Sustainable water management - Nexus between groundwater quality and sanitation practice

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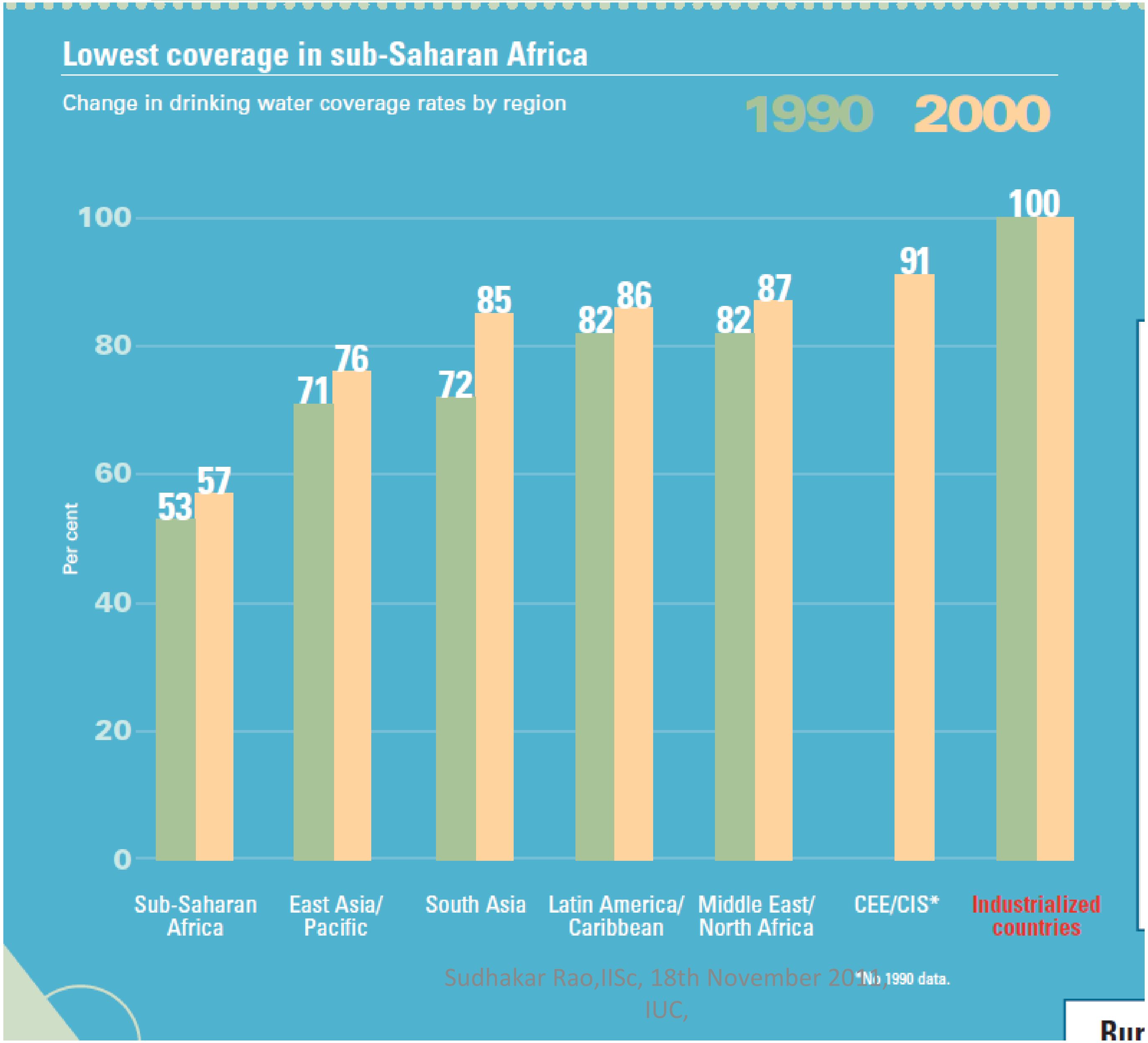
Problem Statement

Per cent of population with access to safe drinking water, (1990) and 2000



WHO/UNICEF Joint Monitoring Programme, 2001.

South Asia

Maldives (-)	100
Bangladesh (94)	97
Pakistan (83)	90
Nepal (67)	88
Regional average (72)	**85**
India (68)	84
Sri Lanka (68)	77
Bhutan (-)	62
Afghanistan (-)	13

WHO/UNICEF Joint Monitoring Programme, 2001.

*Access to safe drinking water is determined by percentage of population using improved water sources.

Improved: Household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection.

Not improved: Unprotected well, unprotected spring, river, pond, vendor-provided water, tanker truck water.

Groundwater serves as a decentralized source of "safe drinking water" for millions of rural and urban people. It accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs of the country.

Kumar and Shah 2004, Groundwater contamination

Issues Impacting SGWM in Indian Context:

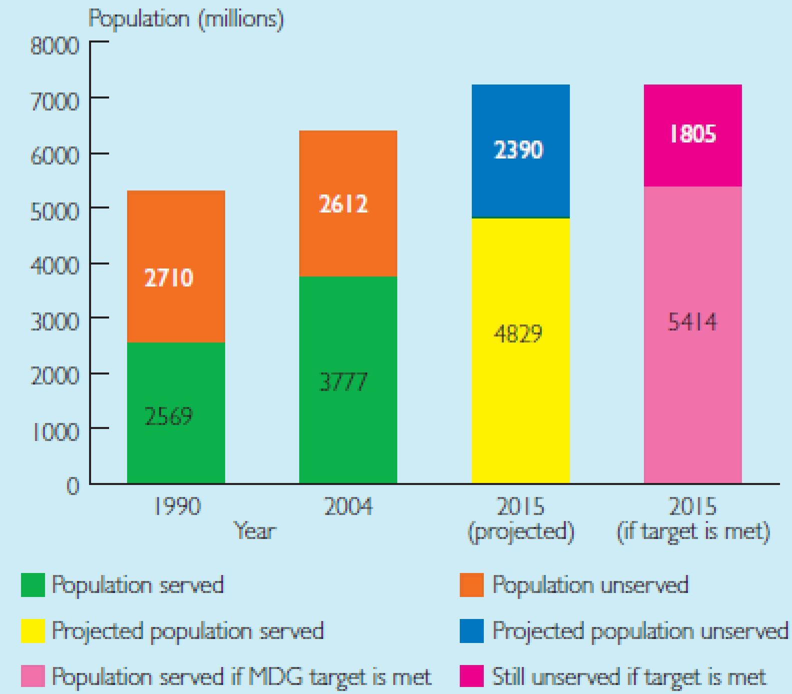
- Sources going dry or lowering of the ground water table.
- Sources becoming quality affected.
- Systems outliving their lives.
- Systems working below rated capacity due to poor operation and maintenance.
- Increase in population resulting into lower per capita availability.
- Emergence of new habitations.
- Acute seasonal shortages
- Over-exploitation of resources

Report of Working group on 11th Plan for DDWS 2007-2012

Sanitation coverage

63% of the urban population in **India** has got access to sewerage and sanitation facilities (47% from sewer and 53% from low cost sanitation) as on March 2004. As a consequence, open defecation is prevalent widely in rural areas but also significantly in urban areas too.

Figure 2
World population with and without access to improved sanitation in 1990, 2004 and 2015



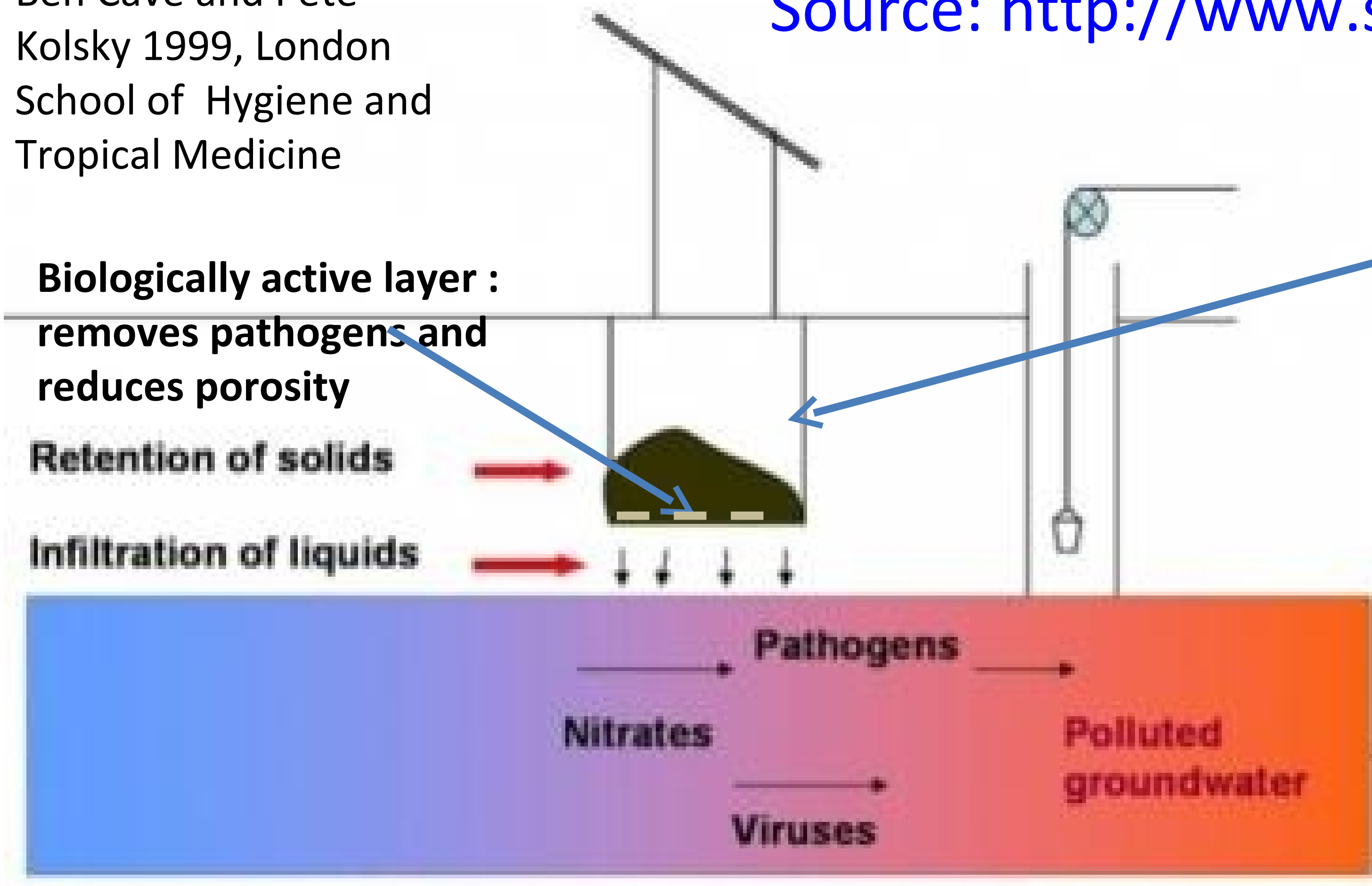
> The number of people without improved sanitation decreased by only 98 million between 1990 and 2004.

> The global MDG sanitation target will be missed by more than half a billion people if the trend 1990–2004 continues up to 2015.

11th Plan Document on Drinking Water Supply & Sanitation

Ben Cave and Pete Kolsky 1999, London School of Hygiene and Tropical Medicine

Source: http://www.sswm.info)



Pit latrine, ventilated improved pit latrine and pour flush toilets.

Pathogens: Bacteria (0.4 to 2.5μ) and viruses (0.01 to 0.25 μ)

Most nitrogen is excreted as urea, which readily degrades to ammonium. Nitrate is formed by the sequential, microbially-catalysed oxidation of ammonia to nitrite and then to nitrate

Ben Cave and Pete Kolsky 1999, London School of Hygiene and Tropical Medicine

Pathogen movement and removal by soil

Bacteria travel depends on velocity of groundwater flow. During travel, fraction die or retained (adsorbed or screened) on soil matrix.

Key factor for removal of bacteria and viruses from groundwater: effluent residence time between contamination source and point of water abstraction.

Unsaturated zone is most important line of defence against faecal pollution of aquifer as it is less permeable

Probable survival time for coliforms in anaerobic groundwater environment is 4-7 days.

Case study

Background & Scope

- The population is 60,000 and supply is ~ 5 MLD and entirely through GW.
- To develop a sustainable water management plan towards the future needs. To efficiently manage the groundwater resources in terms of quantity & quality.
- Geochemical & Microbiological surveys were performed simultaneously.

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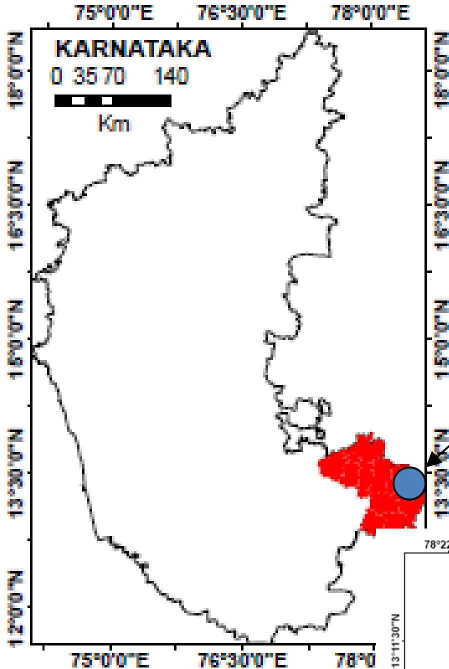
Groundwater Management under IUWM

Karnataka State



Mulbagal Town

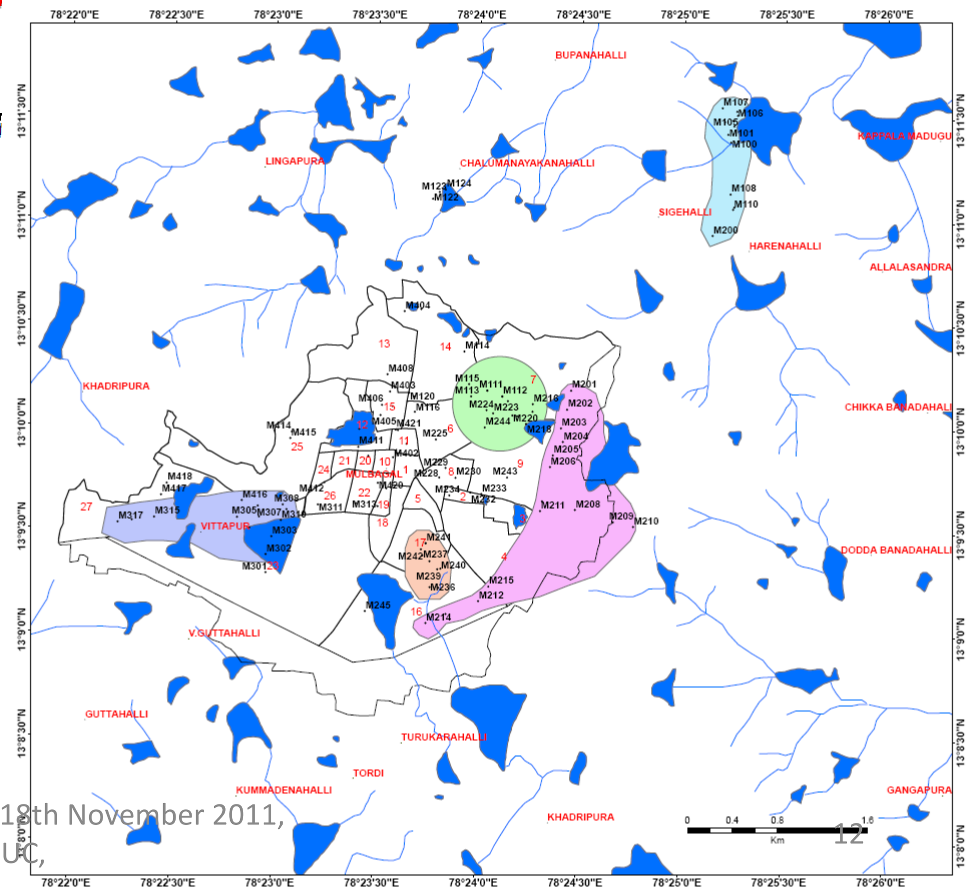
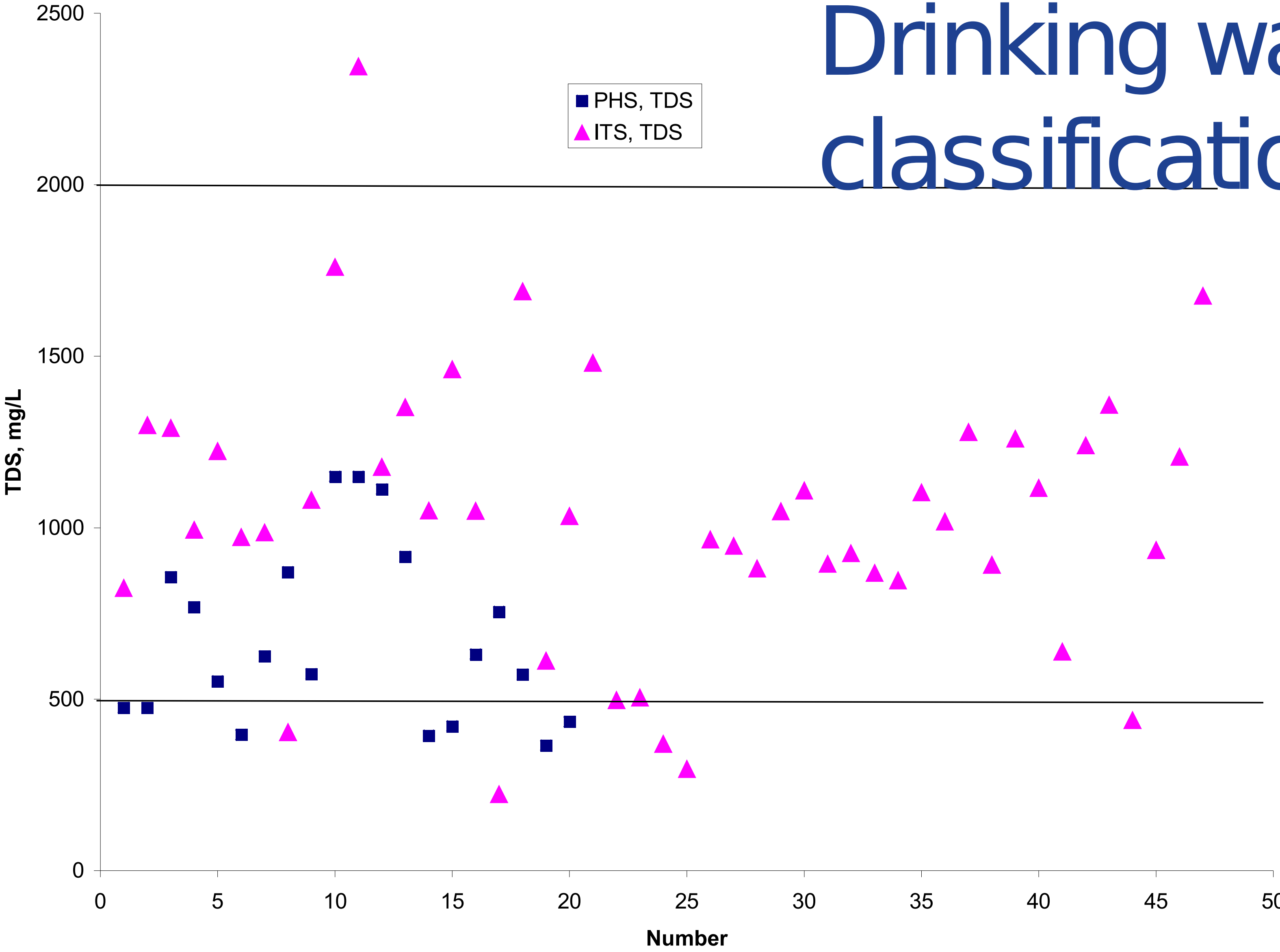


Table 5: Bore-well details of pump-house series

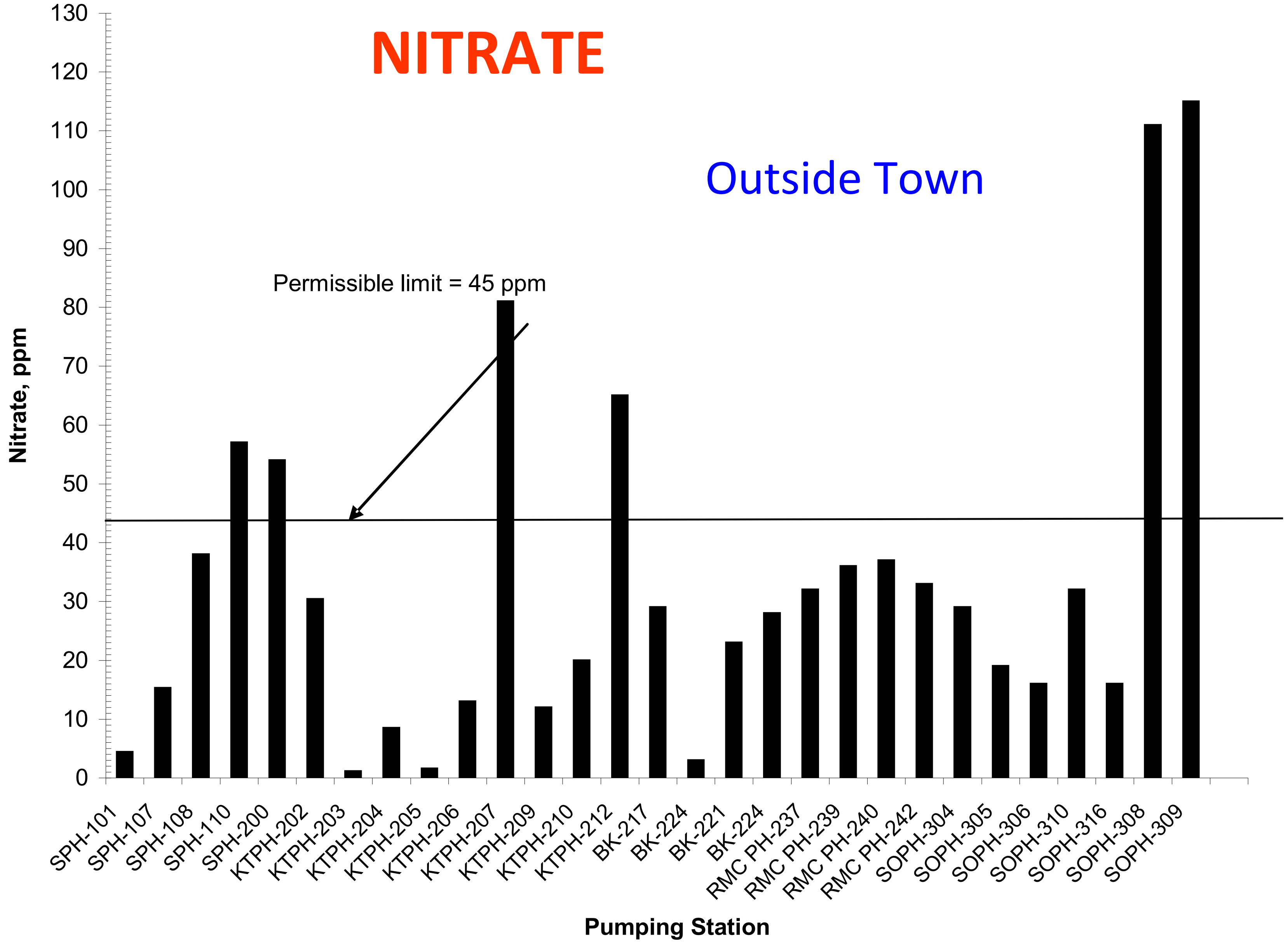
Pump-house series	Supplying bore-wells
Seeganahalli pump house (SPH)	M-101, M-107, M-108, M-110, M-200
Kalikamba pump house (KPH)	M-202, M-203, M-204, M-205, M-206, M-207, M-209 , M-210
Someshwarapalya pump house (SOPH)	M-304, M-305, M-306, M-308, M-309, M-310, M-316, M-317
Busal Kunte pump house (BPH)	M-111, M-217, M-221
RMC pump house (RMCPH)	M-237, M-239, M-240, M-242

The remainder 47 bore-wells contribute to the Inner town series. These bore-well numbers are: M-114, M-115, M-116, M-117, M-118, M – 119, M – 120, M-121, M-122, M-123, M-124, M – 225, M-226, M-227, M-228, M-229, M-230, M-231, M- 233, M-234, M-235, M-236, M-244, M-245, M-300, M-312, M-313, M-314, M-400, M-401, M-402, M – 403, M-404, M-405, M-406, M-407, M-408, M-410, M-411, M-412, M-413, M-414, M- 415, M-417, M-419, M-421 and M-422 respectively.

Drinking water classification

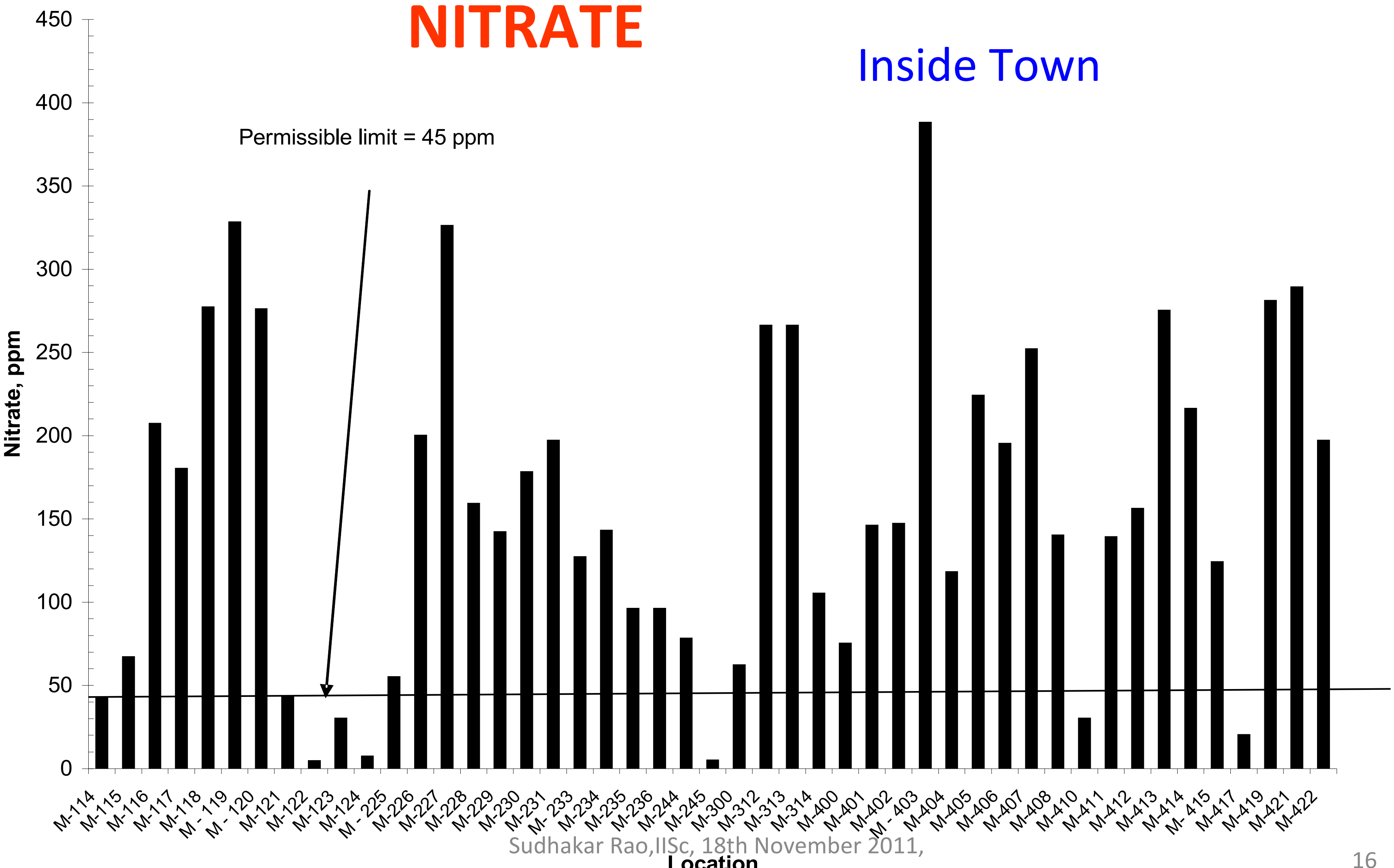


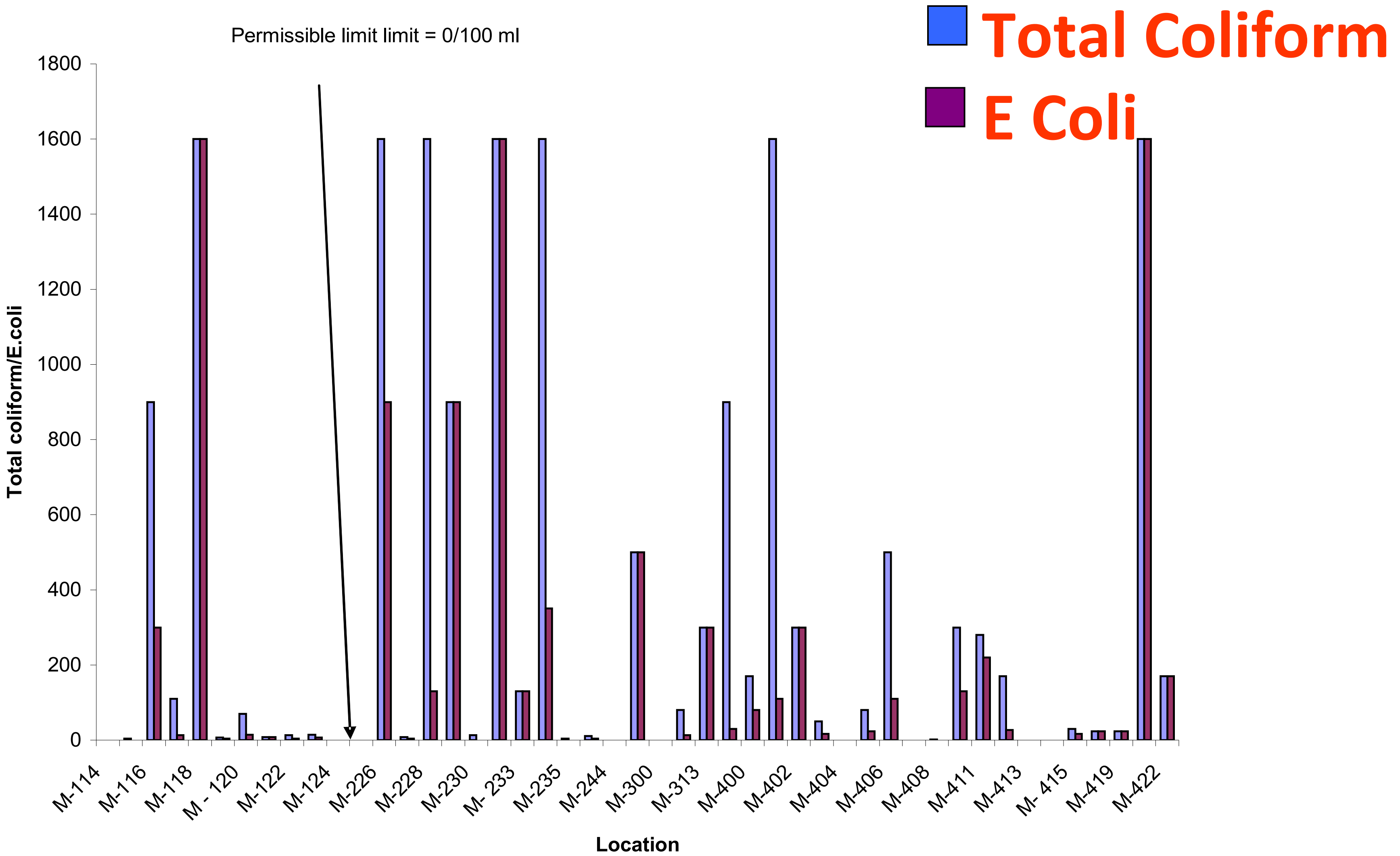
Nitrate, Pump house series



$$2\,NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 4H^+ + 2H_2O \text{ (Nitroso-bacteria) (2)}$$

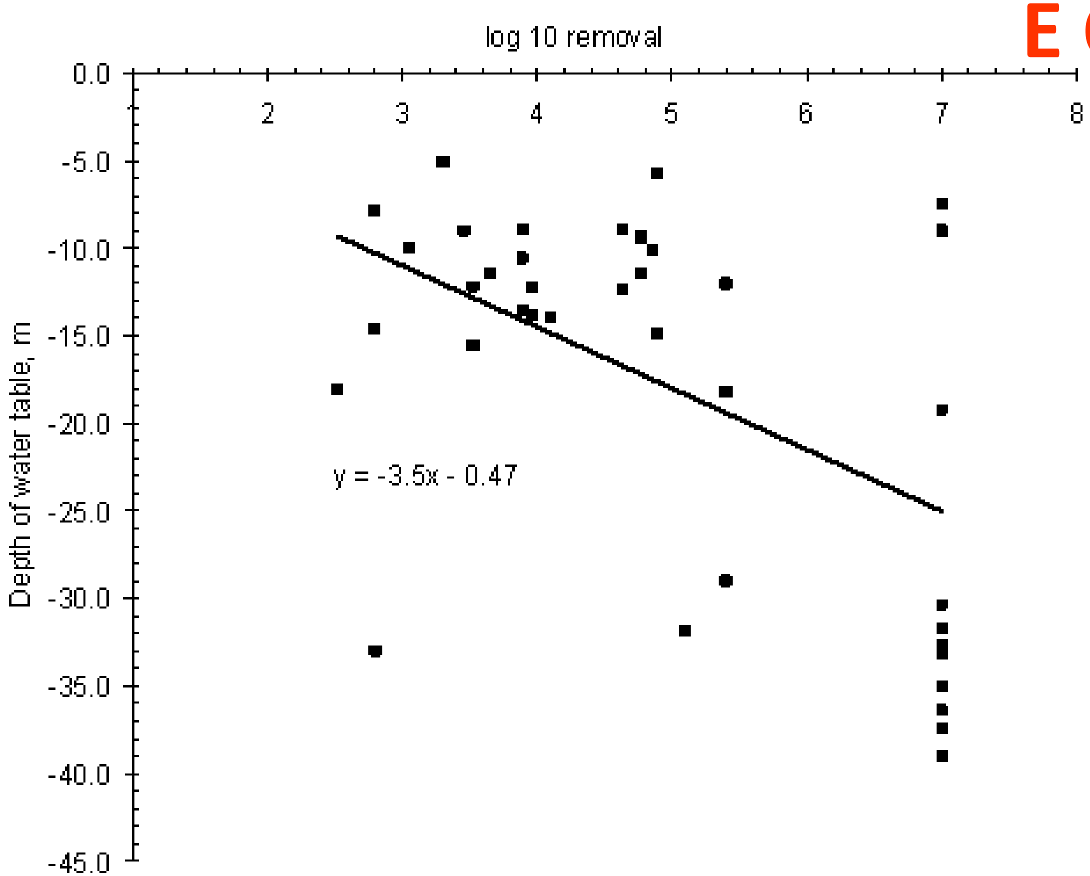
$$2NO_2^- + O_2 \longrightarrow 2NO_3^- \text{ (Nitro-bacteria) (3)}$$





The presence E. coli in the groundwater samples indicate fecal contamination “inside the town”. No contamination was found “outside town”

E Coli Attenuation



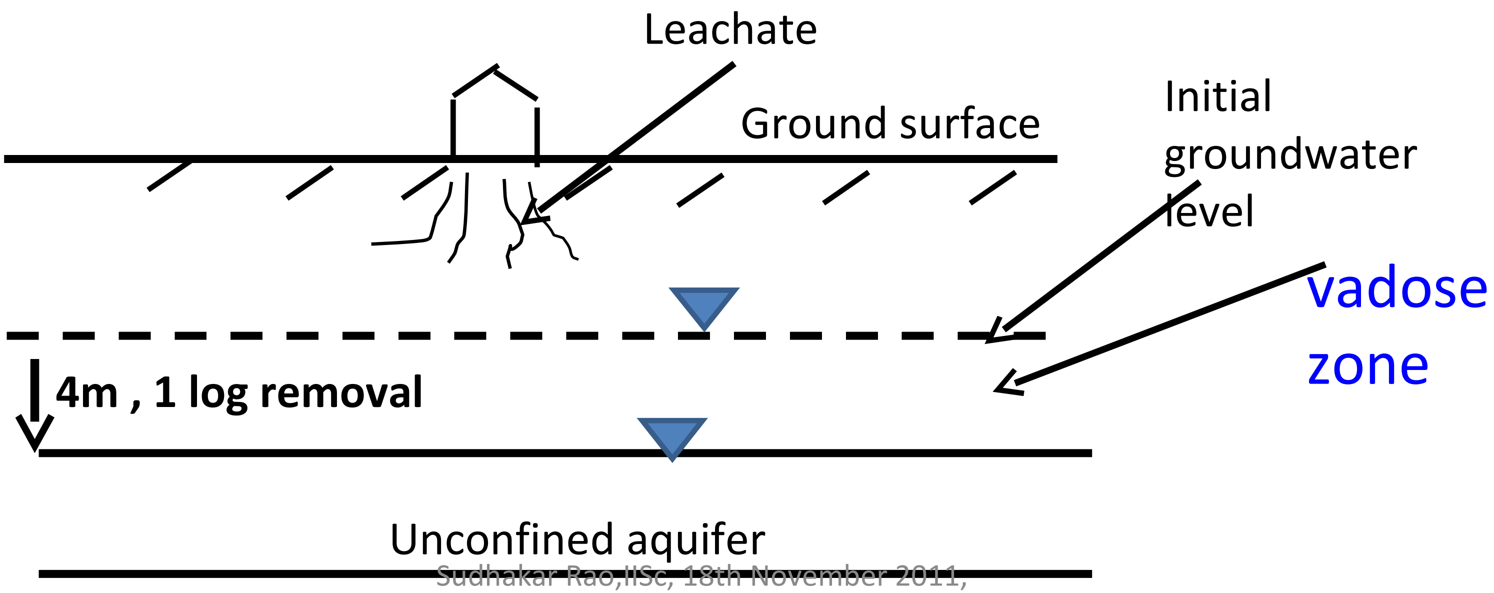
One log removal of E Coli needed 4 m of decline in groundwater level

Probable survival time for coliforms in anaerobic groundwater environment is 4-7 days: Average say 5.5 days

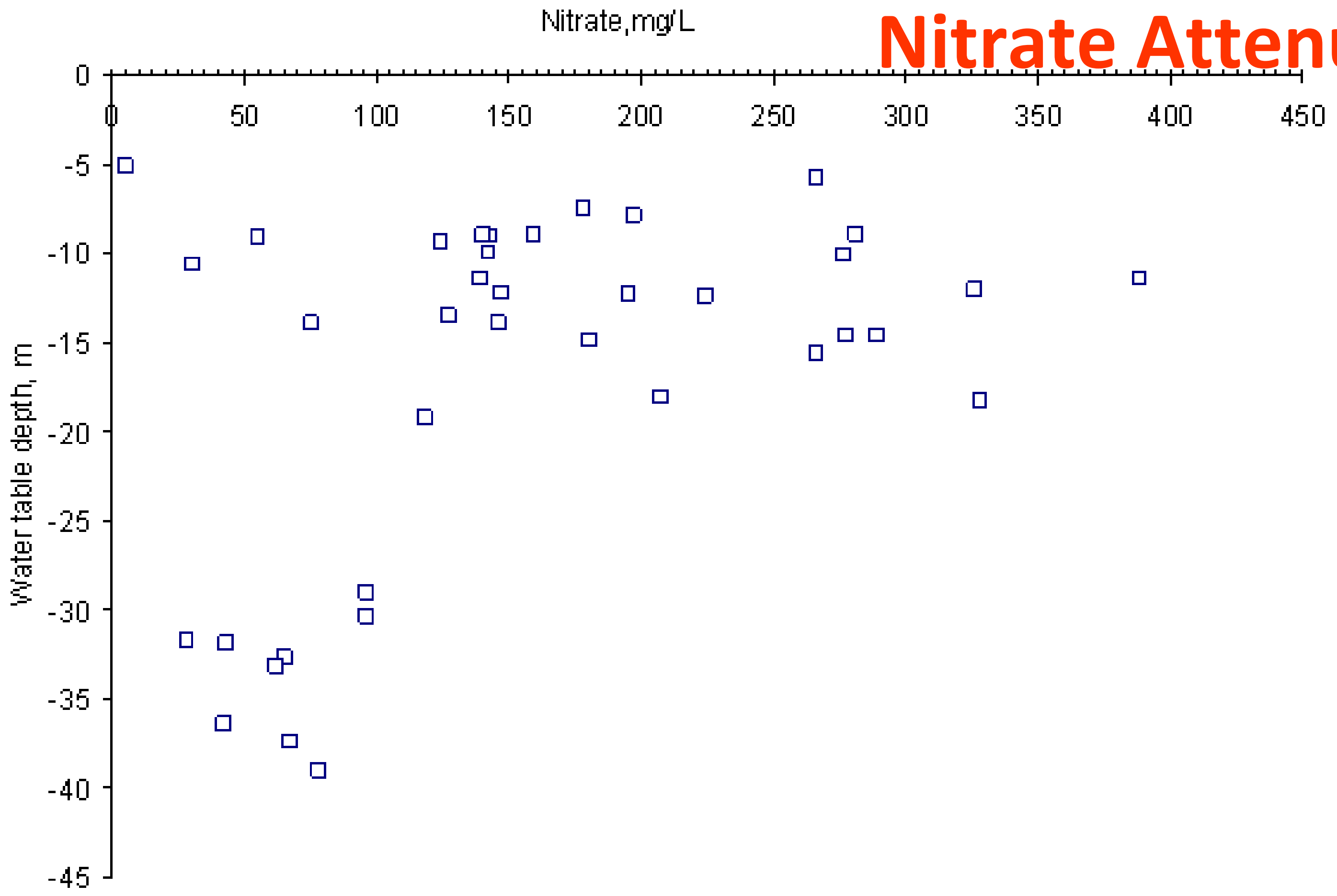
One log removal of E Coli needed 4 m of decline in groundwater level which leads to creation of 4 m of vadose zone

Groundwater travel of 4 m in vadose zone over 6 days is necessary for one log removal of E coli

This suggests that permeability of vadose zone was close to 10^{-8} cm/s



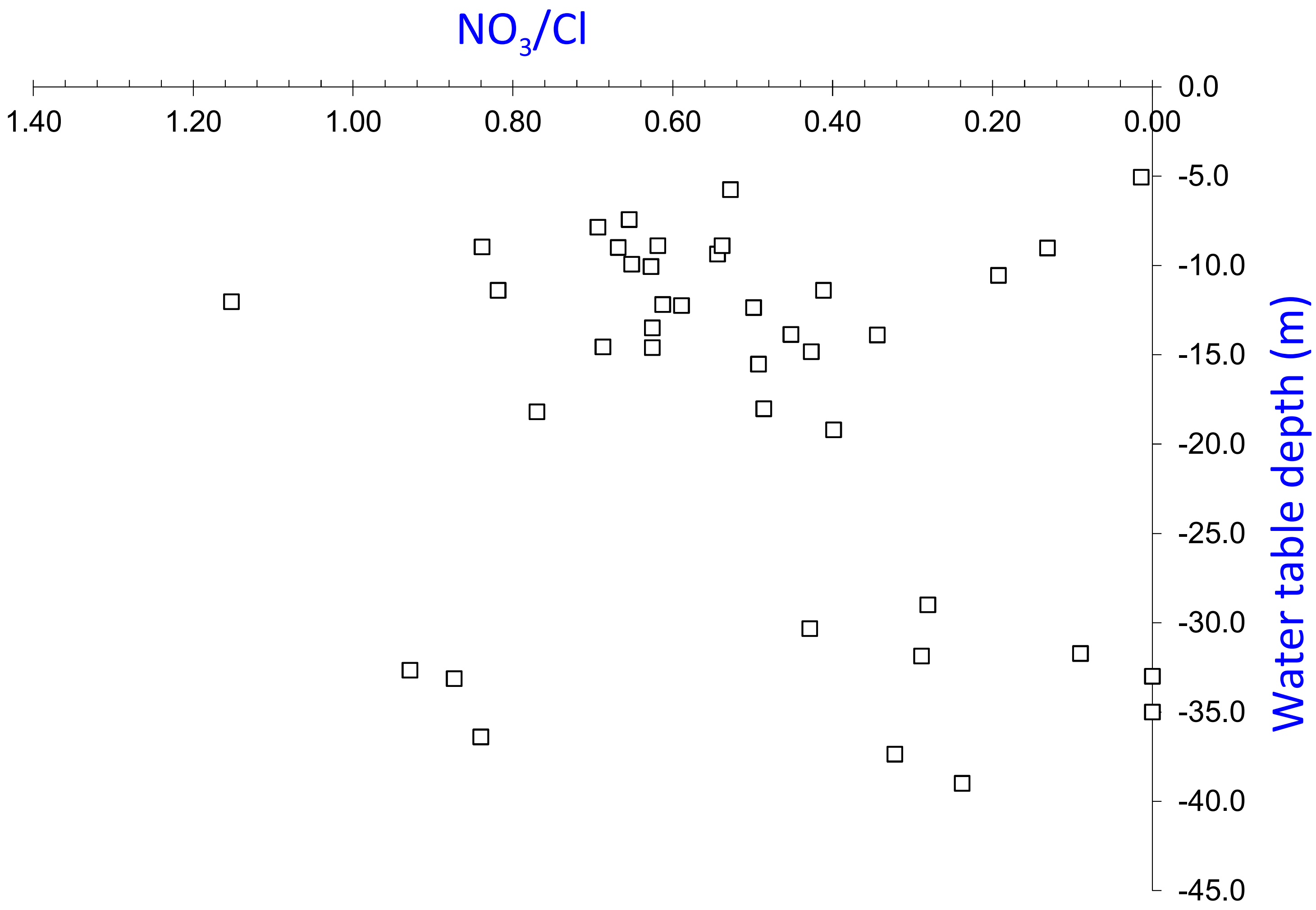
Nitrate Attenuation



Nitrate was insensitive groundwater level upto 15 m

> 15 m the Nitrate levels varied with depth

Nitrate Attenuation - Mechanism



Constant NO_3/Cl ratio with depth implied Nitrate reduction at depths >15m due to **Dispersion**

Contamination during water transmission

Table 4: Nitrate and microbial levels in Outer Town Bore-wells (supplying to Someshwarapalya reservoir) during set I and set II testing

BW No.	304		305		306		308	
Parameters	I set	II set	I set	II set	I set	II set	I set	II set
Nitrate, mg/L	29	14	19	3.5	16	22	111	101
Total coliforms, MPN/100 mL	21	2	Nil	4	2	Nil	Nil	2
E.Coli, MPN/100 mL	6	Nil	Nil	2	Nil	Nil	Nil	2

Table 5: Microbial levels at Someshwarapalya reservoir supplied by BW Nos. 304, 305,306 and 308

Parameter	Value
pH	7.48
TDS, mg/L	334
Total Coliform, MPN/100 mL	500
E. Coli, MPN/100 mL	240

Figure 9: Water being pumped to Someswarahpalya reservoir

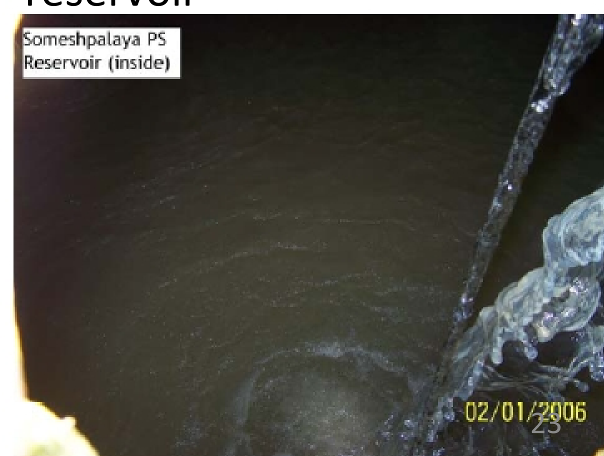


Figure 10: Water supply point at individual household (inside town) supplied by Someshwarapalya reservoir

Table 6: Microbial levels at individual household (inside town) supplied by Someshwarapalya reservoir

Parameter	Value
pH	7.39
TDS, mg/L	642
Total Coliform, MPN/100 mL	1600
E. Coli, MPN/100 mL	500

Health Implications

Drinking Water Quality in Urban Areas: Why and How it is Getting Worse?

A Case Study of South Indian Cities[1]

N Praveen[2], B K Anand[3], N Deepa[4], N Latha[5], K.V Raju[6] and HL Shashidhara[7]

Table 2: Estimates of Water-Related Mortality Source

Source	Deaths per Year
World Health Organization 2000 2.2	2.2 million (diarrheal diseases only)
World Health Organization 1999 Water Dome 2002	2.3 million More than 3 million
World Health Organization 1992	4 million
World Health Organization 1996	More than 5 million
Hunter et al. 2000	More than 5 million
UNDP 2002	More than 5 million
Johannesburg Summit 2002	More than 5 million
Hinrichsen et.al, 1997	12 million

No mention of pathogen contamination in groundwater resources

Nature of Quality problem	No. of affected habitations
Excess Fluoride	31306
Excess Arsenic	5029
Excess Salinity	23495
Excess Iron	118088
Excess Nitrate	13958
Multiple quality problems	25092
Total	216968

RURAL WATER SUPPLY SECTOR BACKGROUND PAPER

Questions, Solutions & Reflections

Questions emerging from the studies

Can bore-well water be considered free of pathogen presence

Contamination from leachates of on-site sanitation systems and improper well-protection tend to render bore-well water contaminated with pathogens.

Should alternative forms of sanitation be adopted

Wherever possible off-site sewerage systems be implemented. However in country like India, where the proposed alternative requires a great deal more water or a substantially increased cost, on-site sanitation system remains a viable choice

Possible solutions to reduce pathogen contamination of bore-wells

In pathogen contaminated aquifers, guided by the site hydro-geology, engineer the vadose zone thickness to ensure 7 log removal of pathogen in infiltrating leachate.

Improve well construction & protection to minimize groundwater contamination.

As studies have identified transport, storage, and user practice in the home, as contamination source, end-of-use point treatment be implemented.

Questions, Solutions Cont.

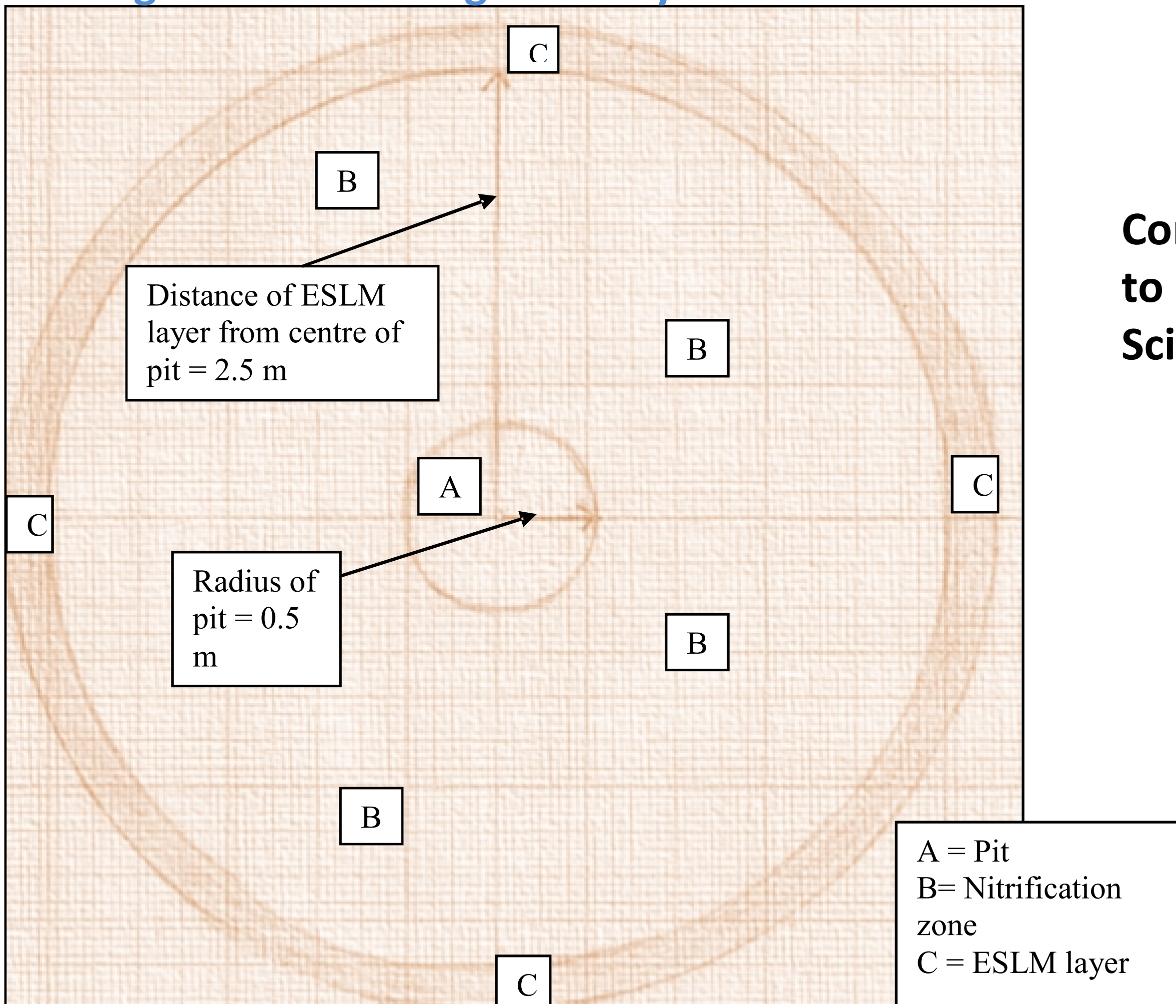
Dilution Versus Abstraction-Which serves the cause of quality improvement better:

In aquifers having pathogens as major contaminant; abstraction of groundwater to increase the thickness of vadose zone would serve the cause of quality improvement. In other words re-charge of aquifers or groundwater dilution is not recommended as they would reduce the vadose zone thickness.

In aquifers having chemicals as major contaminants; dilution/re-charge would serve the cause of quality improvement for obvious reasons.

How to minimize nitrate production in on-site sanitation systems?

By introducing nitrate reducing ESLM layer



Communicated to Current Science

ESLM+ elemental sulfur+lime material

Should Mulbagal model of study extended to other towns

Nearly 50 % of drinking water in urban centres of the country depend on groundwater for their drinking water requirement. An equal percentage depend on on-site sewage system for human waste disposal.

The nexus between groundwater quality and sanitation practice observed in Mulbagal town can be expected to repeat in these towns .

Further, while Mulbagal town had no small-scale industries compounding the water quality issue, the same cannot be said of other towns and needs a detailed study of the groundwater quality scenario.

Quality coupled with quantity studies are essential to develop possible hydrogeological solutions as in Mulbagal town

Acknowledgements:

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