Nitrate Contamination in Groundwater and Health Effects due to Unhygienic Sanitation Practices: Study of Rural India

Pinky Taneja, AcSIR-PhD Senior Research Fellow
Water Technology and Management Division,
CSIR-National Environmental and Education Research Institute,
Nagpur, India-440020

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Elementary Highlights

1. Nitrate Pollution

2. Background

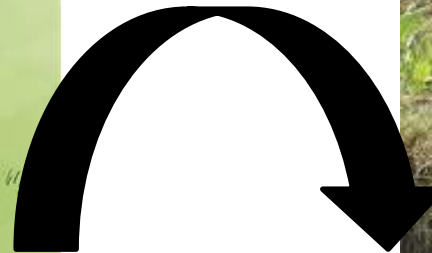3. Nitrate contamination of groundwater: Study in Nagpur district

4. Nitrate contamination of groundwater and vegetables: Intake and Health risk assessment in Nagpur and Bhandara district
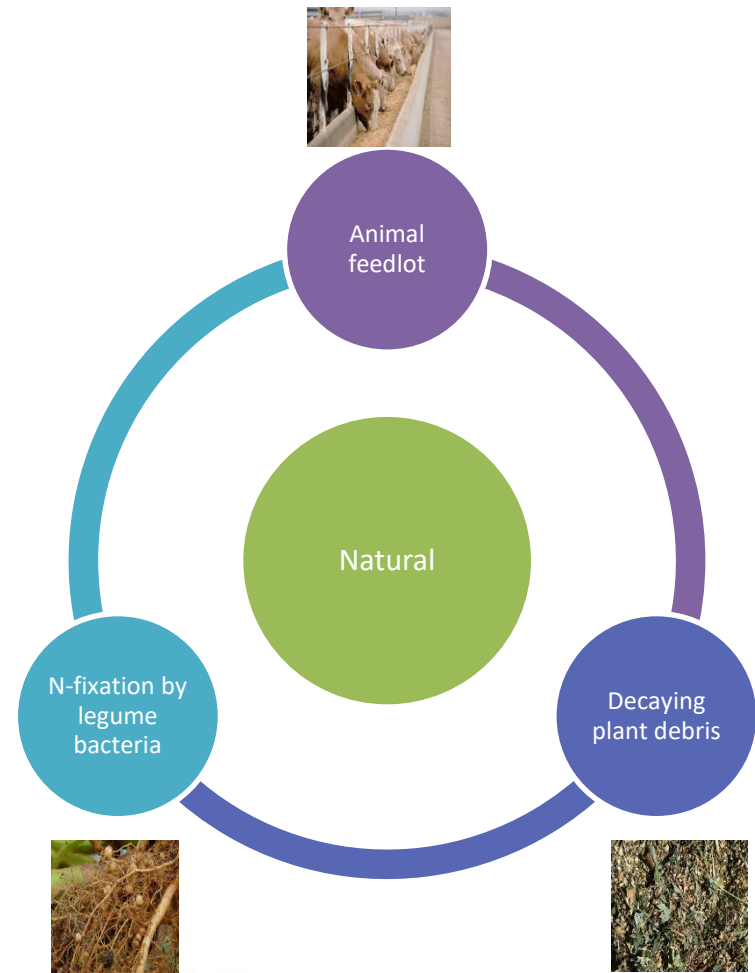
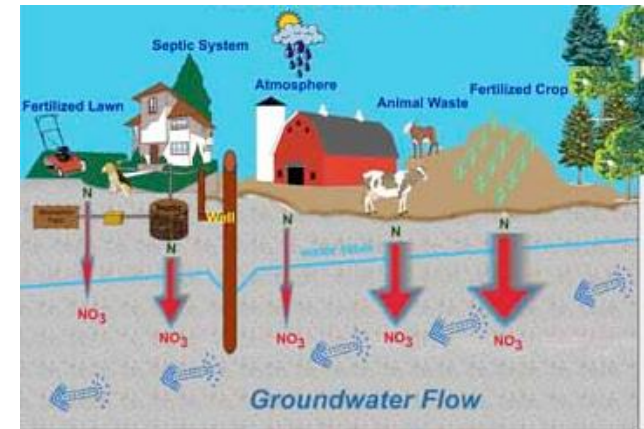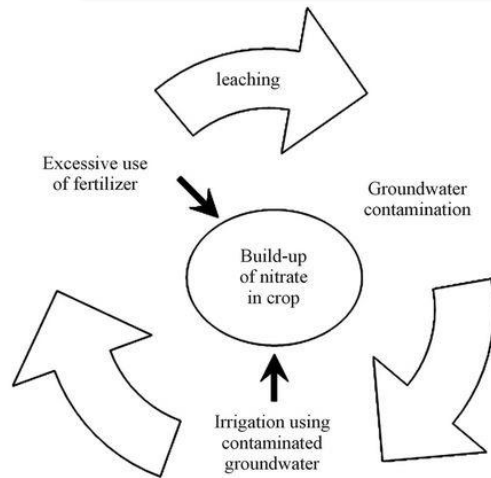5. Prospective Studies

1. Nitrate Pollution

Sources

Exposure

Food

Nitrates

Drinking water

Standards

WHO

50 mg/l

Guideline Value

European Union

50 mg/l

Maximum contaminant level

EPA

44 mg/l

Maximum contaminant level

BIS

45 mg/l Acceptable limit
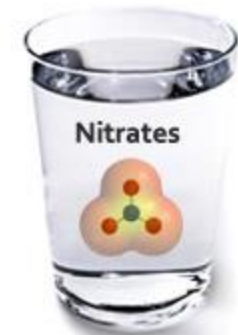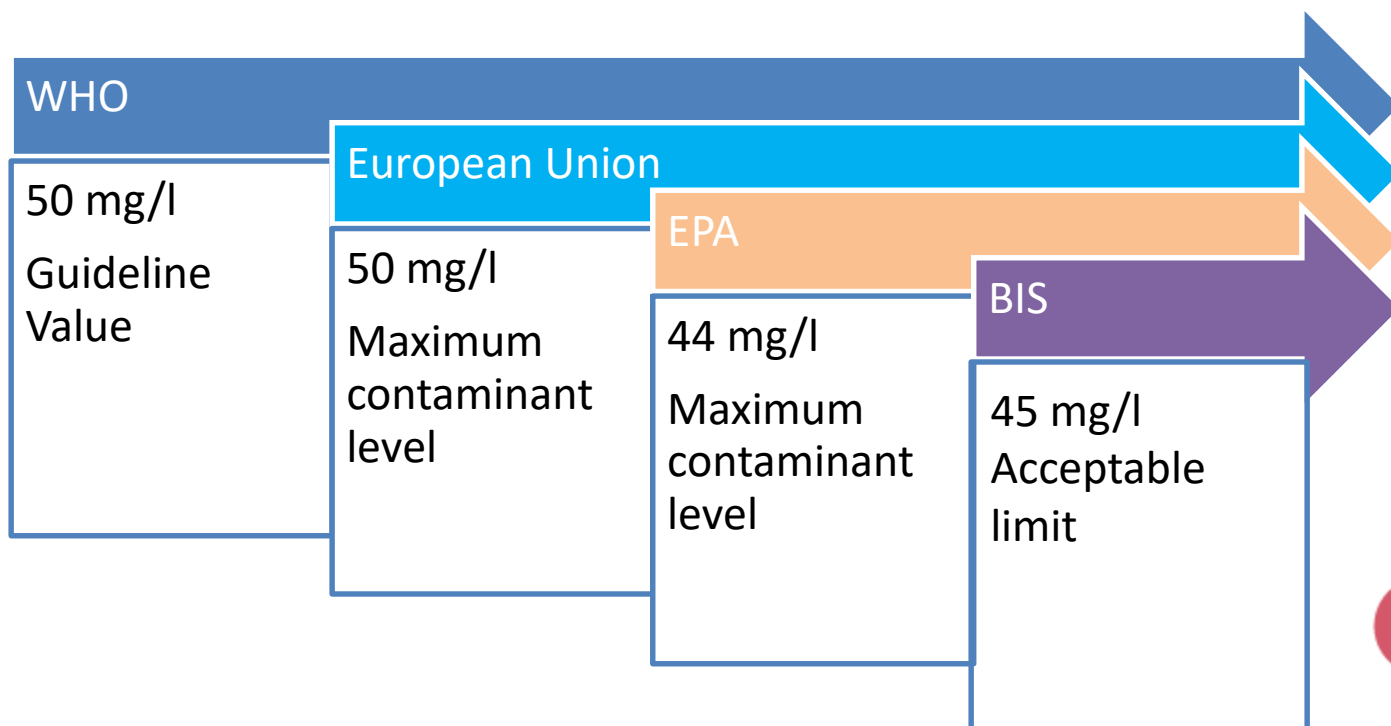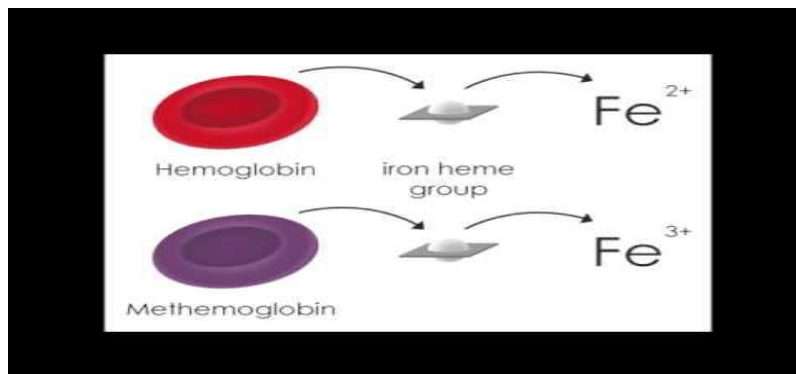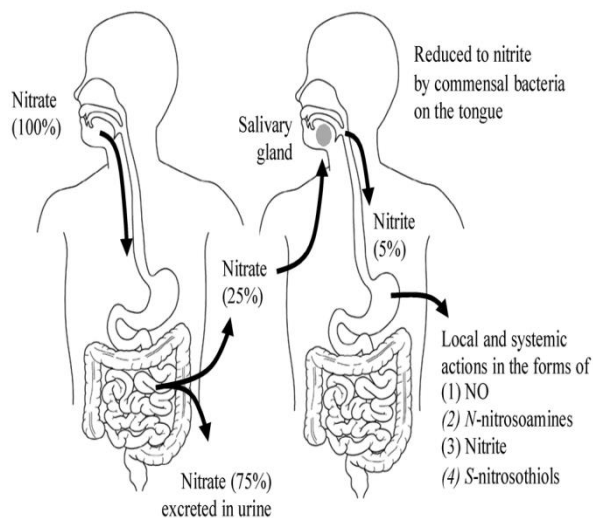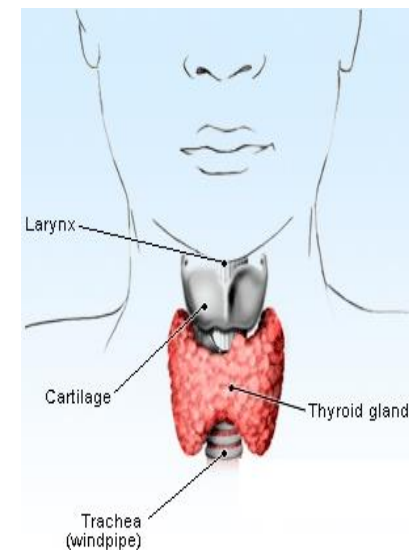
Acceptable level of Nitrate
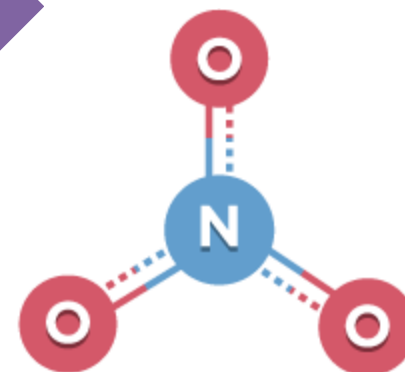
Methemoglobinemia

Health Effects of Nitrate

Carcinogenic Compounds
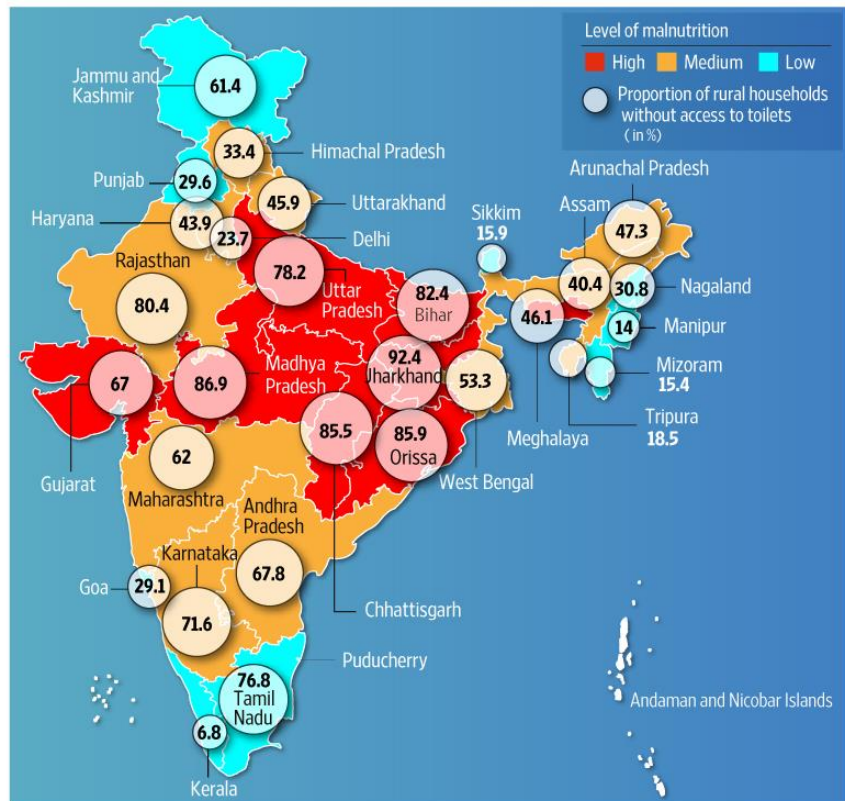
Iodine Inhibition

2. Background

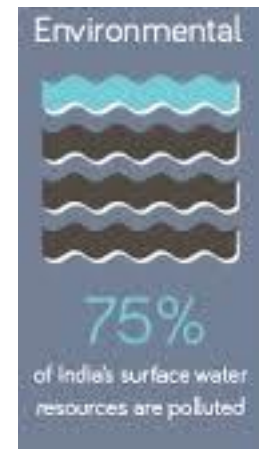SANITATION CRISIS

Level of malnutrition
High | Medium | Low
Proportion of rural households without access to toilets (in %)

Jammu and Kashmir — 61.4
Himachal Pradesh — 33.4
Punjab — 29.6
Uttarakhand — 45.9
Haryana — 43.9
Delhi — 23.7
Rajasthan — 80.4
Uttar Pradesh — 78.2
Sikkim — 15.9
Assam — 47.3
Arunachal Pradesh
Bihar — 82.4
Nagaland — 40.4 / 30.8
Manipur — 14
Madhya Pradesh — 86.9
Jharkhand — 92.4
— 46.1
Mizoram — 15.4
— 67
— 53.3
Tripura — 18.5
Gujarat — 62
Orissa — 85.9
Meghalaya
Maharashtra — 85.5
Andhra Pradesh
West Bengal
Karnataka
Goa — 29.1
Chhattisgarh — 67.8
— 71.6
Puducherry
Tamil Nadu — 76.8
Andaman and Nicobar Islands
Kerala — 6.8

Source: National Family Health Survey, Census

Environmental
75%
of India's surface water resources are polluted

Human Health
386,600
children under the age of five die each year in India from diarrhoea, through fecal-oral transmission

Economic
India loses
$120 MILLION
a year from labor sick days, counting the cost of treatment and the loss of production

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Sanitation and Health

Distribution of sanitation facilities (2008)

Legend:
- Distribution of sanitation facilities (2008)
- Open defecation
- Unimproved facilities
- Public/shared facilities
- Improved sanitation facilities

Pie chart values: 17%, 11%, 12%, 60%
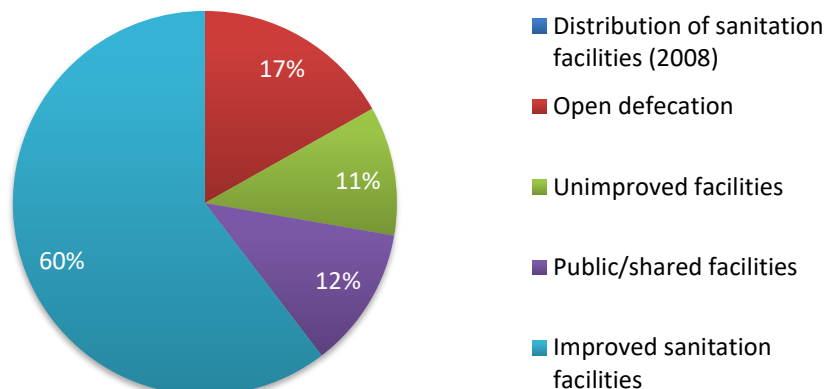
Percentage of households having no latrine in India: 2001-2011

Bar chart (2011 and 2001):
- Total: 53.1, 63.6
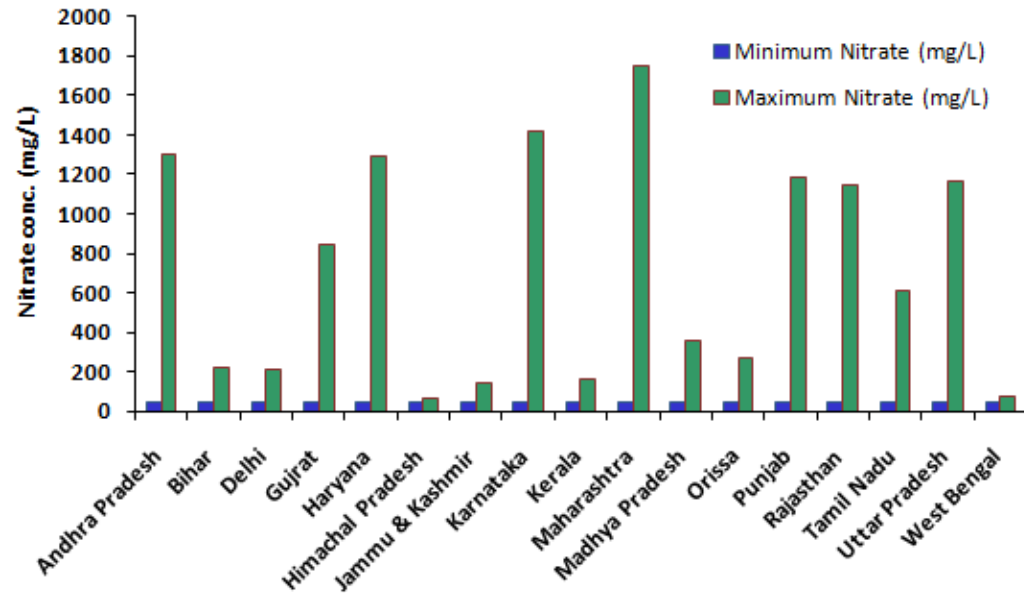- Rural: 69.3, 78.1
- Urban: 18.6, 26.3
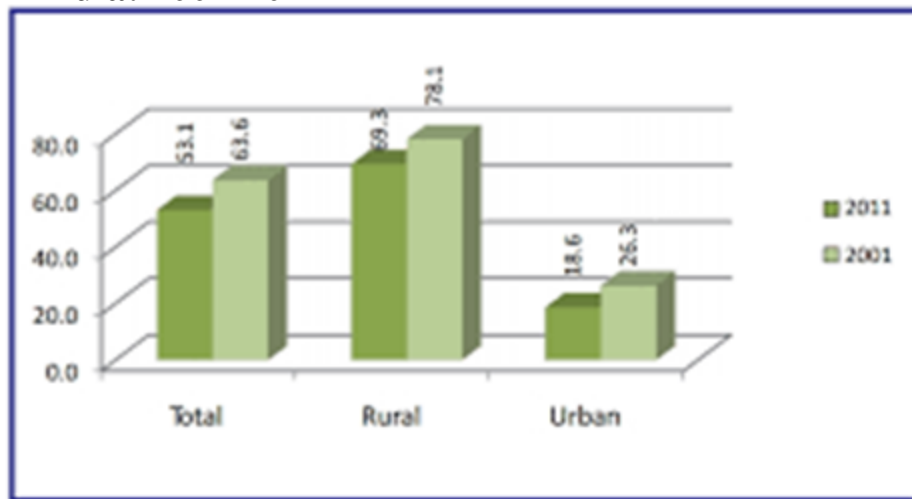
✓ **40% population lack improved sanitation facilities (WHO,UNICEF)**

✓ **7.97% urban Indian households do not have access to toilets and defecate in open**

✓ **67% rural Indian households defecate in open**

✓ **Unsafe or inadequate water, sanitation and hygiene cause 3.1% deaths worldwide**

Indian Scenario

Localized Occurrence of Nitrate (>45 mg/litre) in Ground Water in Different States of India
Source: CGWB, March,2010

✓**Mean nitrate levels have risen by 36% globally (GEMS, 2004)**

✓**20-50% of wells in India and Africa have higher nitrate levels (FAO, 2000)**

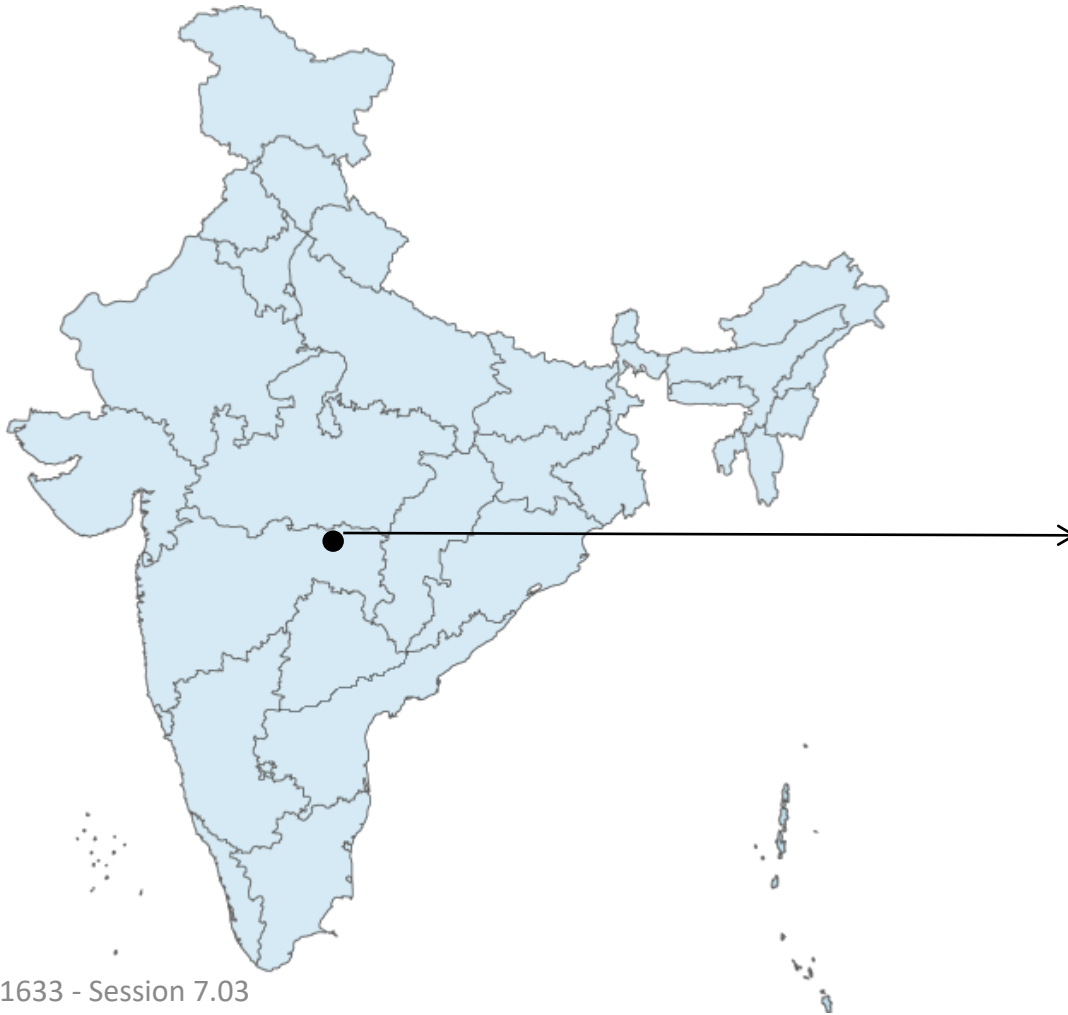✓**Chennai, India over-extraction of groundwater resulted in saline water 10 km inland of sea**

3. Nitrate contamination of groundwater : Study in Nagpur district

Methodology

pH

EC

Chloride

Nitrate

Alkalinity

Potassium

Sodium

Hardness

Sulphate

Hazard risk assessment

Physico-chemical analysis

Collection of groundwater samples
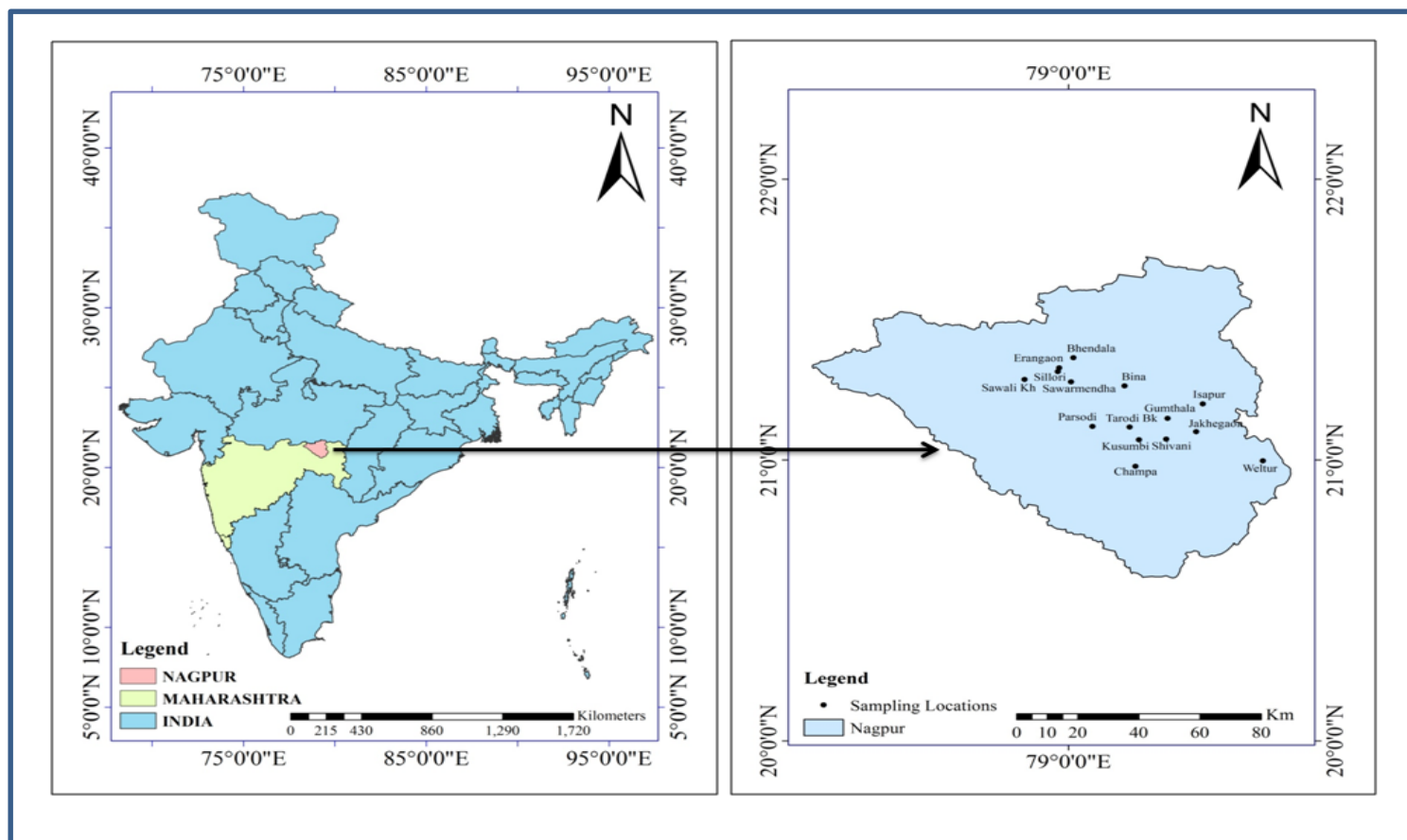
Sample area selection
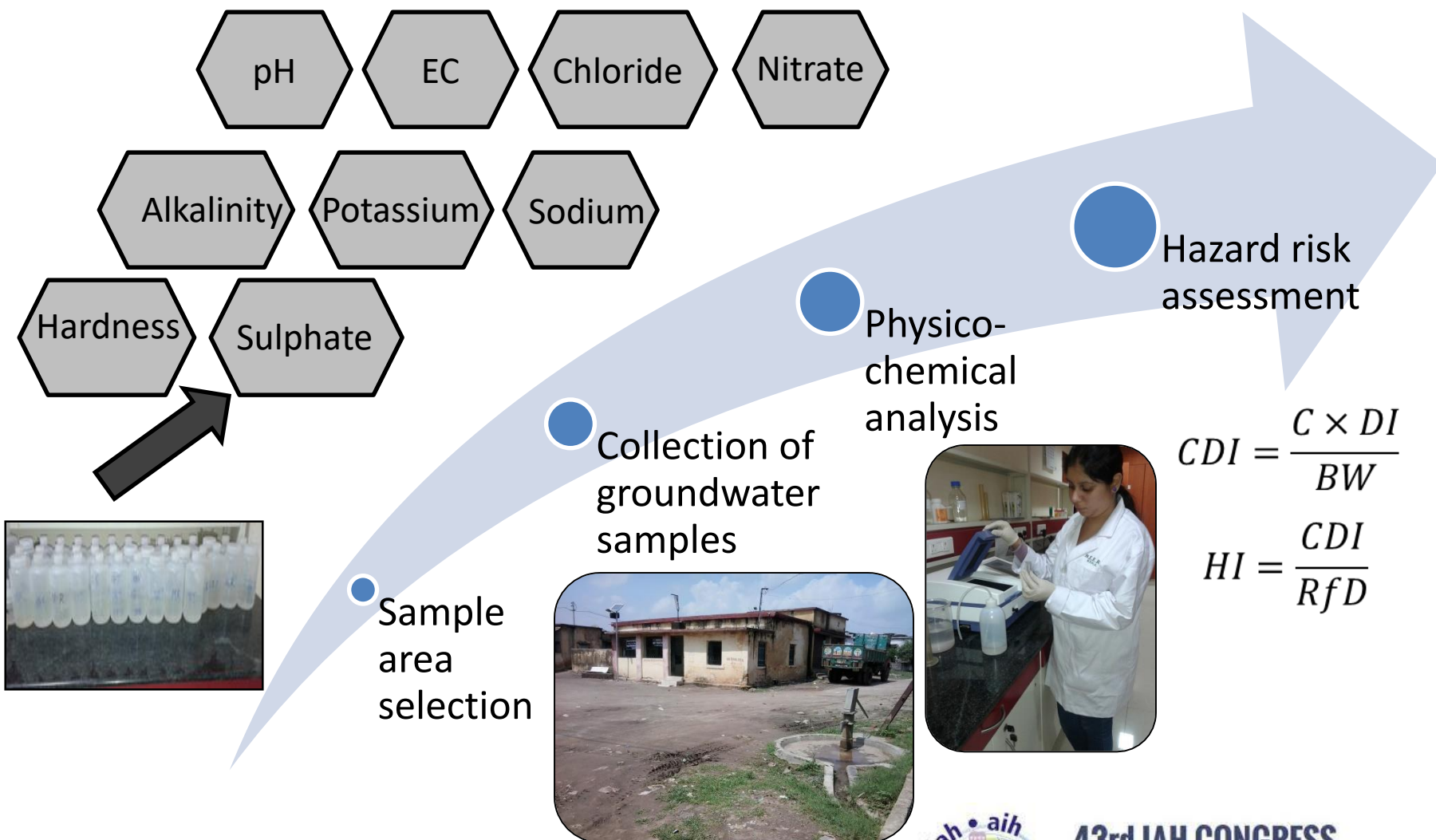
$$CDI = \frac{C \times DI}{BW}$$
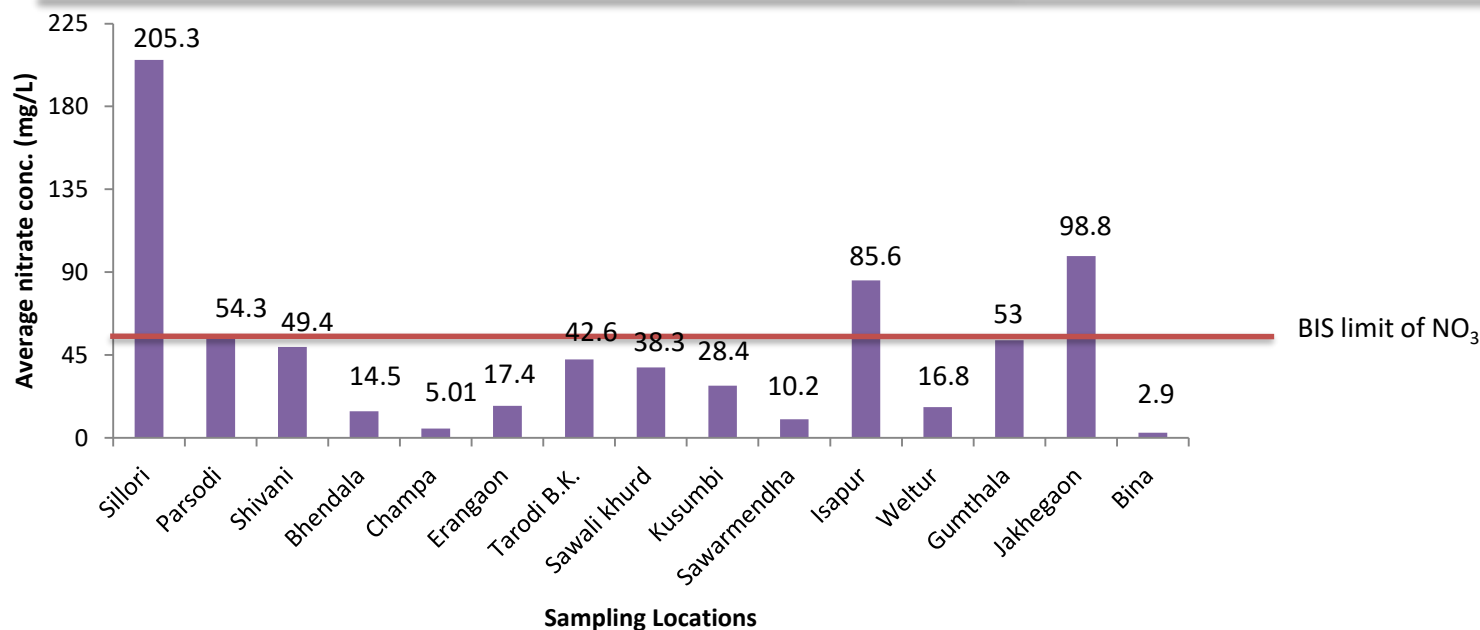
$$HI = \frac{CDI}{RfD}$$

Study Area

- ❖ **In total 15 villages were selected as sampling sites**
- ❖ **Sample size n= 64**
- ❖**Sample description: Groundwater samples**
- ❖**Quantity of sample : 1 L**

Results

Village	Range	Average	S.D.
Sillori	110.4-208.1	205.3	0.83
Parsodi	39.8-56.7	54.3	1.7
Shivani	42.2-51	49.4	0.71
Bhendala	10.6-15	14.5	1.32
Champa	2.9-7.3	5.01	0.75
Erangaon	9.6-19.4	17.4	6.2
Tarodi B.K.	40.5-51	42.6	0.93
Sawali khurd	29.7-43	38.3	8.4
Kusumbi	14.8-29.7	28.4	0.22
Sawarmendha	2.9-12.5	10.2	1.7
Isapur	79-88.2	85.6	0.02
Weltur	11.6-22	16.8	3.6
Gumthala	27.8-59.3	53	0.4
Jakhegaon	86.2-102	98.8	1.9
Bina	1.3-5.9	2.9	0.91

➢**Range of average nitrate concentration: 2.9-205.3 mg/L**

➢**Maximum nitrate concentration of 208.1 mg/L found in Sillori village**

Results

Physicochemical parameters

Range:
- **pH** 7-7.9
- **EC** 127-1669
- **Alkalinity** 105.8-379 mg/L
- **Total hardness** 71.3-638.3 mg/L
- **Chloride** 8.7-444 mg/L
- **Sulphate** 7-255.4 mg/L
- **Sodium** 24-221.7 mg/L
- **Potassium** 0.3-122.4 mg/L
- **Significant positive correlation**: Nitrate and Sulphate indicating application of fertilizers as the major cause of concern

Health Risk Assessment

$$CDI = \frac{C \times DI}{BW} \qquad HI = \frac{CDI}{RfD}$$

*__CDI__= Chronic daily intake (mg/kg/day)

*__C__= Nitrate conc. (mg/L)

*__DI__= Average daily intake of water (L/day)

*__BW__= body weight (kg)

*__HI__=Hazard Index

*__RfD__= Reference dose (mg/kg/day)

Chronic daily index :2.29±0.03 mg/kg/day
Hazard index:1.27±0.02 (above 1) indicated serious health risk due to nitrate contamination in groundwater

Conclusion

- Maximum average nitrate concentration was found in Sillori village

- Groundwater nitrate contamination in Nagpur increasing at a greater pace

- Increasing nitrate concentration : Periodic assessment

- Higher nitrate contamination : Attributable to both point and non-point sources

- Enormous application of fertilizers : Major role in nitrate contamination

4. Nitrate contamination of groundwater and vegetables: Intake and Health risk assessment in Nagpur and Bhandara district
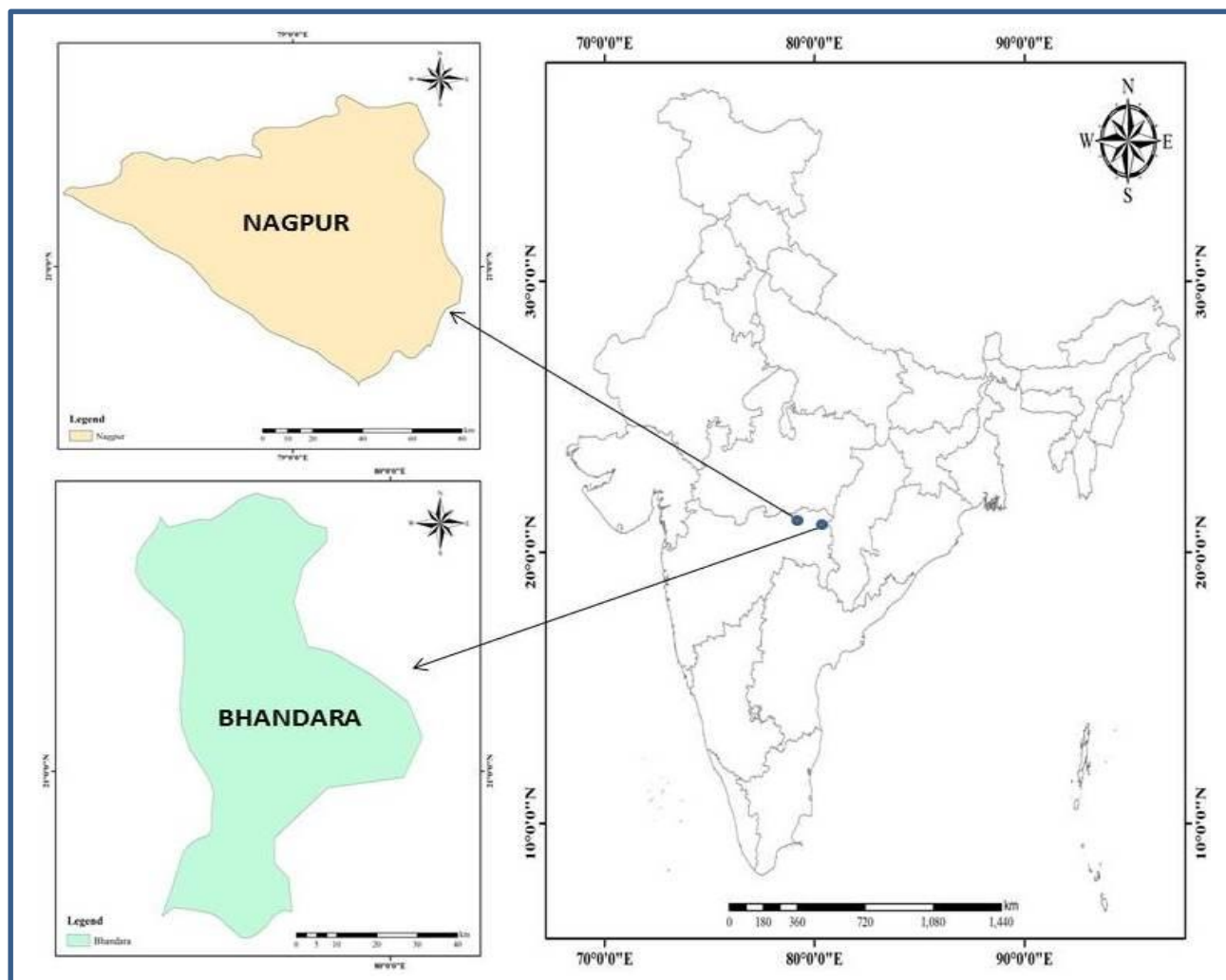

Nitrate contamination
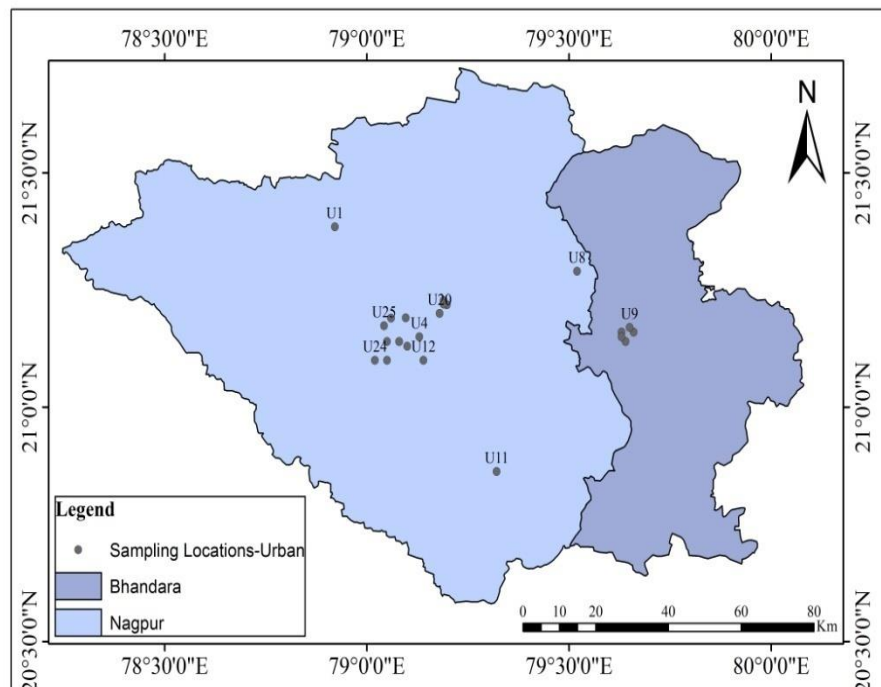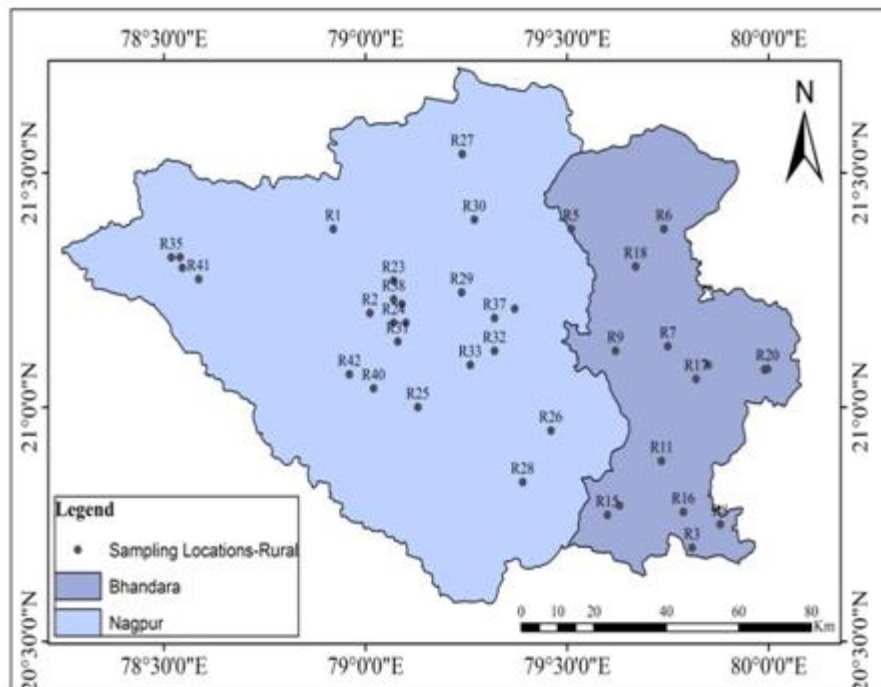
APHA-4500 nitrate method

AOAC 993.03 method

Do not drink water that have high concentration of Nitrates or Nitrites.

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Study area

Study area
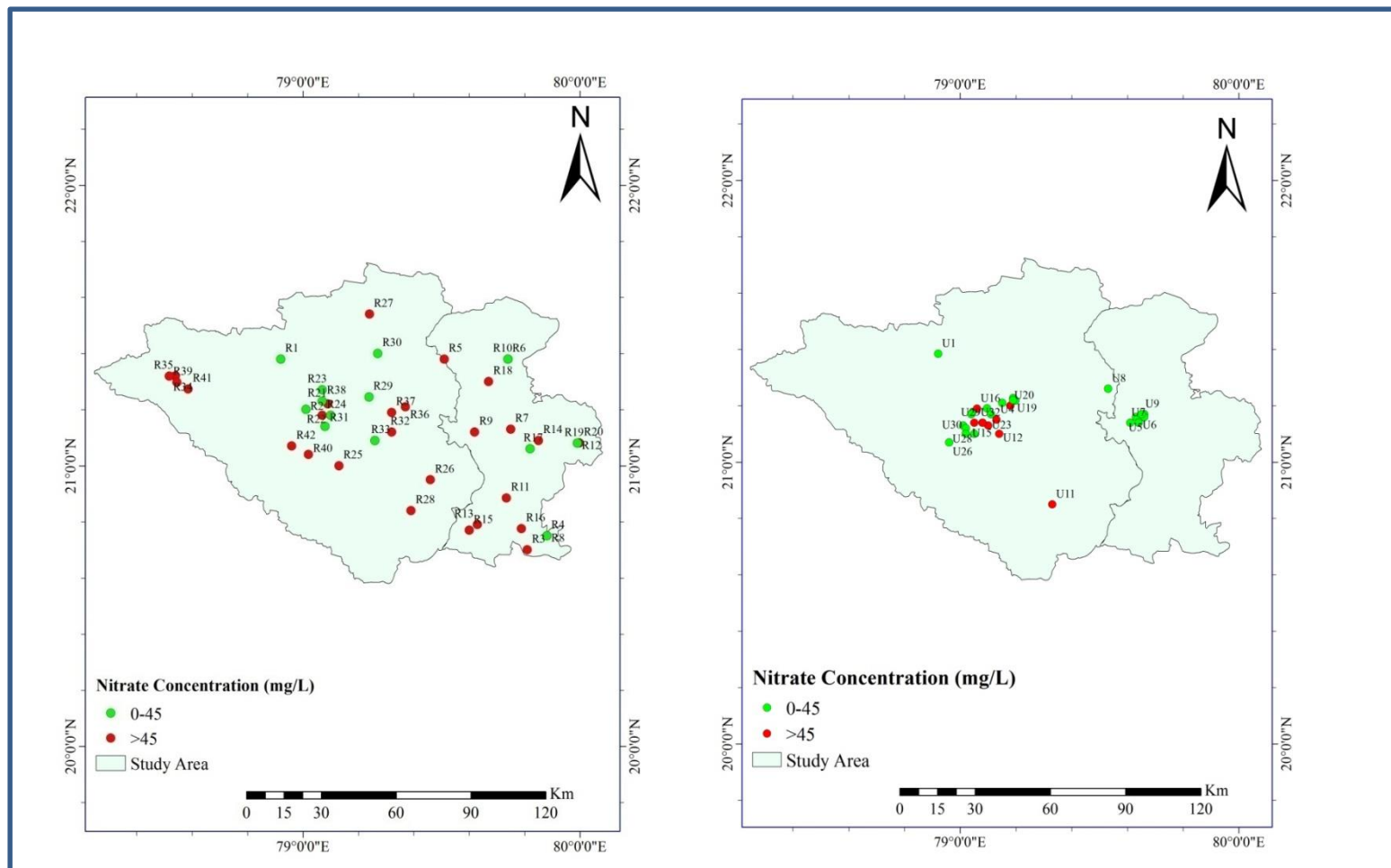

Sampling	Urban	Rural
Nagpur	24	18
Bhandara	18	17

Sampling locations: 77 rural and urban sites in Nagpur and Bhandara

Samples: Drinking water and vegetable samples

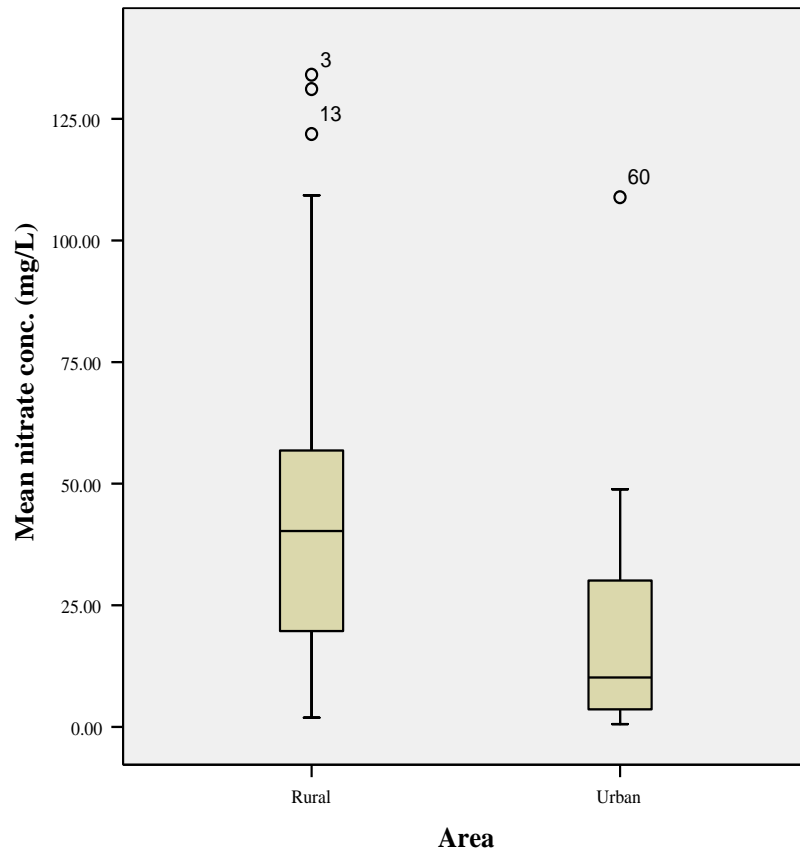**Sampling seasons: March-April; September-October**

Results

Nitrate Concentration (mg/L)
- 0-45
- >45
- Study Area

❖**Sites above permissible limit (>45 mg/L)**

❖**Rural : 40%**

❖**Urban : 12%**

Results

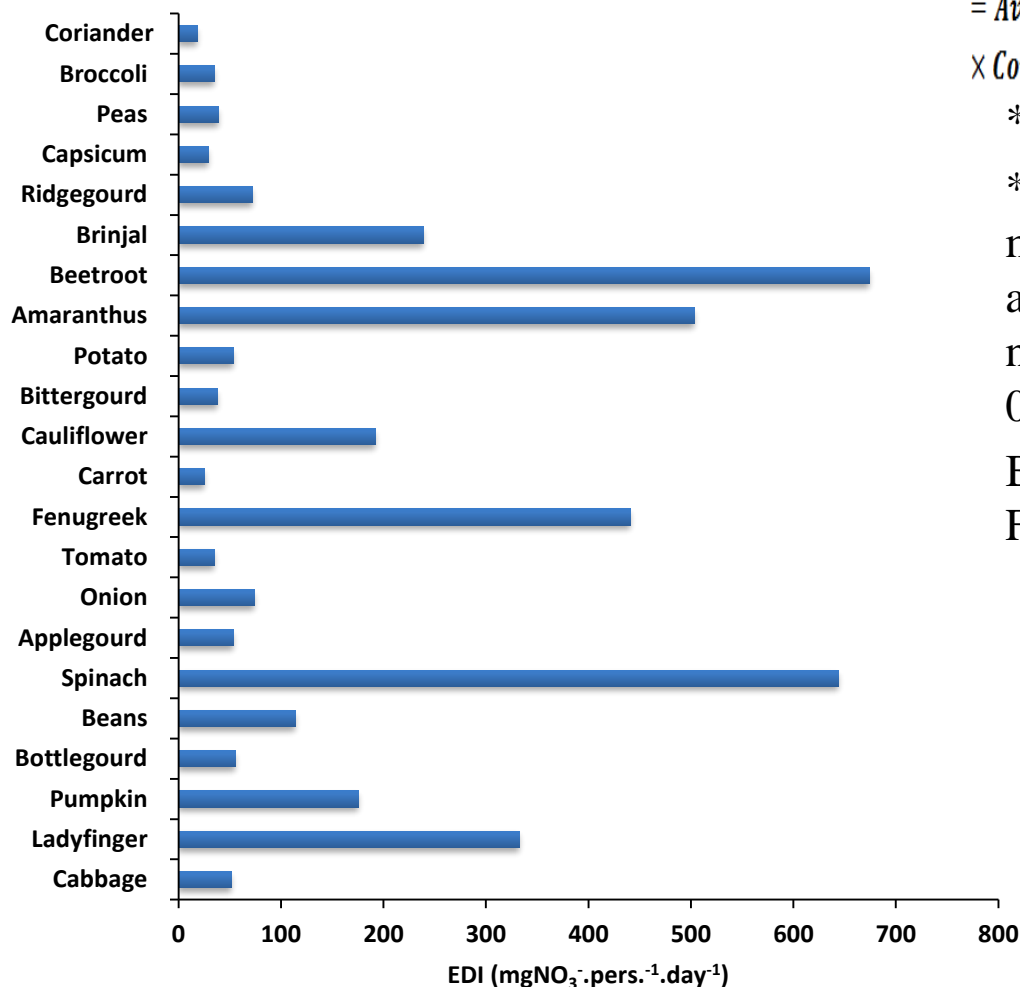| Season	Average nitrate concentration (mg/L)	
	Rural study sites	Urban study sites
Pre-monsoon	1.9-134.1	2.1-223
Post-monsoon	0.6-108.9	126.3-0.92

- Mean nitrate concentration
- Rural study sites - 45.7 mg/L
- Urban study sites - 22.5 mg/L

Results
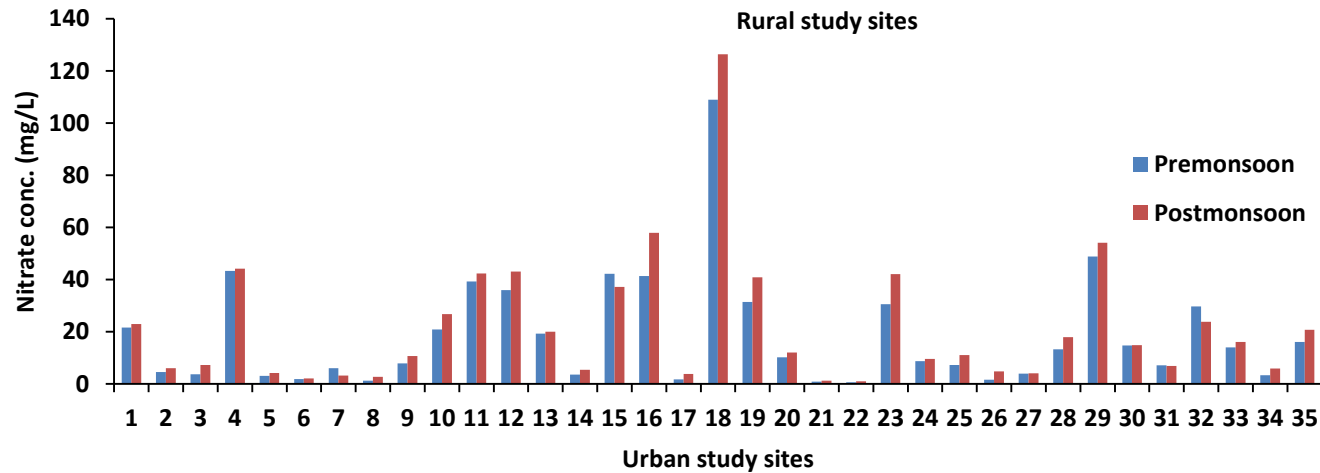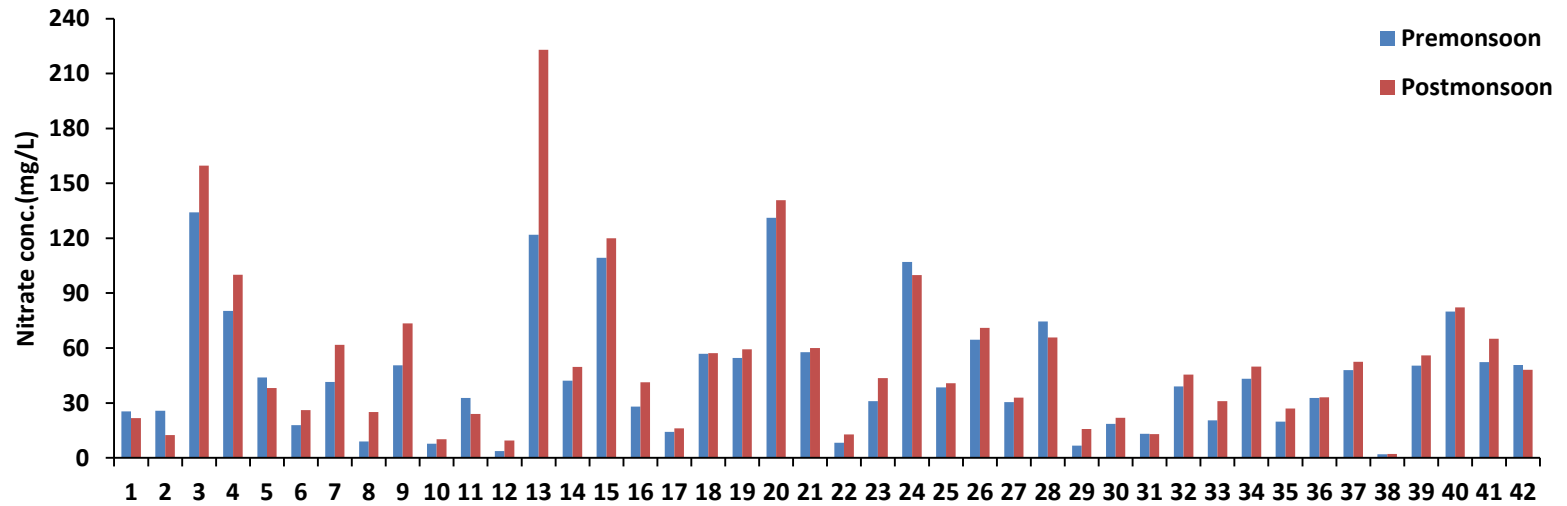
Results

EDI ($mgNO_3^-.pers^{-1}.day^{-1}$)

EDI (mgNO₃⁻.pers.⁻¹.day⁻¹)

EDI

$$= Average\ daily\ vegetable\ consumption\ (0.5\ kg.person^{-1}.day^{-1})$$
$$\times Concentration\ of\ nitrate\ in\ vegetable\ (mg/kg)$$

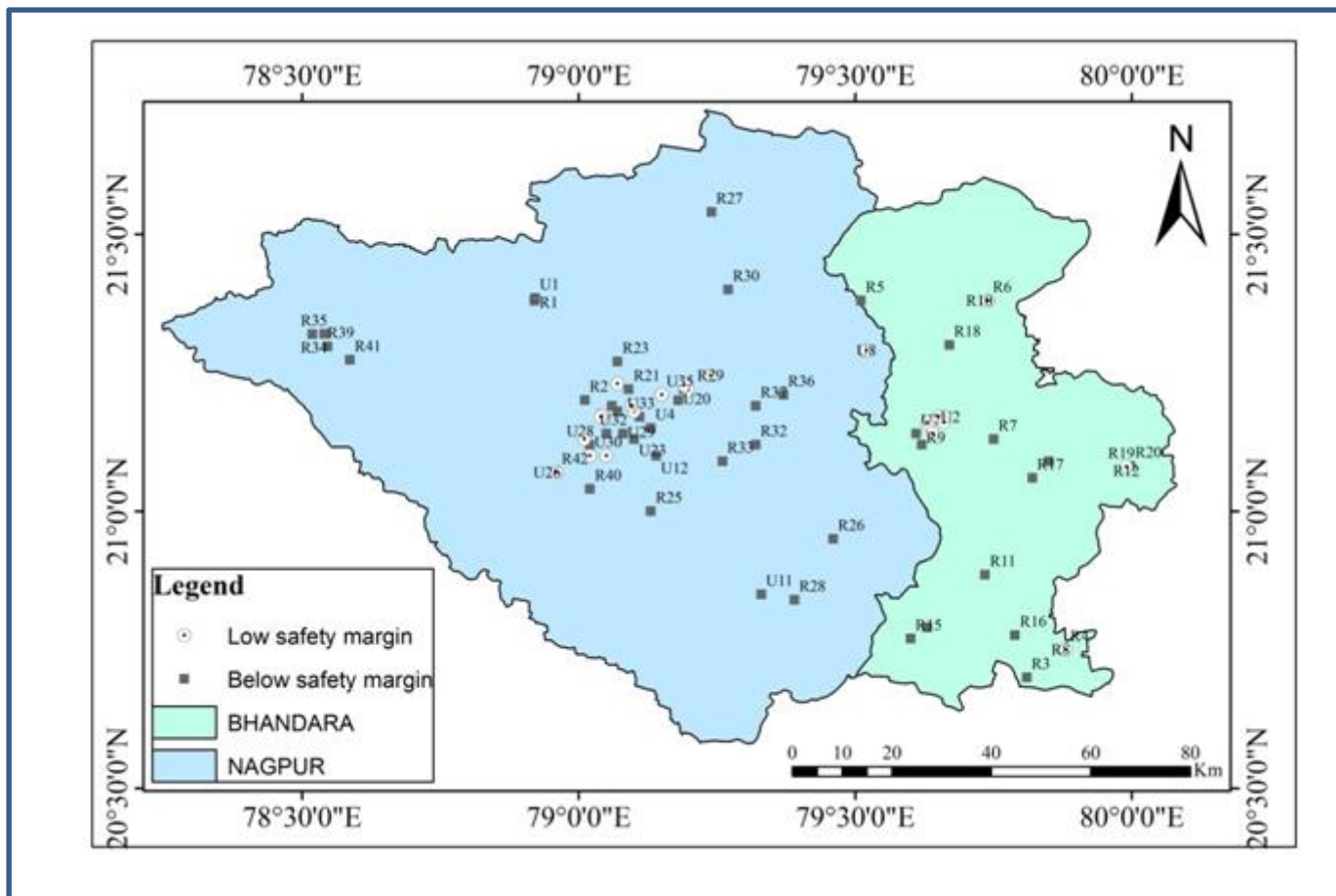*EDI- Estimated daily intake

*ADI- Acceptable daily intake (3.7 mg/kg body weight) for dietary nitrates as per JECFA or 432 mg/kg maximum nitrate level for daily consumption of 0.5kg vegetables per person.

Beetroot, Spinach, Amaranthus and Fenugreek exceeded the **ADI limit**
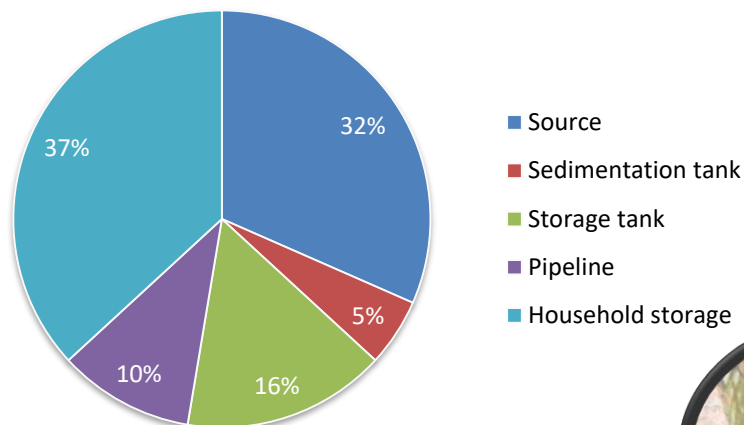
Results

Safety margin ratios: Medium (10-20); High (20-30); Very high (>30)
Low safety margin (ADI:EDI<10) : 35 study sites
Below safety margin (ADI:EDI<1): 42 study sites

Sanitary survey

- Source
- Sedimentation tank
- Storage tank
- Pipeline
- Household storage

Pie chart values: 32%, 5%, 16%, 10%, 37%

- **Nitrate contamination from source different from household**
- **To explore ambiguity sanitation and safety measures were studied in 12 study sites**
- **Sanitation survey Sanitary Survey based on 6 categories**
- **Observational study and participant survey of 24 participants collected**

Conclusion

- Urban water supply more safer than Rural water supply

- Nitrate in drinking water more pronounced during postmonsoon

- Source water contamination and inadequate household water storage practices : key sources of contamination

- EDI of drinking water and vegetables below safety margin: High hazard level due to excessive contamination

- Safe drinking water, sanitation and hygiene practice : help reduce health effects from contaminated groundwater intake

4. Prospective studies

Health risk assessment of nitrates in humans

- Nutritional and health based survey of cancer affected patients
- Epidemiological study to assess cancer risk due to nitrate intake

Study efficient treatment technology options for nitrate in water

- Lab based reactor study on advanced reduction and adsorption techniques for nitrate removal from drinking water

Acknowledgement

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Thank You

Questions, suggestions and comments are always welcome

Name: Pinky Taneja
Designation: SRF (AcSIR PhD Fellow)
Contact: +91(00) 712-2249756
Email ID: p_taneja@neeri.res.in

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