # 59	Nil/100ml	320	1329	104	666	27
Dhoke Ratta TW # 76-B	10/100ml	332	1348	108	675	27
Chamanzar TW # 60-B	50/100ml	320	926	104	463	19
Arya Mohallah TW # 58-A	20/100ml	318	1143	102	571	23

5. Geo-chemical investigation of soil strata of two tube wells were carried out with energy dispersive X-Ray fluorescence spectrometer (XRF) equipment. The logging and XRF analysis are shown in fig. 5.1 and 5.2 below;

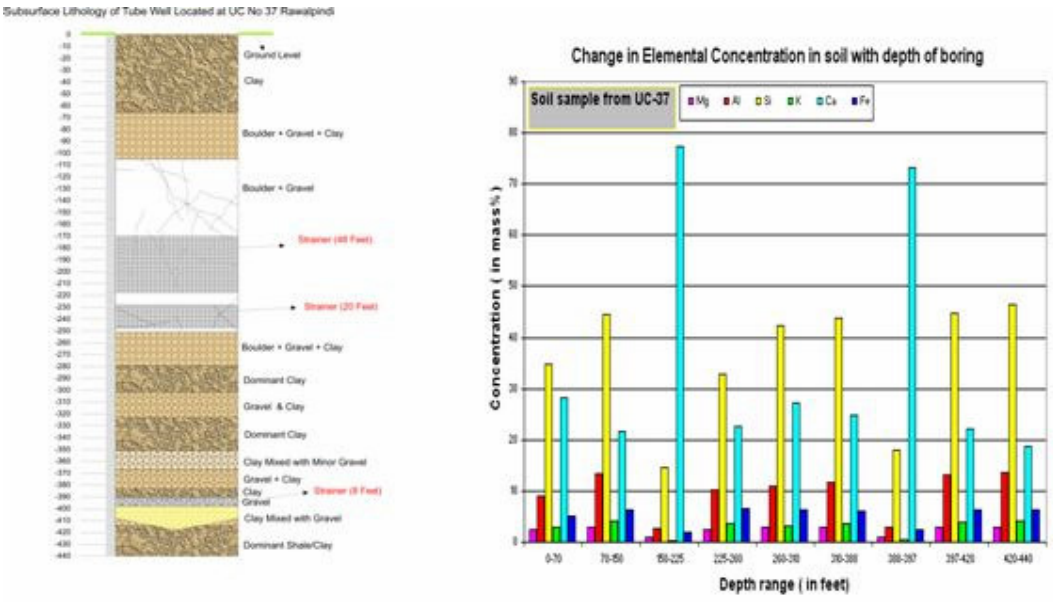

Fig. 5.1 Geo – Chemical analysis of soil strata of Tube well-37 near bank of Nallah Lai

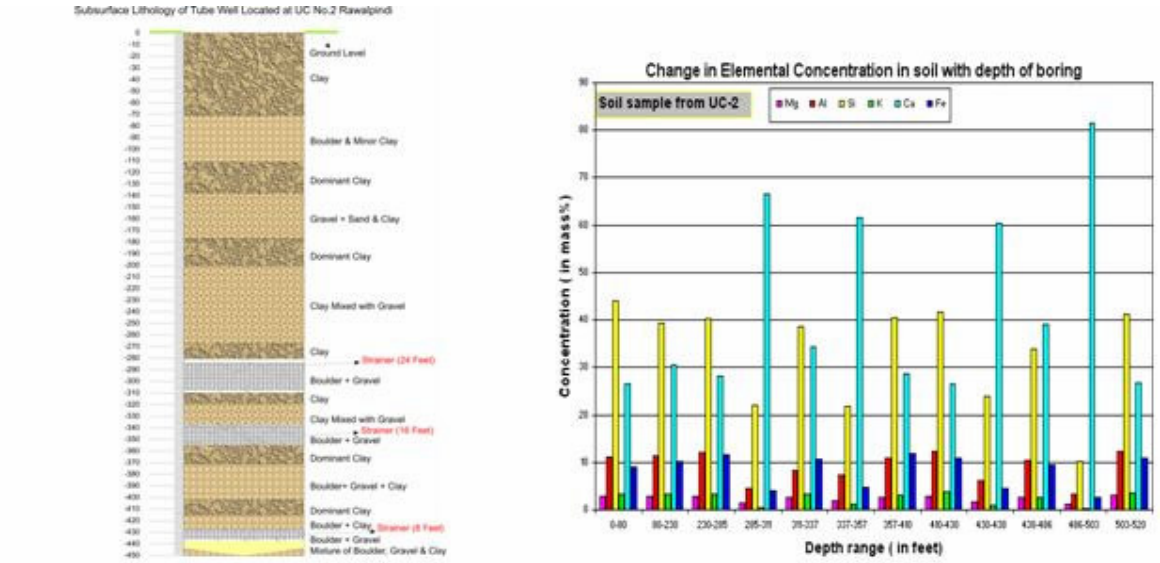

Fig. 5.2 Geo – Chemical analysis of soil strata of Tube-2 well near bank of Nallah Lai

6. Due to the puncturing of impervious rock from various locations, the bacteria can find easy route to the clear water aquifer, which is causing ground water contamination. Therefore, recent analysis of 220 tube wells has shown that all most 50 % of the 220 tube wells have shown bacterial contamination in the year 2007 against 33 % contamination in the year 2003/2004.

CHALLENGES AND ISSUES

7. There are several challenges due to following problems, as described below;

Organizational

1. Faulty Data base
2. Managerial intensive Organizational Structure
3 Imbalance Funding and Budgeting
4. In competency of management

Water Supply

8. Most of the distribution net work lines are passing through sewerage drains which are causing contamination at consumer's end. The other factors responsible for contamination are as under;

a. Non-existence of legislation on ground water extraction
b. Imbalance/ill-planned/Un-documented Distribution Network
c. Un-regulated / Non-metered / Non-judicious water supply
d. Major Leakages in Feeding mains (Old PRCC Pipe lines)
e. Hand-in-gloves laying of drinking water and sewerage lines-contaminant intrusion route, as shown in figure-8.1
f. Installation of unauthorized suction pumps by consumers – major cause of contamination.
g. Un-Authorized Installation of water connection & without approved ferrule size- In Commercial Plazas
h. Bacterial contamination in Ground water
i. Contamination in Filtration Plants installed by TMA
j. Poorly maintained Chlorination/Disinfection System.

Fig. 8.1: Hand in gloves laying of drinking water distribution pipe lines with sewerage drains.

Sewerage and Drainage- Contributing bacterial Contamination

a. Technically and Hydraulically ill planned sewerage network
b. Undersize sewer-frequent choking & overflow-mixing with drinking water lines.
c. Damaged sewer lines/appurtenances.
d. Encroachments on Sewers resulting in-accessibility for cleaning and maintenance.

NEW VISION AND MITIGATION STRATEGIES:

Short Term

9. Following short term mitigation measures have been taken which has reduced the water contamination at source and at consumer's end.

a. Installation of hypo chlorinators on contaminated tube wells.

b. Re-routing of the distribution lines away from the sewerage drains and replacing the damaged / rusty water pipe lines.

c. Managing the wastewater by constructing nodal system of wastewater treatment plants

d. Constant water quality monitoring

Short term measures have reduced water contamination at consumer's end from 46 % to nil at high risk areas. Figure-9.1, below shows nil contamination due to re-routing / replacement of water pipe.

REPLACEMENT / RELOCATION AND REROUTING OF WS LINES IN HIGH RISK AREAS

Location	Total Length of Pipe Replaced	Complaints of Water Contamination		Remarks
		Before	After	
WEST ZONE				
Union Council No. 1, 3, 5, 7, 9, 11, 12, 34, 37, 41	10773 RFT	> 1000	Nil	Replacement has been caried out in high risk areas
EAST ZONE				
Eastern Side of Murree Road, UC, 31, 46, 17, Surfraz road, kartar pure, abasia abad and kashmir colony	6248 RFT	910	Nil	Replacement has been caried out in high risk areas

This exercise has reduced the overall contamination level by approx. 18 %

Fig-9.1 Re-routing and replacement drinking water pipe lines - statistics

Long Time Mitigation Measures

10. Following long terms mitigation measures have been planned which help in checking the fast depleting ground water aquifer;

a. Ground water modelling and preparation of three dimensional water mapping showing water movement with the view to identify recharge areas / zones. This objective is be achieved with the assistance of International Ground water Assessment Centre(IGRAC)- Nederland's.

b. Switching over from ground water to surface water, in this regard a new dam (15 MGD) has been planned which reduce reliance considerably on ground water.

c. Concreting of Nallah Lai to Lining to stop seepage of wastewater. The recommended design is as shown in fig-10.1

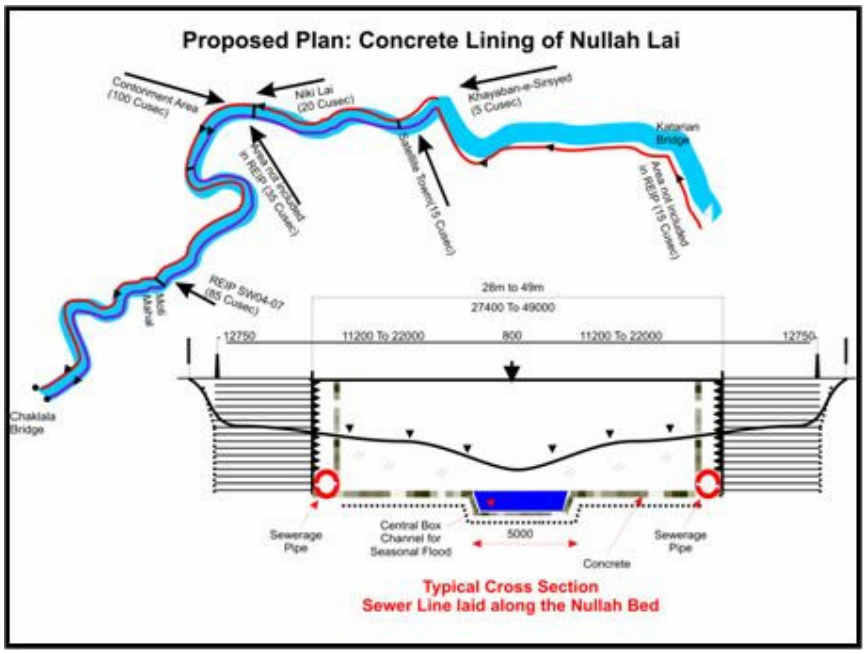

Fig.10.1 Plan View and Cross section - Concrete Lining of Nullah Lai (Wastewater Drain)

d. Construction of wastewater treatment plant of capacity 60 MGD to manage wastewater.

e. Twinning of Water and Sanitation Agency, Rawalpindi with mega cities for sharing best practices. This objective was achieved during the 2nd annual mega city water forum at Atlanta, USA, as described below;

Partner city	**Area of interest**
Seattle	Funding and Budgeting
Sarajevo	Water quality Management
Tucson	Water efficiency
Atlanta	Water Management
Alburqurque	Adequate water supply

RESULTS DISCUSSION

11. During the course of research, following have observed;

a. The rate of extraction of ground water (120 MGD) is much more than the recharge. Virtually there is no planned recharge mechanism in place, therefore, the

aquifer depletion rate is about 10 feet/year. Hence, due to this phenomenon, there can be a big environmental disaster in the city of Rawalpindi-Pakistan.

b. Over extraction of ground water has exposed the upper aquifer, thus causing bacterial contamination at a faster rate. About 50% tube well now producing contaminated water verses 33% in 2003.
c. Most of the un-treated domestic wastewater flowing in open drains is also contributing towards ground water bacterial contamination.
d. Geo-chemical analysis of soil strata has shown some traces of heavy metals, which may be polluting ground water chemically as well.
e. Nullah Lai is the main source of bacterial contamination, as all the tube wells installed near the Nullah bank are producing contaminated water.
f. There is an immediate requirement of ground water modeling to identify the ground water movement and recharge areas.

CONCLUSION

12. By compulsion, the city of Rawalpindi has to rely on ground water sources. Over extraction of ground water has caused fast depletion of aquifer which has raised alarming levels of bacterial contamination. Though, the surface water is available, but due to ill planning and mismanaging the cheaper sources of surface water. There is a dire need of switching from ground water to surface water, now with realization; the government is planning for conductance of surface water from River Indus, Terbella Dam. The concrete lining of Nullah Lai will also reduce the bacterial contamination considerably.

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ABBREVIATIONS AND ACRONYMS

a. MGD: Million Gallons per Day.
b. ppb parts per billion.
c. TMA Tehsil Municipal Administration
d. PRCC Pre-stressed Reinforced Cement Concrete
e. TW Tube Well
d. m^3 Meter Cube