Concentration and average chain lengths of leaf wax n-alkanes in tropical deciduous and evergreen species

A Saishree, V Sarangi , SR Managave
Email:amrita.saishree@students.iiserpune.ac.in

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Earth and Climate Science

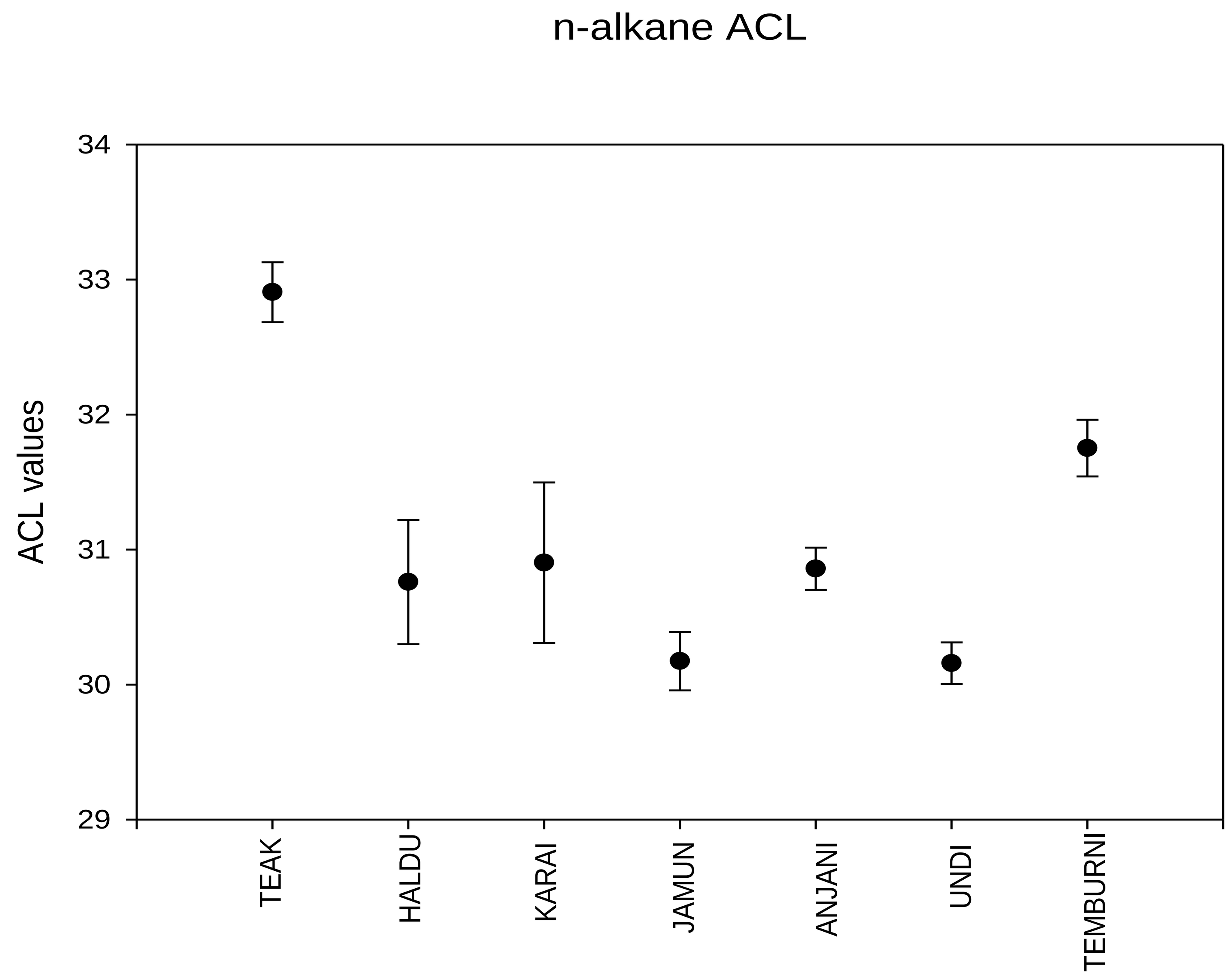
INTRODUCTION

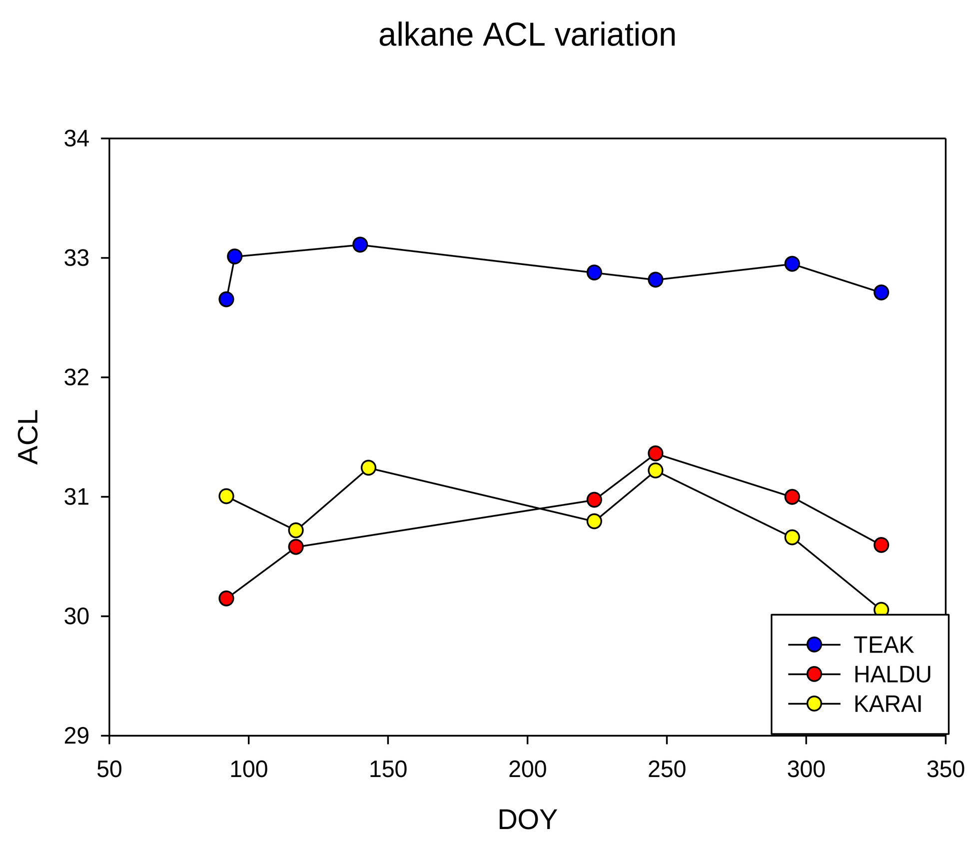
Understanding of time of synthesis of leaf wax compounds has bearing on assessing seasonality in reconstructed paleoclimate variability. Although the primary leaf wax synthesis occurs during leaf flush, its synthesis in mature leaves is not well understood.

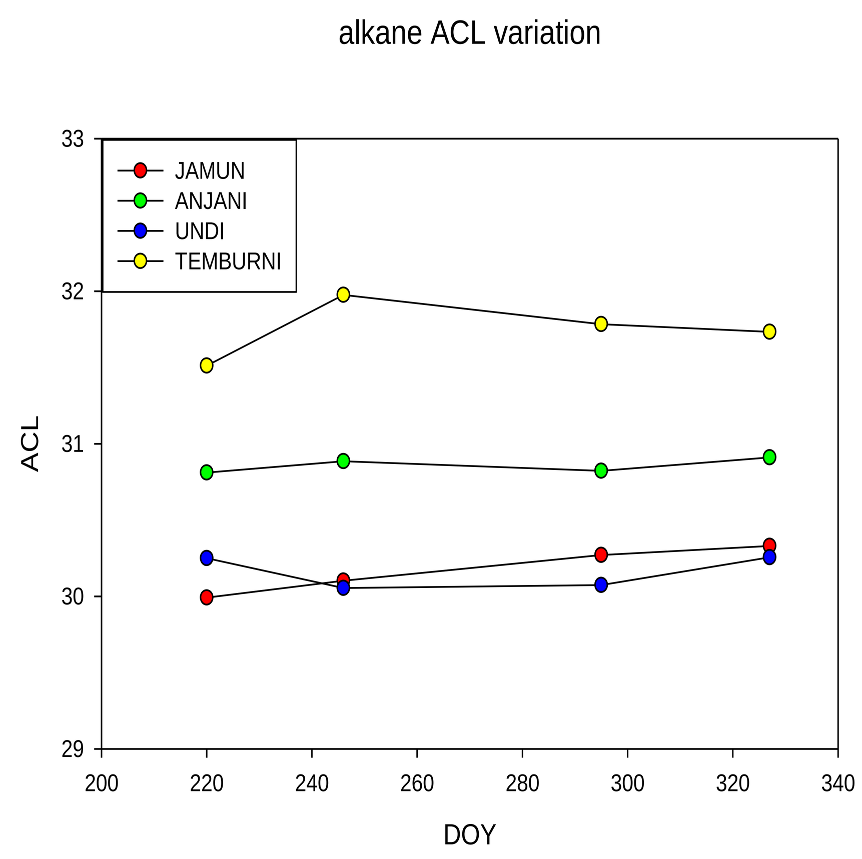
METHODOLOGY

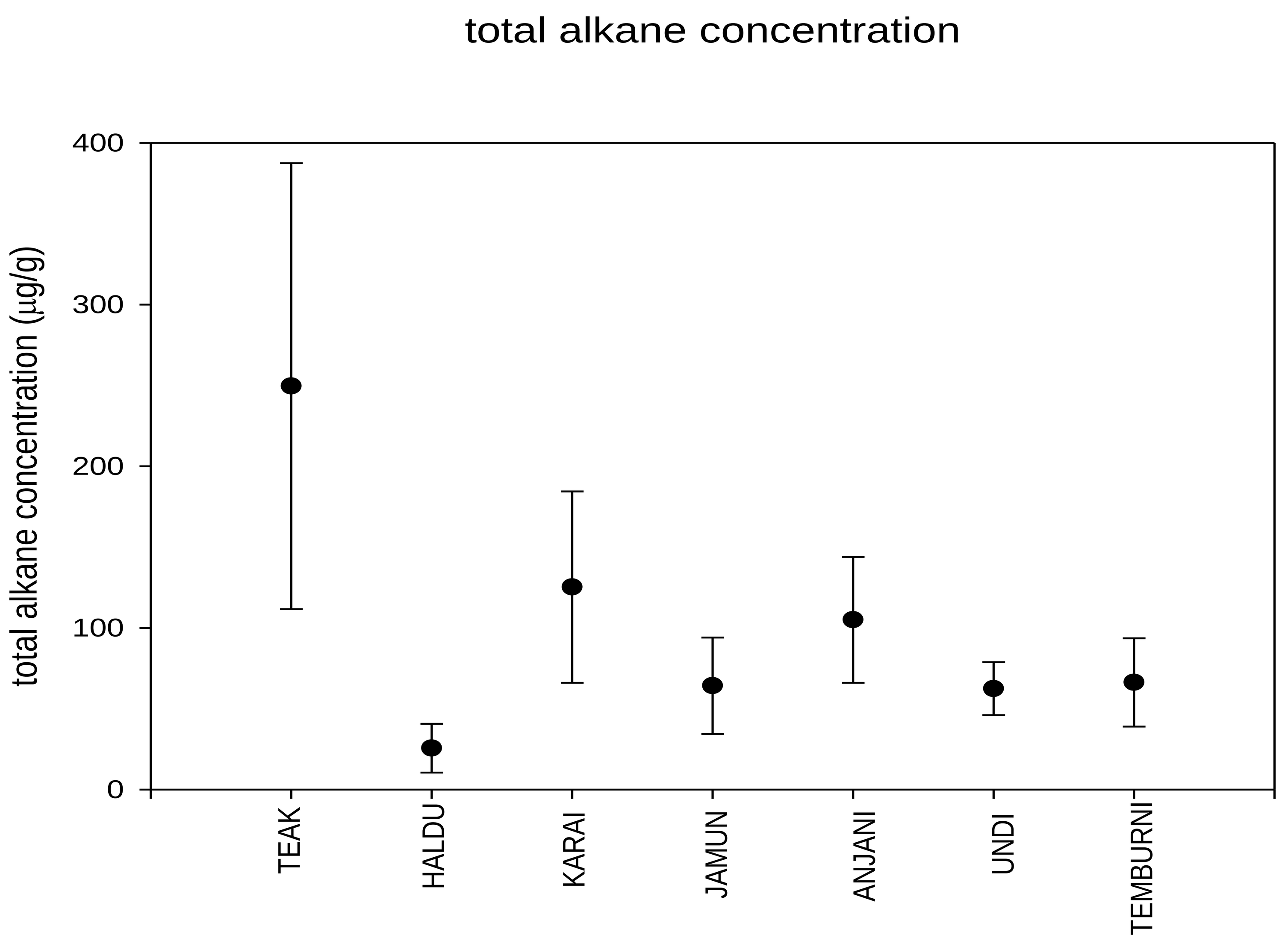
To address this issue, three tropical deciduous and four evergreen species were grown under similar conditions. Leaves were periodically sampled and characterized for n-alkane concentration.

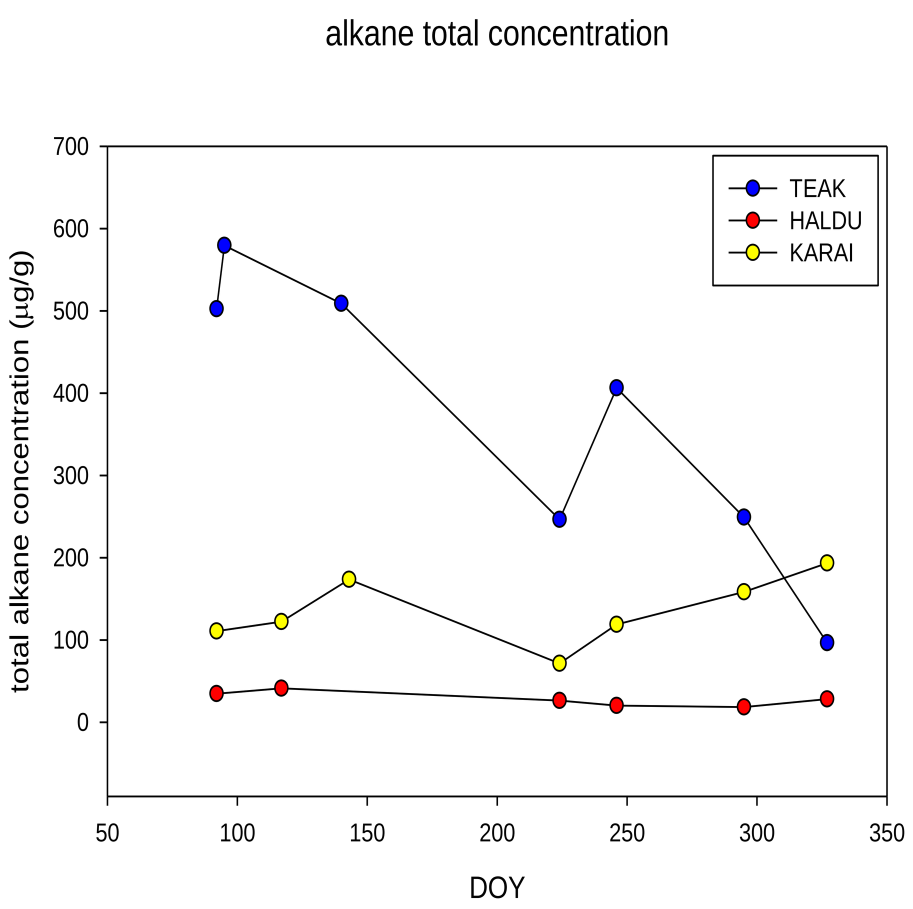
RESULT

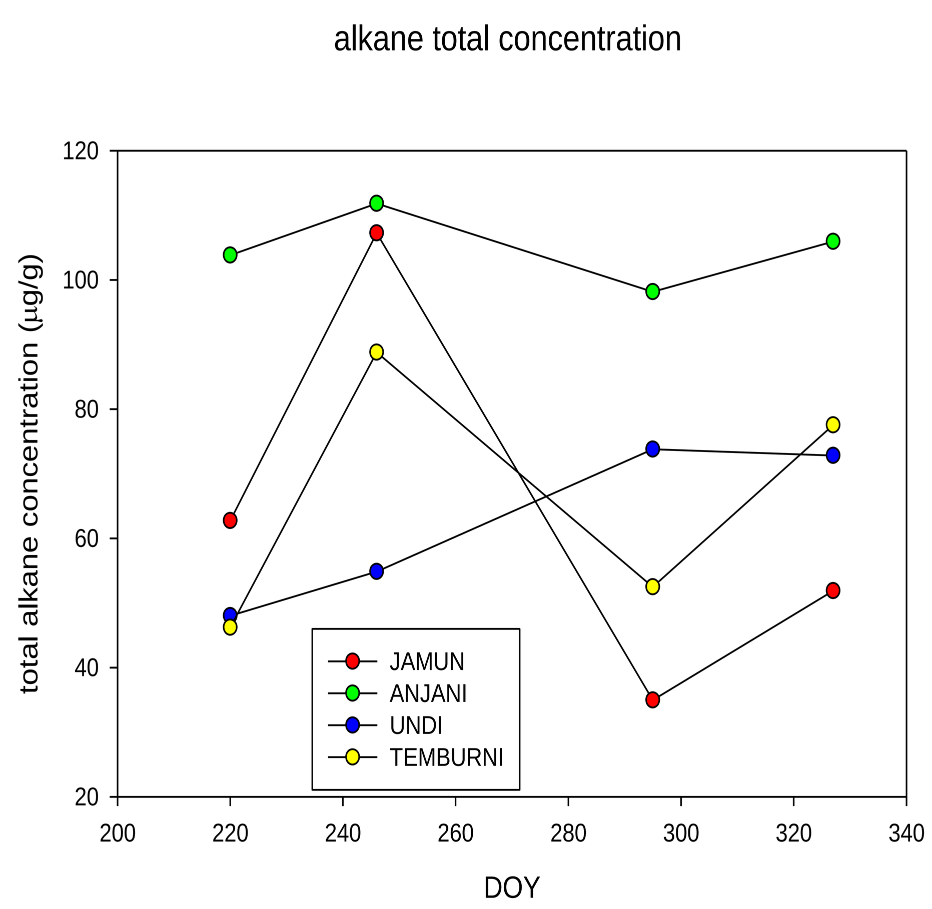












OBSERVATION

The n-alkane concentrations varied among the species. Among deciduous species, the maximum concentration was observed in *Tectona grandis* (~250 µg/g) and least in *Haldina cordifolia* (26 µg/g). Values of all evergreen species varied from 46 to 143.8 µg/g with *Memecylon umbellatum* having maximum (105µg/g) value. Various species showed different seasonal variations in total n-alkane concentrations. The average chain length (ACL) of n-alkanes varied among different species. Deciduous species' ACLs were almost constant with a significant drop observed towards the end of the growing season. Evergreen species' ACLs did not show a trend during the experiment.

Seasonality of particulate REEs in the estuarine water column of the Gulf of Cambay

Abul Qasim* (abul16@iiserb.ac.in) and Satinder Pal Singh (satinder@iiserb.ac.in)

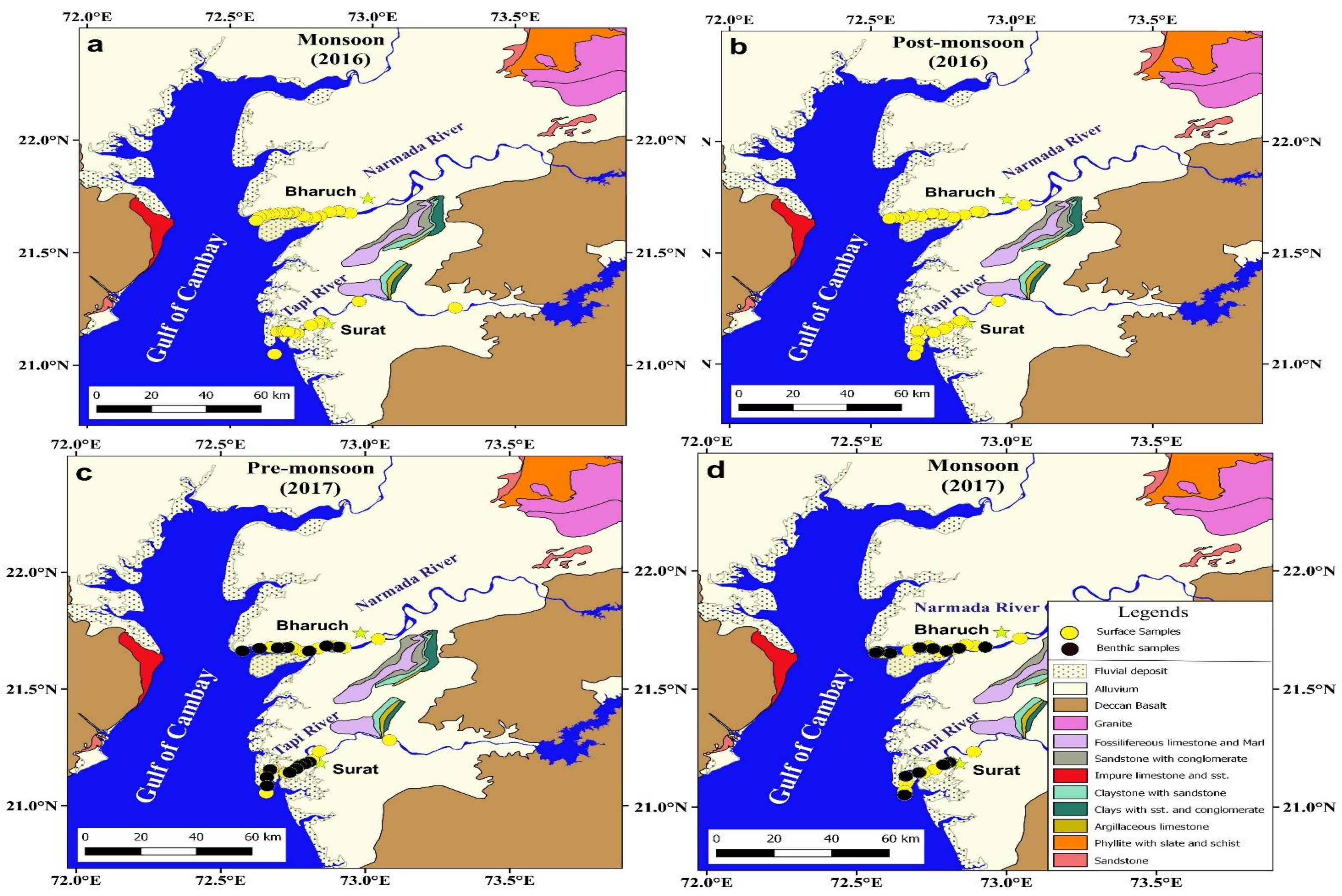
Earth and Environmental Sciences, Indian Institute of Science Education and Research, Bhopal

Abstract

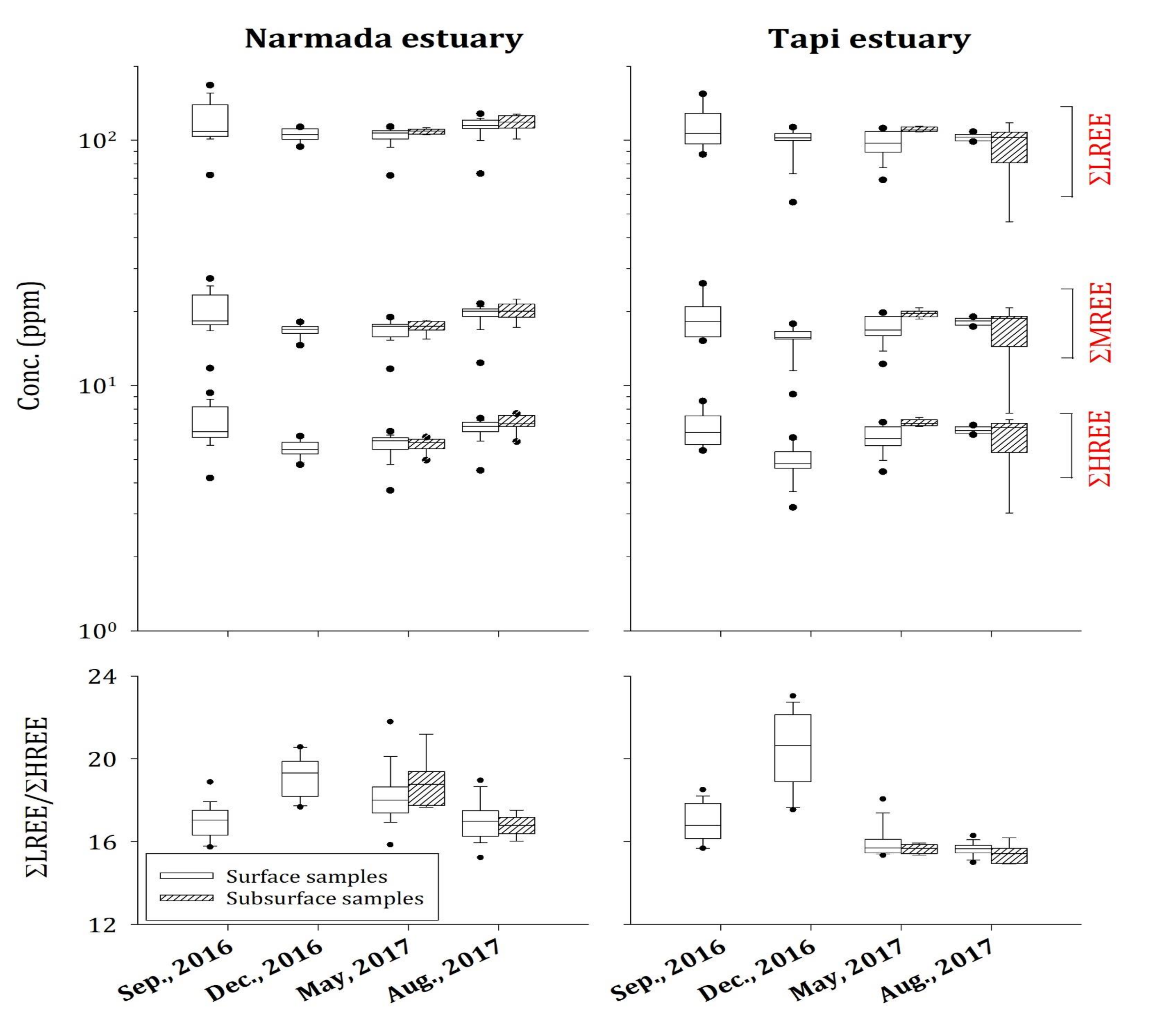
Spatio-temporal distributions of rare earth elements (REEs) have been widely utilized to understand various earth surface processes including provenance and sedimentary processes [1–3]. In this study, we present the concentrations of REEs in the suspended sediments (>0.45µm) collected from surface and sub-surface waters of the Narmada and Tapi estuaries during four different seasons in 2016–2017. The major goal is to explore seasonally varying sediment sources and sediment-water interactions in governing the REEs abundances in these estuaries. The ΣREE in surface and subsurface suspended sediments are comparable in each estuary indicating negligible grain size variations. The absence of Ce anomaly suggests aluminosilicates as a major carrier of the particulate REEs rather than Fe–Mn coatings. The distribution patterns of Chondrite normalized REEs (LREE>MREE>HREE) reveal a similar drained lithology in the watersheds irrespective of seasons. Interestingly, non-monsoonal samples show a significant depletion of HREE in both the estuaries indicating HREE removal in heavy minerals. The ternary plot of La–Th–Zr also reveals heavy mineral sorting effects in these estuarine sediments.

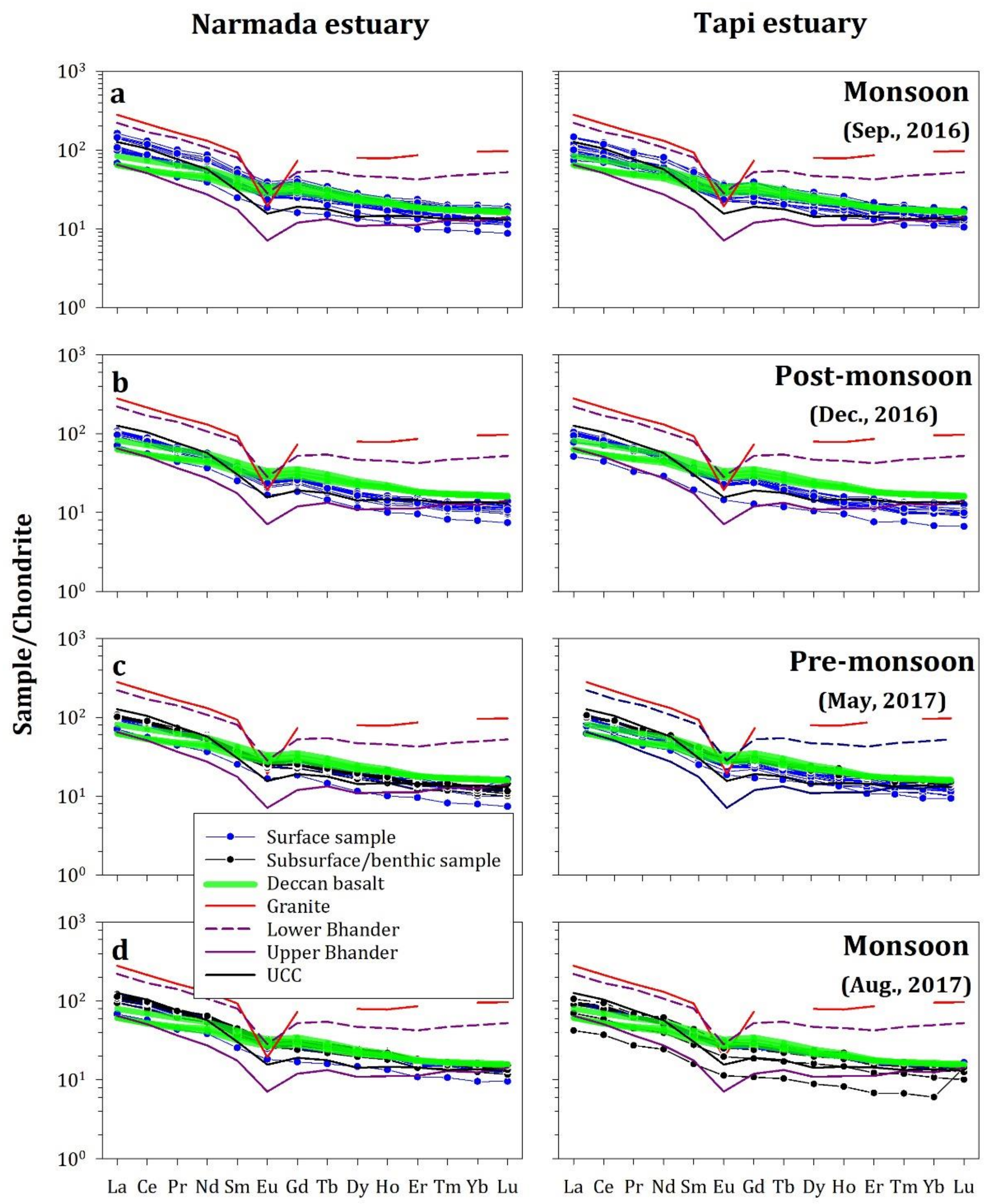
Objectives & Sampling

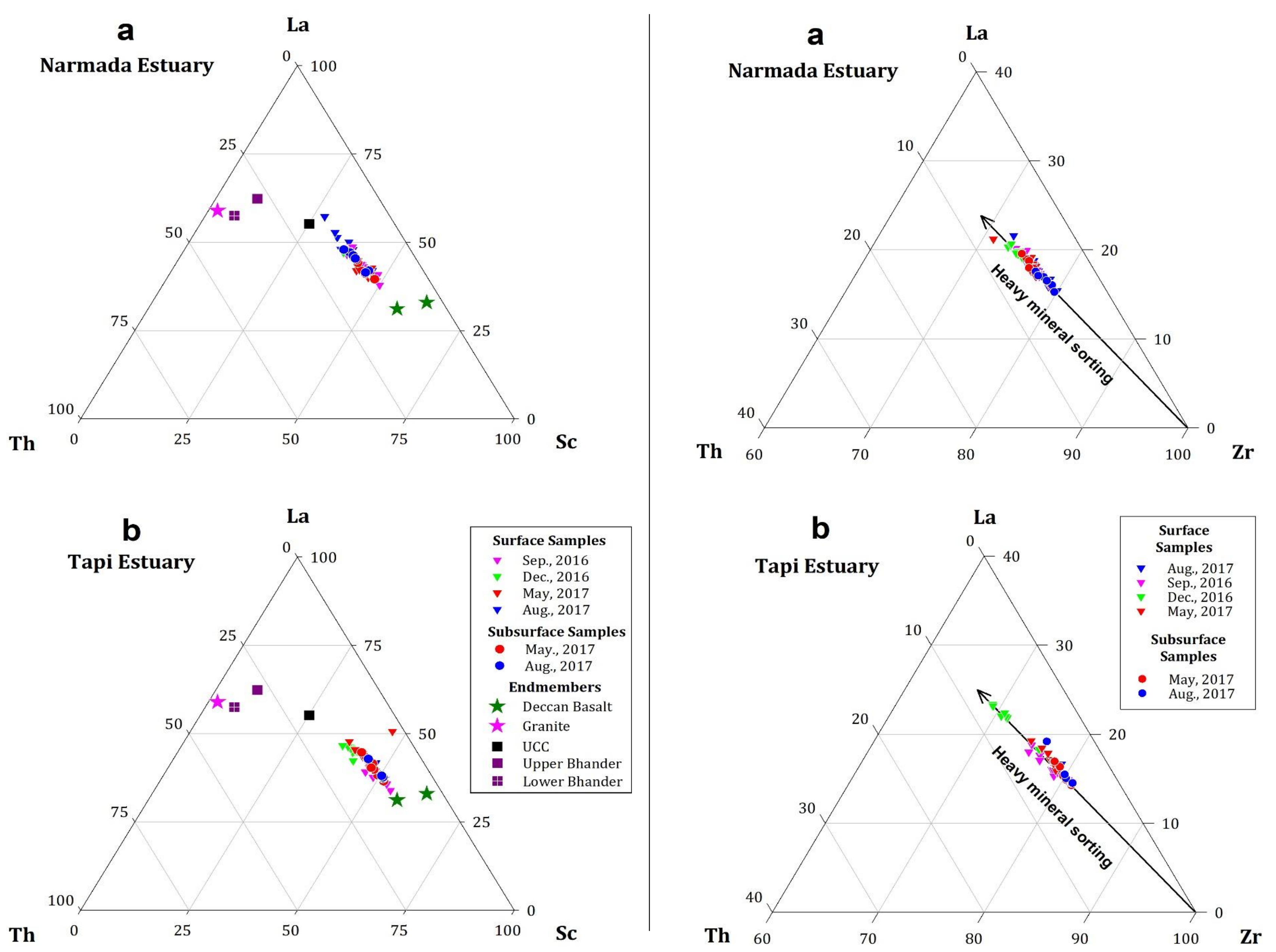
- To determine the seasonal REE compositions of estuarine suspended sediments from the Narmada and the Tapi Rivers
- Explore the seasonal variations in sediment provenance
- Explore the role of sediment-water interactions and heavy mineral sorting on the particulate REE abundances



Results







Summary

- The La-Th-Sc plot shows a mixed lithology in all seasons.
- No Ce anomaly in the estuarine sediments suggests negligible hydrogenous REEs.
- Seasonal variations in LREE/HREE due to heavy mineral sorting preferentially sequestering HREE.

References

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Acknowledgements

We thank IISER Bhopal for providing research facilities and thankfully acknowledge A. Arya, A.K. Chandrashekhar, and D. Borgohain for help during field work, sample preparation, and data exploration.

Assessment of spatial distribution of metal contamination in shallow groundwater of Udyavara river basin, Southwest India

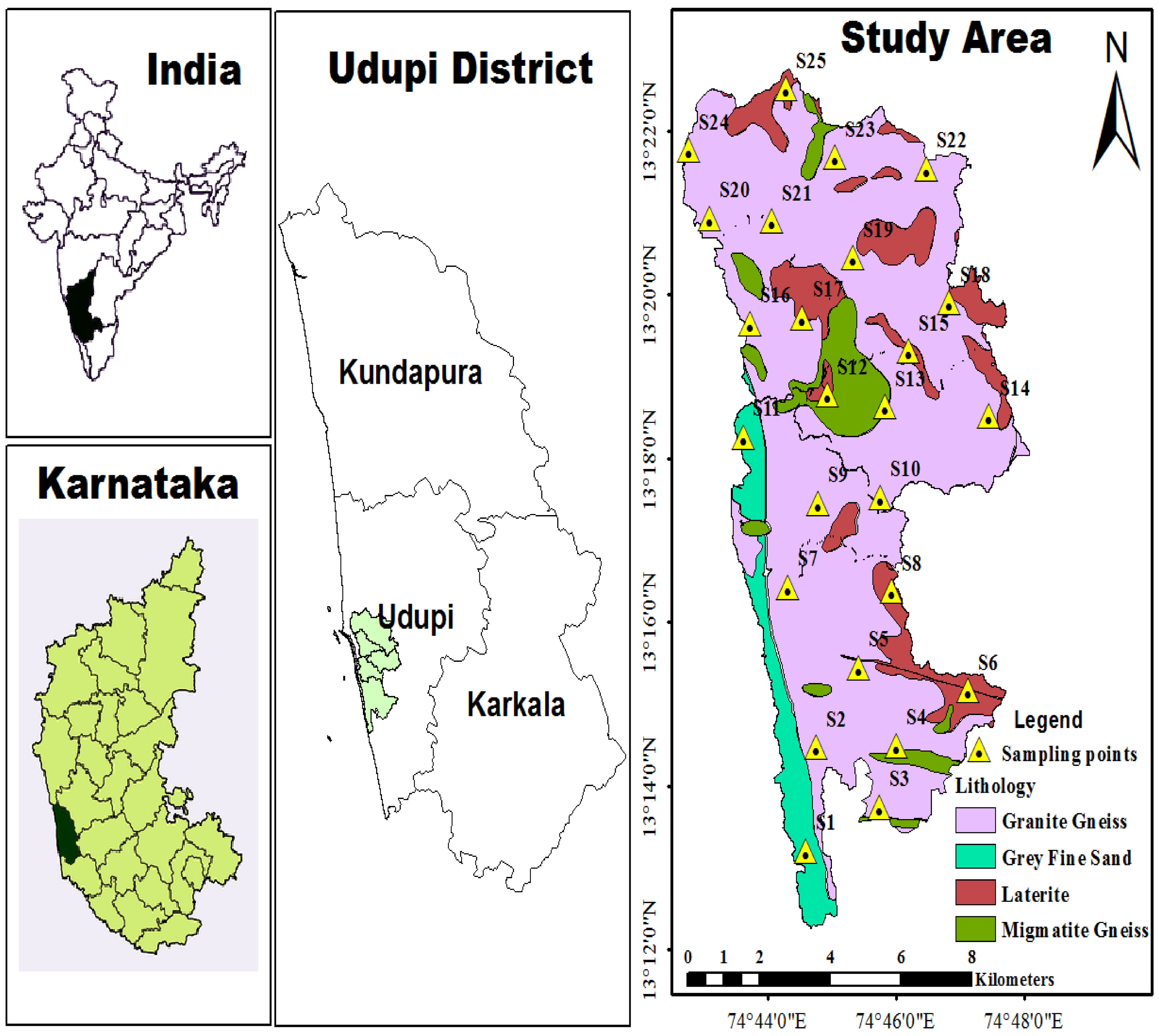
Vignesh Akshitha, Keshava Balakrishna, Harikripa Narayana Udayashankar

Department of Civil Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education

Introduction

Heavy metal contamination in groundwater is a global concern and leads to potential health risks to humans and the ecosystem.

Study area



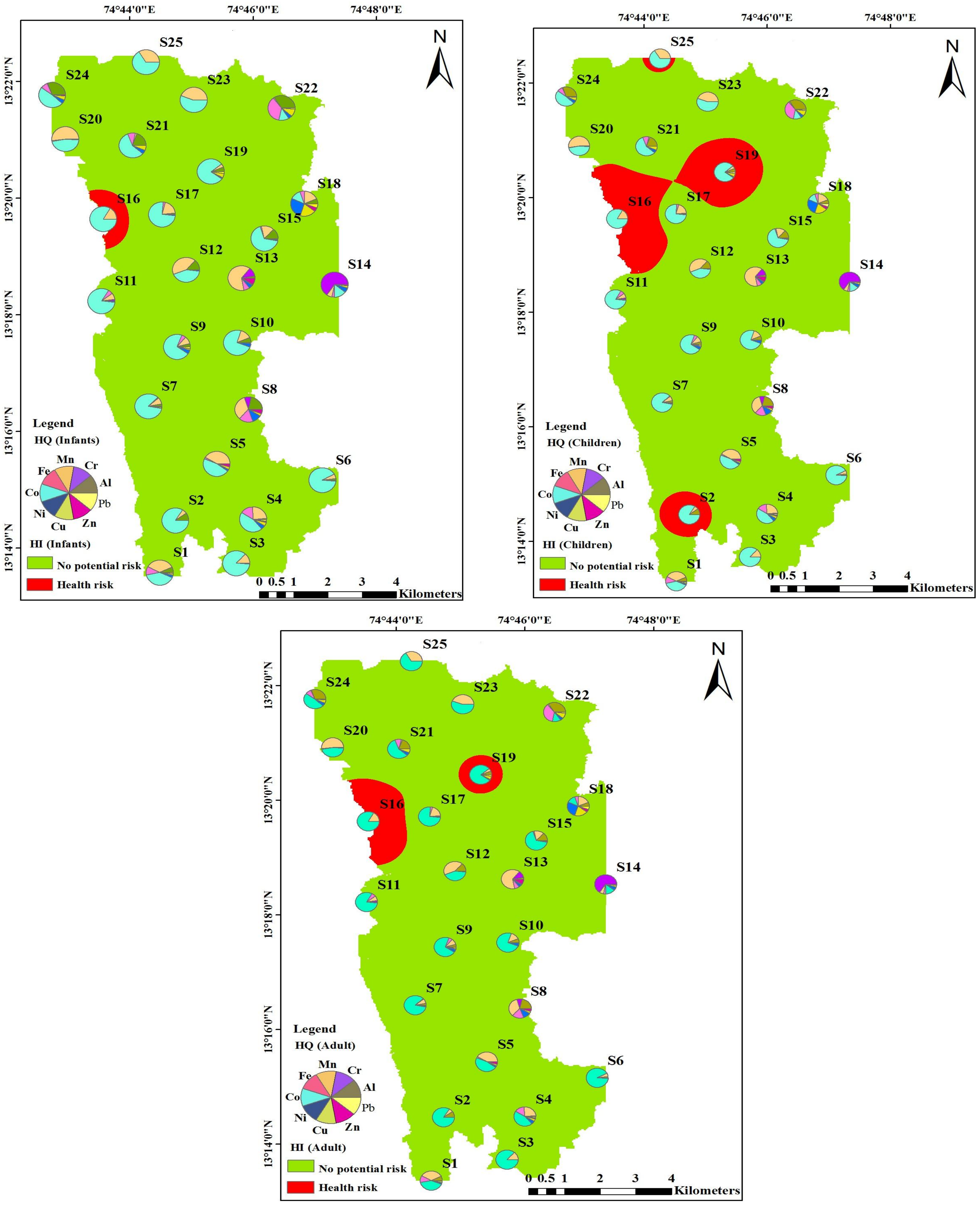
Methods

Seasonal groundwater sampling
↓
Samples were preserved at 4° C
↓
Filtration of samples
↓
Dissolved organic carbon determined using TOC analysis
↓
Heavy metal analysis using ICPMS
↓
Spatial analysis using ArcGIS version 10.1
↓
Human health risk assessment
↓
Ecological risk assessment

Objective

The present study assessed the spatial distribution of heavy metal contamination and human health risk of a shallow groundwater in Udyavara river basin, Udupi district.

Results



Conclusion

The study recommends regular monitoring of groundwater to control heavy metal contamination from anthropogenic activities.

Acknowledgements

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Effect of semidiurnal tides on dissolved inorganic carbon (DIC) and $\delta^{13}C_{DIC}$ in a tropical estuary (Mahanadi river estuary)

Mohammad Atif Khan[1,2], Rajdeep Roy[3], Sanjeev Kumar[1*], Satya Prakash[4], Aneesh Lotliker[4]

[1]Geosciences Division, Physical Research Laboratory, Ahmedabad 380009, India
[2]Gujarat University, Ahmedabad, 380009, India
[3]National Remote Sensing Centre, Department of Space, ISRO, Hyderabad, Telangana, India
[4]Indian National Centre for Ocean Information Services, Ministry of Earth Sciences, Govt. of India, Hyderabad 500090, India

*Corresponding author: sanjeev@prl.res.in

Abstract

Tidal influence on dissolved inorganic carbon (DIC) and its isotopic composition ($\delta^{13}C_{DIC}$) were investigated in tropical estuary, Mahanadi, eastern India. DIC concentration and $\delta^{13}C_{DIC}$ varied between a wide range of 1537.70 to 710.15 µmol Kg^{-1} and −1.7 ‰ to −11.2 ‰ across the salinity gradient. Results indicated that carbonate and/or silicate weathering by possible biogenic CO_2 is the probable DIC source in the freshwater end of the estuary. However, the observed DIC concentration and $\delta^{13}C_{DIC}$ in the mixing regime greatly deviate from the compositions calculated from mixing model. The results suggest that biogeochemical processes such as; primary productivity, organic matter degradation, calcite dissolution and precipitation in addition to physical processes such as; CO_2 outgassing, individually or combination of two and more such processes are simultaneously active in the mixing regime. Our analysis also indicates calcite dissolution during low tide and calcite precipitation during high tide might have been dominant processes affecting DIC dynamics in the mixing zone. The presence of organic matter degradation at the cost of oxygen was observed in the mixing zone, which was more prominent during low tide compared to high tide. The estimated average DIC export flux from the estuary to the Bay of Bengal was ~ 0.89 Tg y^{-1} and the average annual DIC yield was ~ 6.4 g m^{-2} y^{-1}. Our results highlight the complex nature of the estuarine ecosystem where tides can have significant influence in shaping the carbon budget, which may be relevant globally.

Introduction

- Estuaries, an integral part of the land-ocean continuum undergo complex biogeochemical and hydrological processes and are under potential threat to enhancing anthropogenic pressure and climate change.
- Studies show that apart from lateral carbon transport, the carbon in estuaries is subjected to various organic and inorganic biogeochemical processes.
- Dissolved inorganic carbon and its isotope ($\delta^{13}C_{DIC}$) are important tools to understand the Carbon(C) dynamics in the estuaries for the fact that DIC in rivers and in turn, estuaries comes from various sources and possess distinct $\delta^{13}C_{DIC}$ (Shown in Fig. 1.) making it useful to identify biological and geological sources along with biogeochemical processes responsible for it.

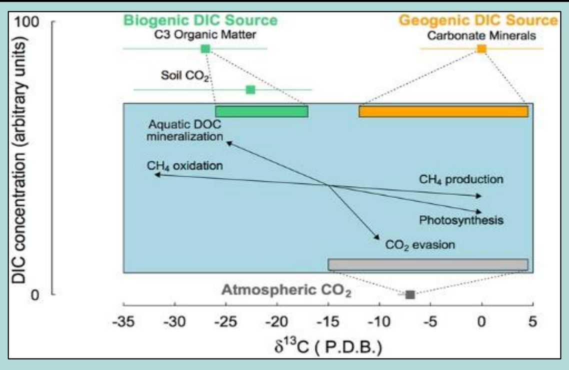

Fig. 1. $\delta^{13}C_{DIC}$ in various reservoirs[1]

- Recent studies show significant effect of tidal cycle on carbon dynamics and it affect the complex biogeochemical interplay occurring in this dynamic estuarine region at short time scale[2,3,4].
- Studies on understanding C dynamics in Indian rivers are limited and especially scarce in Indian peninsular rivers. Mahanadi, the third-largest perennial river in peninsular India remains almost unexplored in this regard.
- The present study attempts to understand the variability in dissolved inorganic carbon dynamics using DIC concentration and $\delta^{13}C_{DIC}$ in the Mahanadi estuary influenced by tidal cycling. The major objectives of the study are to (i) Identify the sources of DIC in the Mahanadi Estuary, (ii) Explore the effect of tidal cycle on the various biogeochemical processes affecting the carbon cycling in the estuary (iii) and estimate the annual DIC export flux and yield.

Material & Methods

Study Area

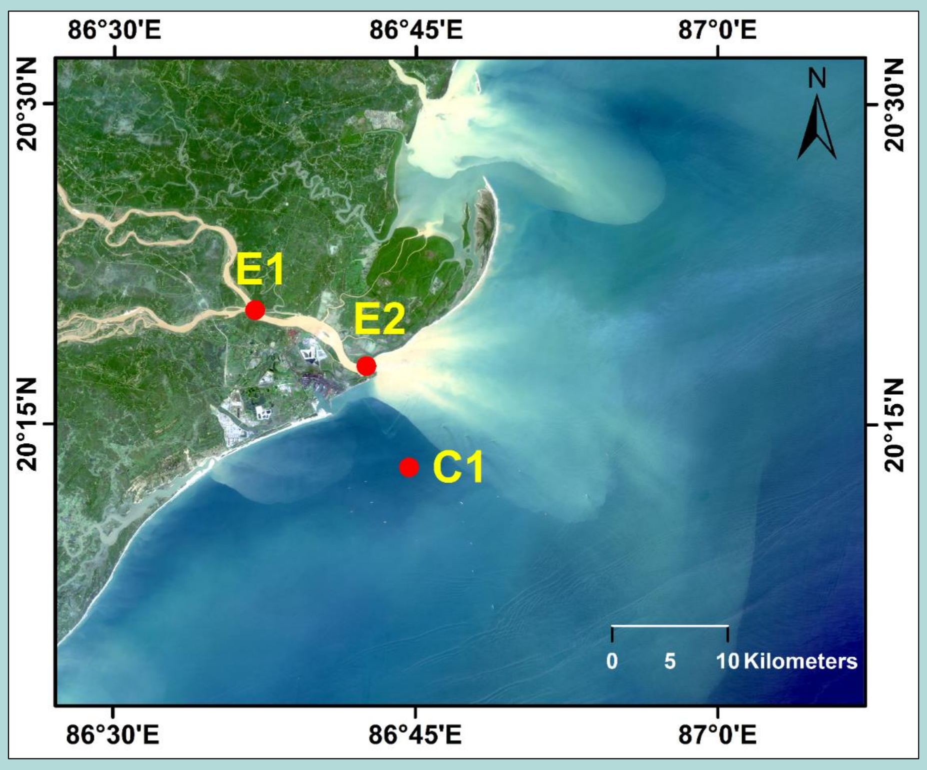

Fig. 2. Map of the Mahanadi estuary

Sampling strategy

- The field conducted during the post-monsoon season from 14 to 23 October 2019 (9 days)
- Sampling was performed at every high and low tide at three stations separated at the distance of 10 km along the salinity gradient of estuary (Fig. 2)

Laboratory measurement

- DIC was analyzed in Coulometer model No: CM5015. The accuracy of DIC < 2 µmol kg^{-1} with precision within 0.1 % on replicate measurements
- The $\delta^{13}C_{DIC}$ in water samples were analyzed using a Gas Bench connected to a continuous flow mass spectrometer (Thermo Scientific MAT - 253). The analytical precision of $\delta^{13}C$ for replicate standards ($\delta^{13}C$= −11.4 ± 0.1‰) was better than 0.1‰. $\delta^{13}C_{DIC}$ have been reported relative to V-PDB (Vienna-Pee Dee Belemnite) and calculated using the standard equation

$$\delta^{13}C_{DIC} = \left(\frac{R_{sample}}{R_{V-PDB}} - 1\right) \times 1000$$

Mixing model calculation

- Assuming, the salinity in the mixing zone is the result of freshwater and saline water fractions, mixing curves drawn following Alling et al. (2012)

$$S_{mix} = S_{fw}F_{fw} + S_{sw}(1 - F_{fw})$$

$$DIC_{mix} = DIC_{fw}F_{fw} - DIC_{sw}(1 - F_{fw})$$

$$\delta^{13}C_{mix} = \frac{DIC_{fw}\,\delta^{13}C_{fw}\,F_{fw} + DIC_{sw}\,\delta^{13}C_{sw}\,(1 - F_{fw})}{DIC_{fw}F_{fw} + DIC_{sw}(1-F_{fw})}$$

- Further and signatures of biogeochemical processes were obtained using model calculation following Erlenkeuser et al. (2003)

$$\Delta DIC = \frac{DIC_{sample} - DIC_{mix}}{DIC_{mix}}$$

$$\Delta^{13}C_{DIC} = \delta^{13}C_{sample} - \delta^{13}C_{mix}$$

Results & discussion

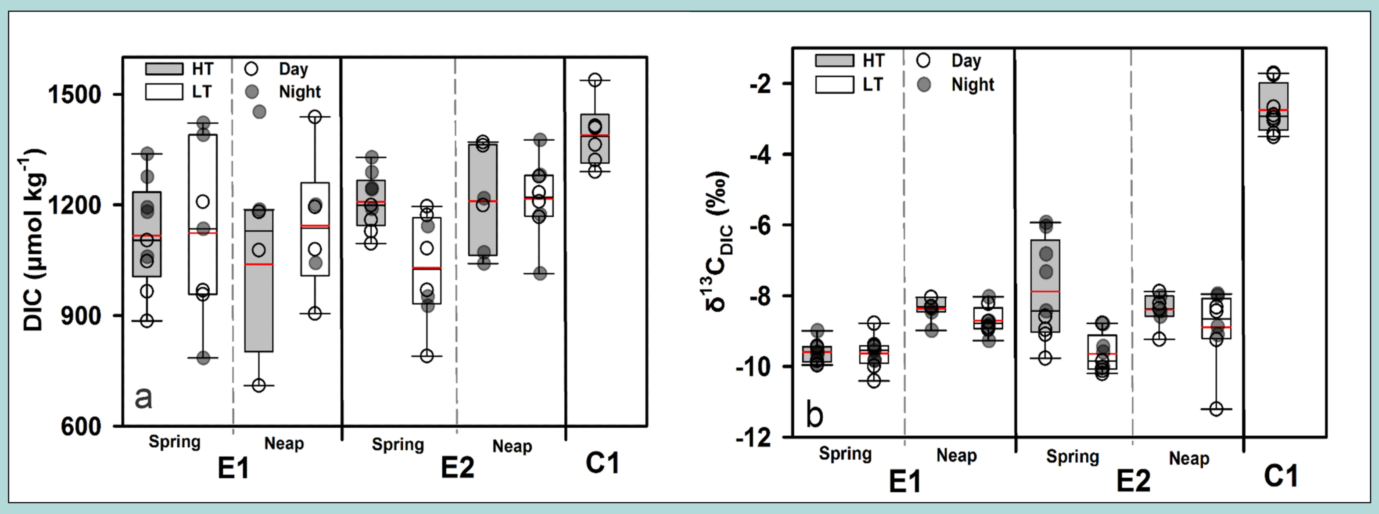

Fig. 3. Box plot showing variability of (a) DIC concentration and (b) $\delta^{13}C_{DIC}$ between stations and different classes. The boxes represent the interquartile range, the whiskers represent the minimum and maximum values, and the black and red line inside the box indicates the median and mean, respectively. Hollow boxes and filled boxes represents samples from high and low tide respectively, whereas hollow and solid dots represents day and night samples, respectively.

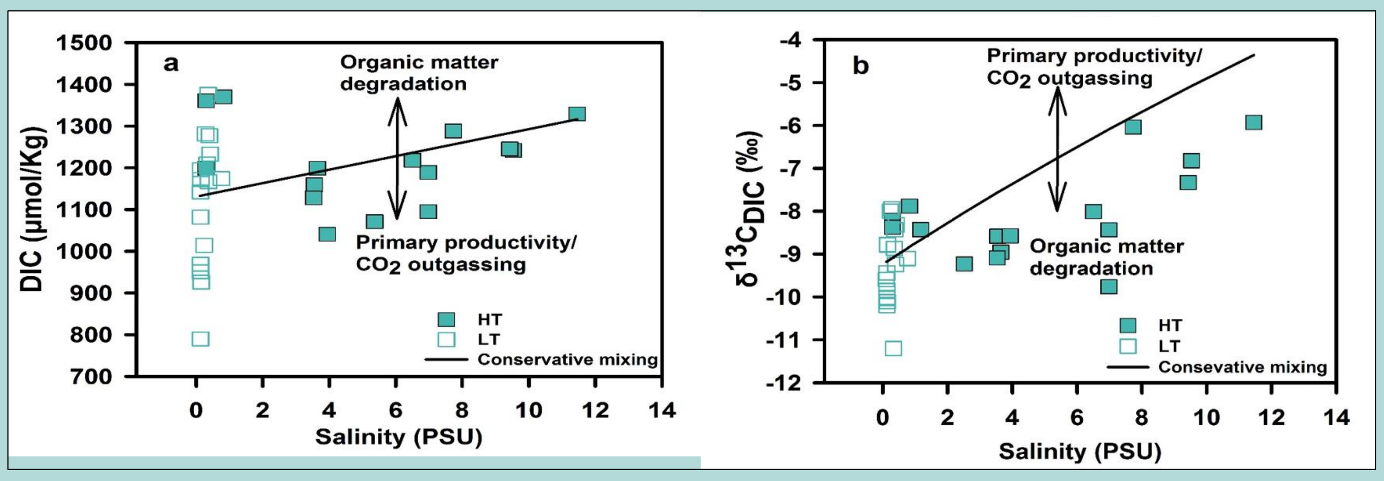

Fig. 4. In the mixing zone (E2) (a) DIC concentrations (B) $\delta^{13}C_{DIC}$ values plotted against salinity. The lines represent conservative mixing, drawn by using freshwater (E1) and coastal salinewater (C1) end member compositions. The samples points do not fall on the mixing line, suggesting presence of additional processes. The arrows indicate the possible effect of primary productivity/CO_2 outgassing and OM degradation on DIC concentrations and its $\delta^{13}C_{DIC}$.

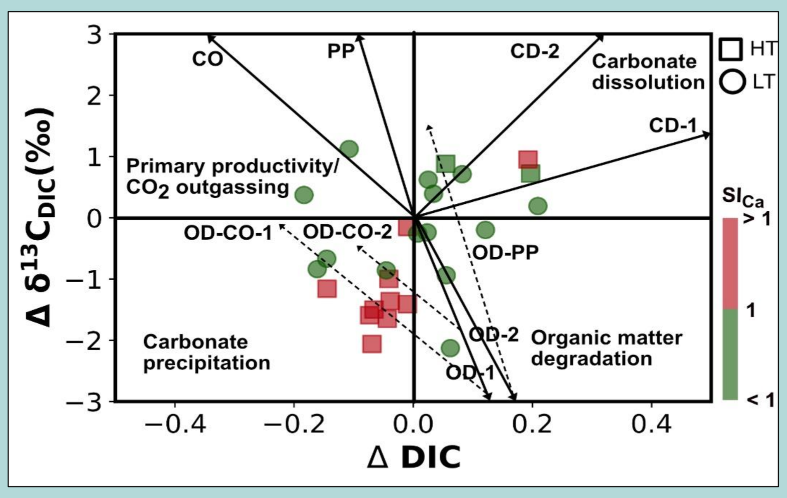

Fig. 5. In the mixing zone (E2), plot of ΔDIC against the $\Delta\delta^{13}C_{DIC}$. The four quadrants represents the processes which are likely to affect the DIC concentration and $\delta^{13}C_{DIC}$ in the Mahanadi estuary. The samples undergone single processes would move away in the direction of solid lines and the samples which have undergone more than one process would plot in direction of dashed arrows. Pink color represent samples with SI_{Ca} more than one (calcite oversaturation), whereas green color represents samples with SI_{Ca} less than one (calcite undersaturation)

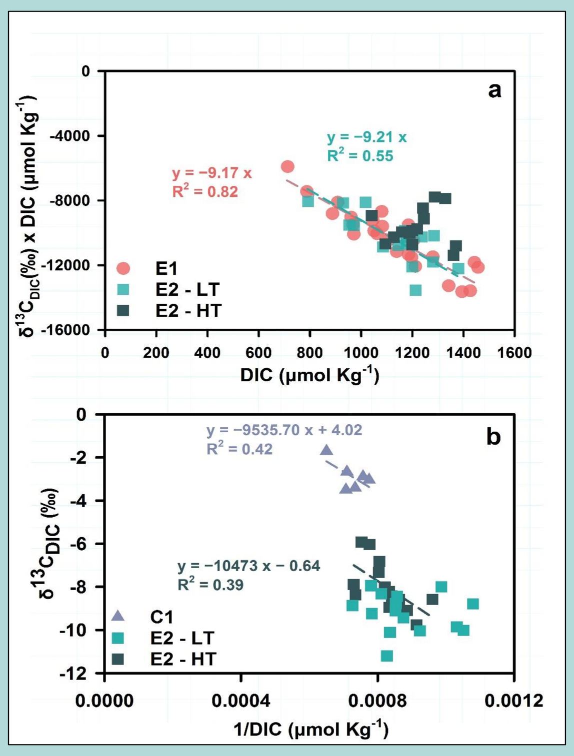

Fig. 6. Regression models of (a) Miller-Tans plot ($\delta^{13}C_{DIC}$ x DIC against DIC concentration), slope of -9.13, suggest carbonate and/or silicate weathering by possible biogenic CO_2, is the probable DIC source in the freshwater.
(b) Keeling plot ($\delta^{13}C_{DIC}$ against 1/DIC), high tide intercept of -0.64 indicating an oceanic water source

Conclusions

- No significant difference in DIC concentration and $\delta^{13}C_{DIC}$ during high tide from low tide
- Model calculation suggests the absence of conservative mixing, instead various biogeochemical and physical processes governed the DIC dynamics in the mixing zone. Signatures of pronounced calcite precipitation during high tide and calcite dissolution during low tide, along with other processes was observed
- Miller-Tan plot suggested that DIC at freshwater zone derived from carbonate and/or silicate weathering by possible biogenic CO_2, whereas Keeling plots at mixing zone suggest significant alteration of $\delta^{13}C_{DIC}$ signature
- The average DIC export flux from the Mahanadi river to the Bay of Bengal was estimated to be ~ 0.89 Tg y^{-1}, whereas the annual DIC yield was ~ 6.4 g m^{-2} y^{-1}

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Biogeochemistry of Nutrient, dissolved Silica along the salinity gradients of three estuaries, Southwest coast of India

D'Souza Nishitha, K. Balakrishna, H. N. Udaya Shankar,

Department of Civil Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal 576104, India

shoan500@gmail.com

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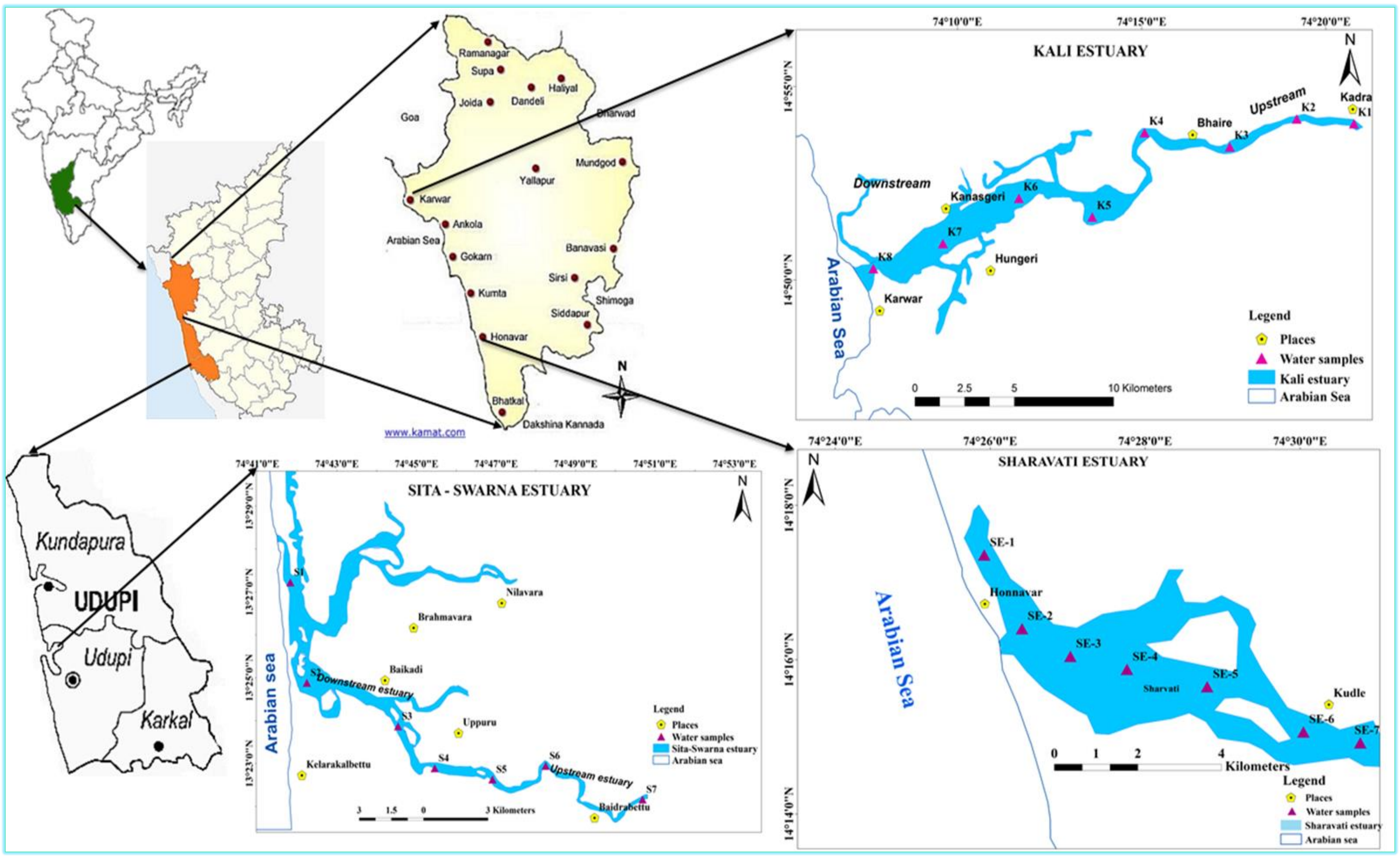
Introduction:

Coastal regions are highly productive due to the nutrients largely supplied by rivers. Dissolved silicate (DSi) is one of the important nutrient in coastal water, which is used by planktonic diatoms for cell division and growth. Major source of riverine export of silica to the coastal ocean is a chemical weathering of soils and rocks in the catchment area. Hence water samples from three west coast estuaries joining to Arabian Sea was examined to quantify the gross flux and net flux of dissolved silica.

Study area and Methodology:



Sampling and Onsite **measurement**

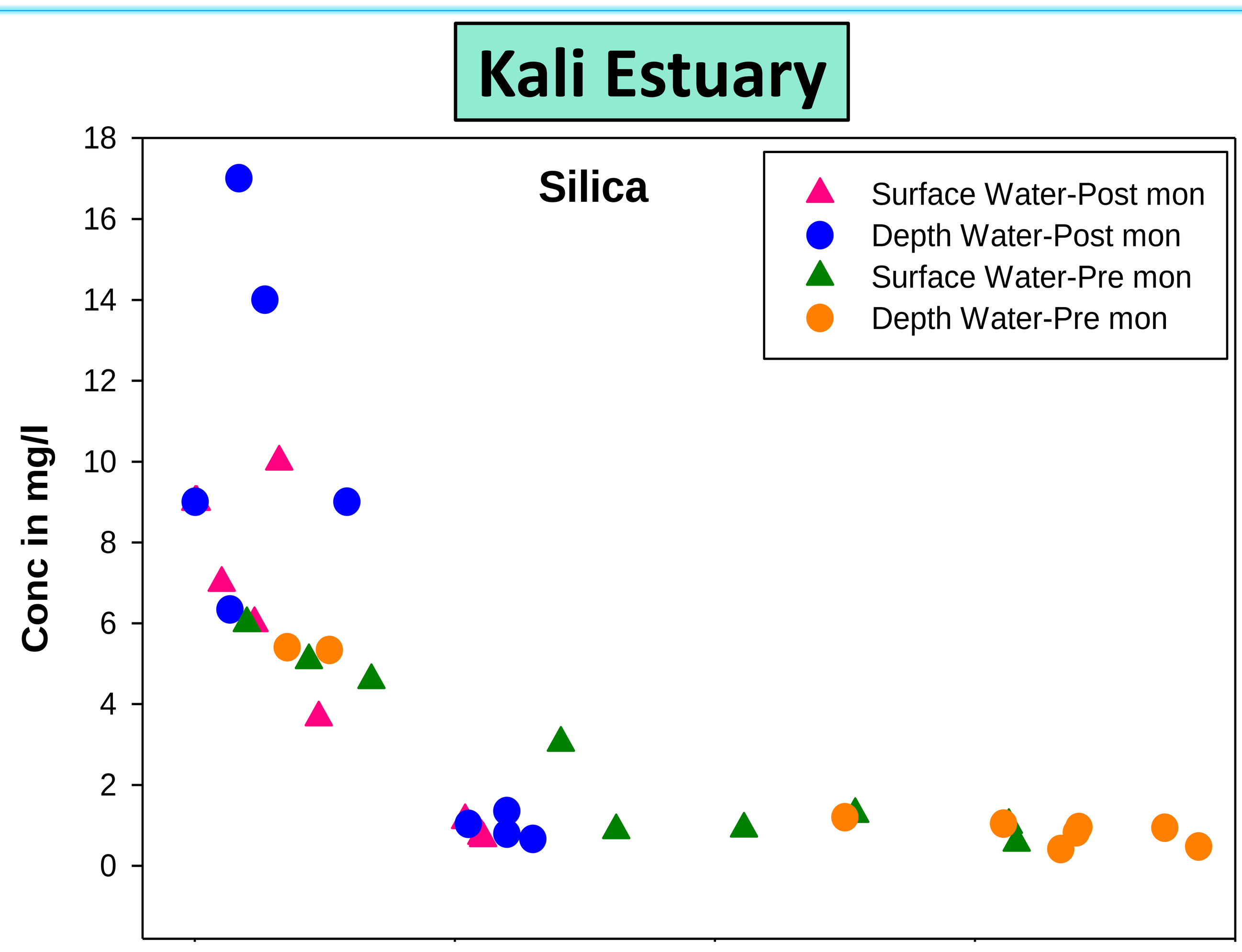
- Sample collection using Niskin sampler
- 2.5 L capacity

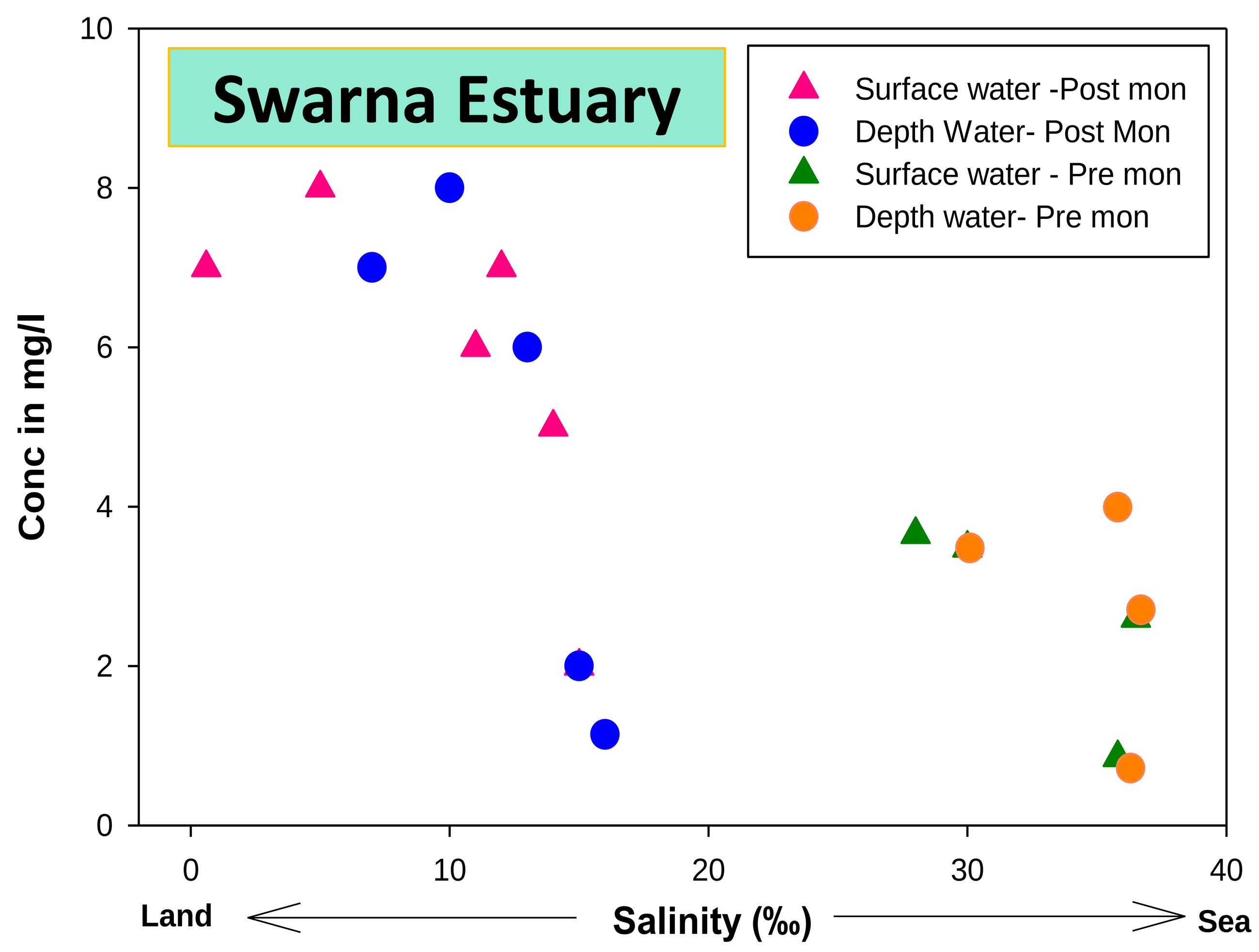
- Onsite measurement using HACH multiparameter

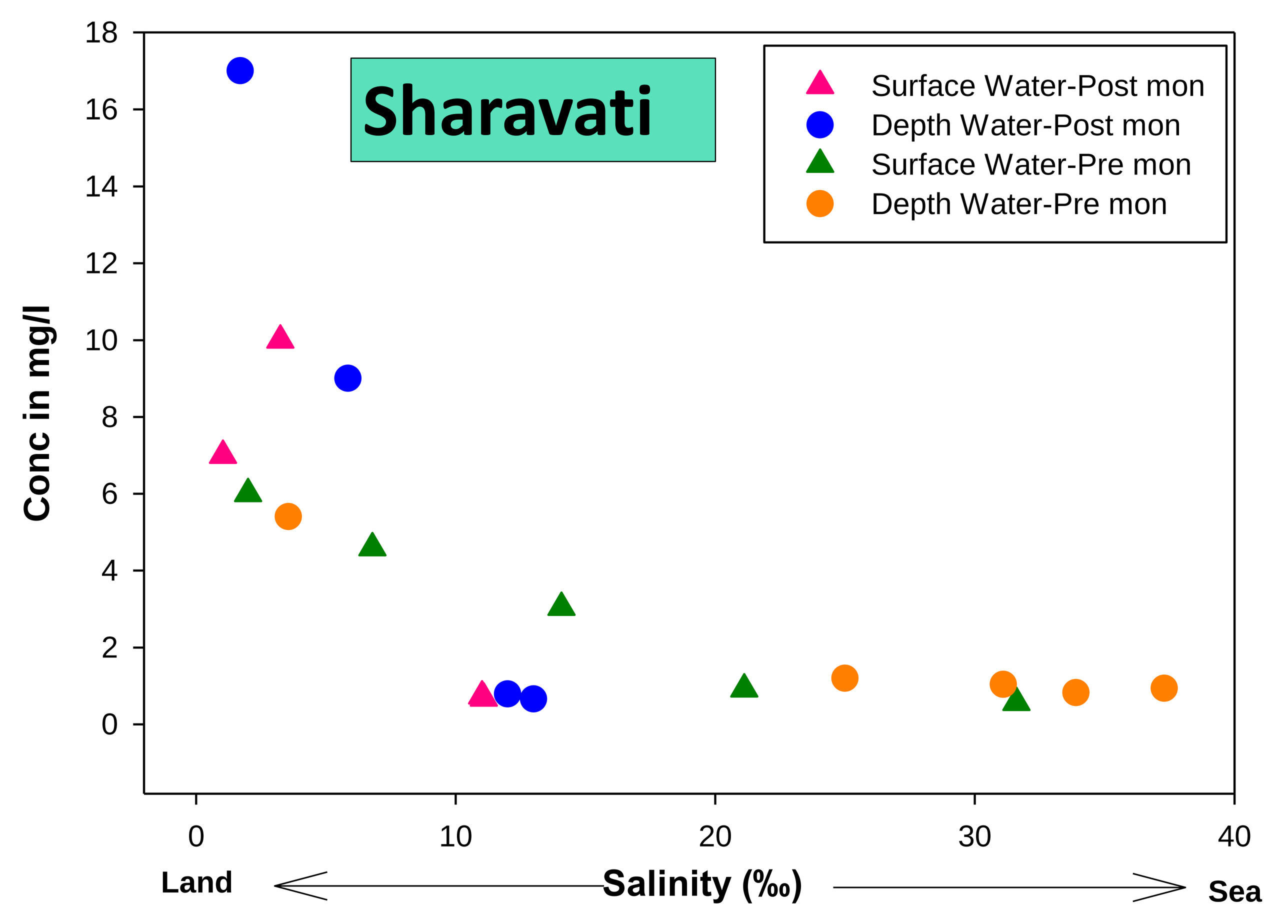
- Filtered using 0.22 μm pore-size Nuclepore filter paper

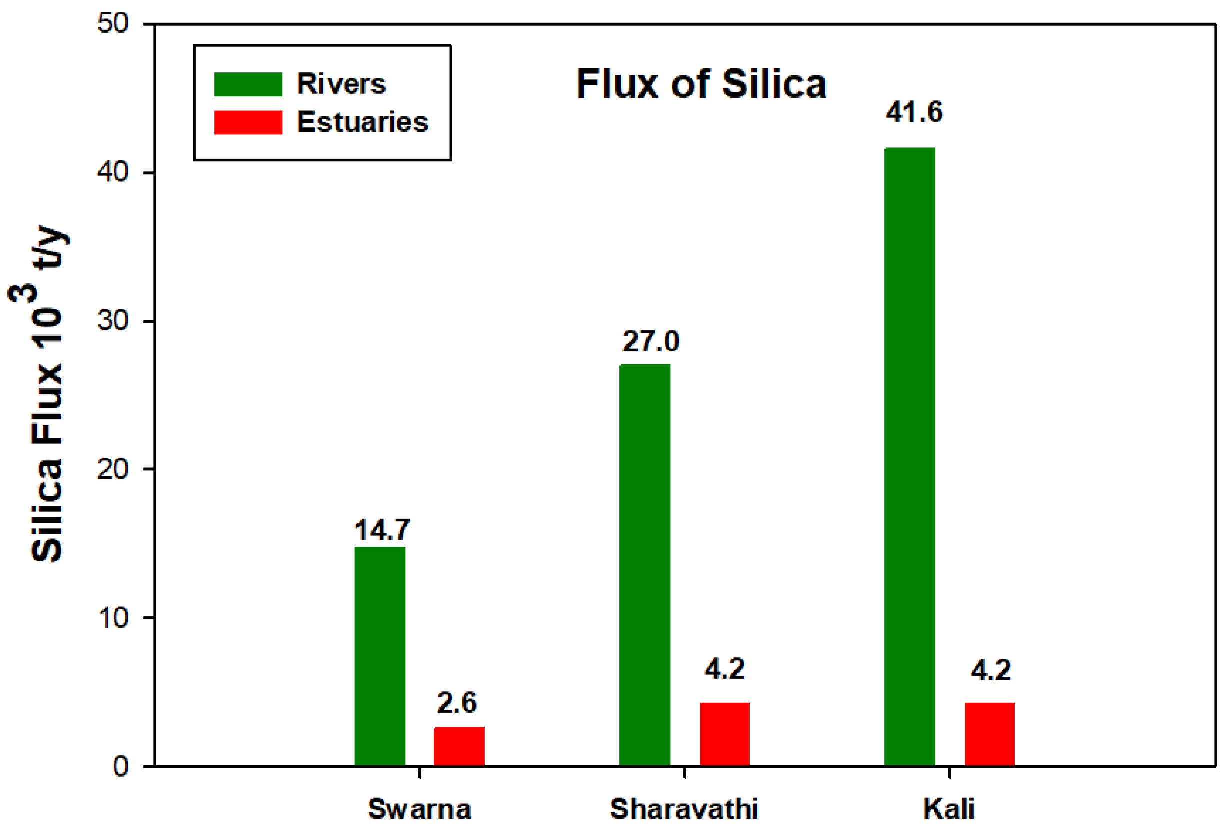
- DSi was analyzed using DR5000 spectrophotometer

Results and Discussions:



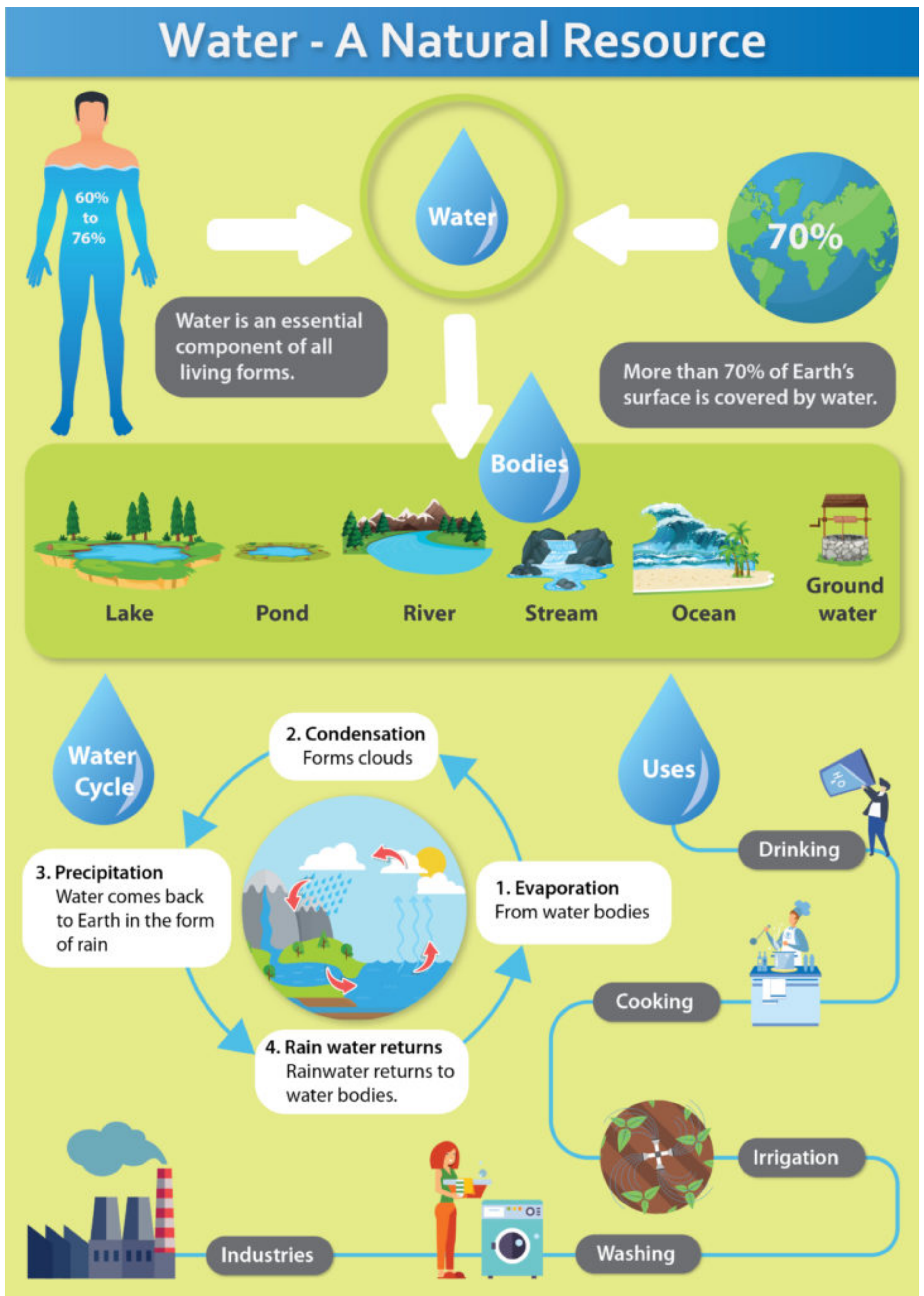






Conclusion:

- ***DSi showed non-conservative behaviour in all the three estuaries***
- ***Together, Kali, Sharavati and Sita-Swarna accounts for gross flux of 0.08Tg/yr and net flux of 0.01Tg/yr respectively.***



Nikita Bhagat

Causes of water pollution

- Natural sources
  - Decomposed vegetables/animals
  - Weathered products (Rocks)
- Anthropogenic sources (Man-made)
  - Industrial
  - Agricultural
  - Mining sources, etc.

Major Water Quality Issues

Common issues of Surface and Ground water

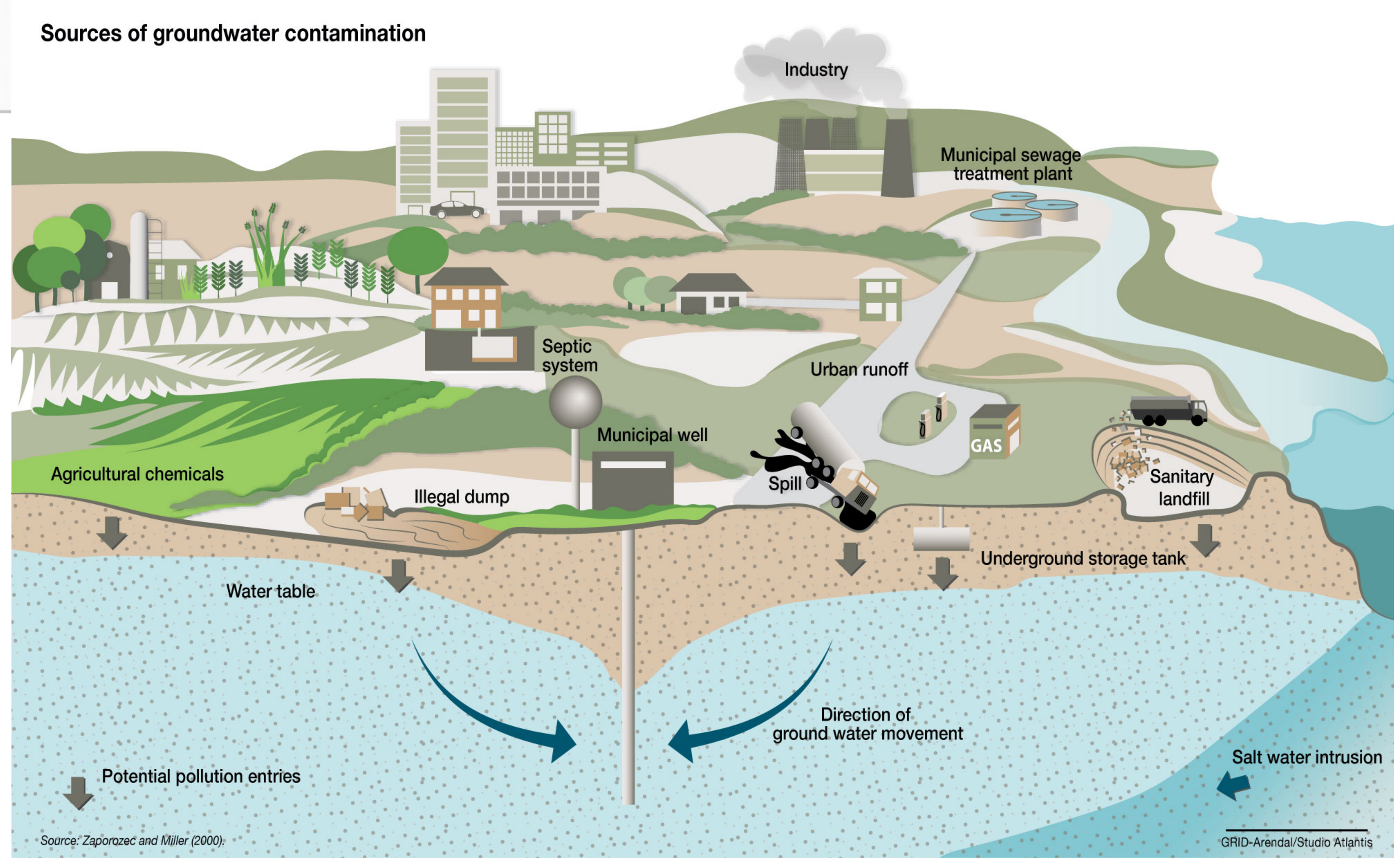
- Pathogenic (Bacteriological) Pollution
- Salinity
- Toxicity (micro-pollutants and other industrial pollutants)

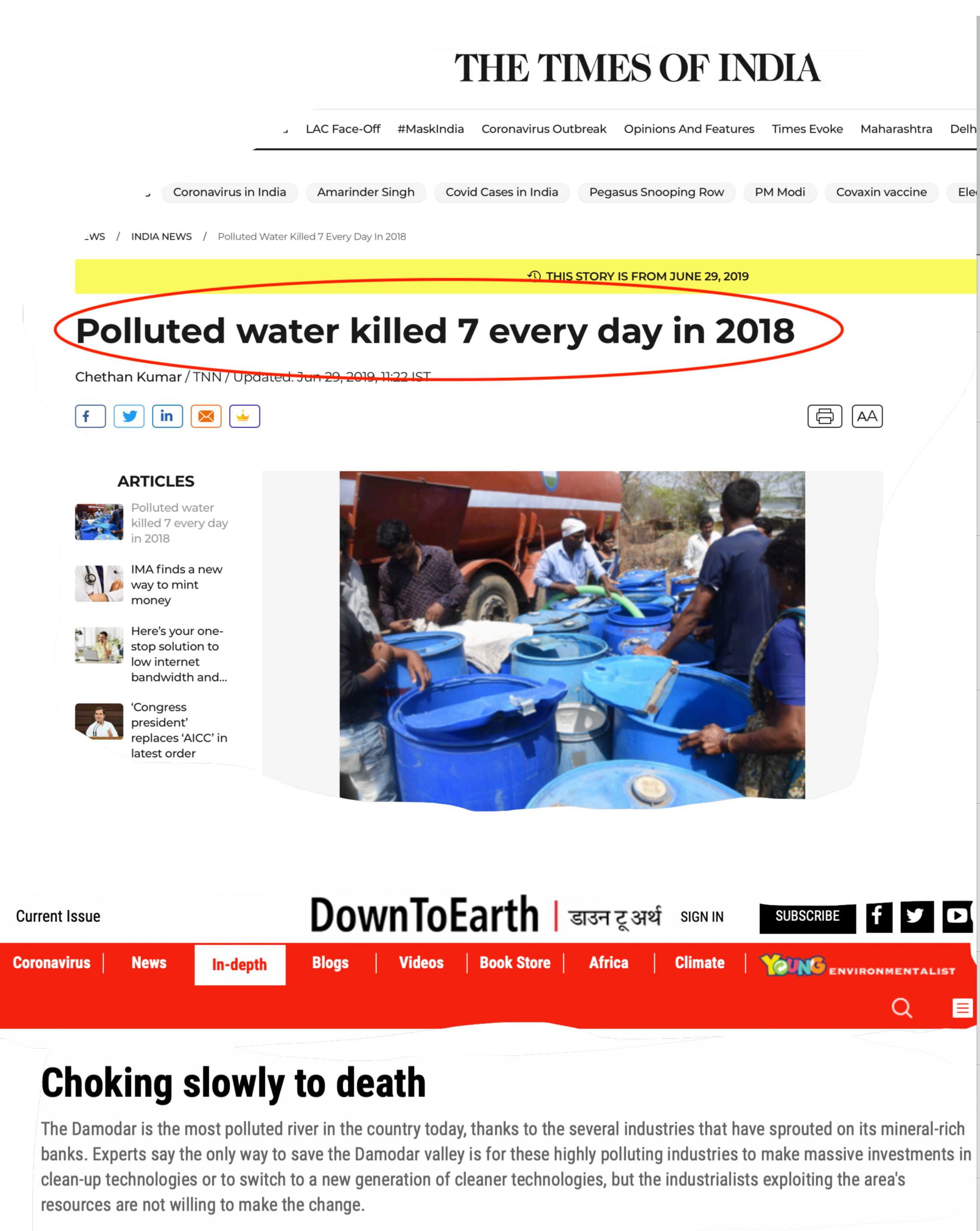
Surface Water

- Eutrophication
- Oxygen depletion
- Ecological health

Ground Water

- Fluoride
- Nitrate
- Arsenic
- Iron
- Sea water intrusion




THE TIMES OF INDIA

Polluted water killed 7 every day in 2018

Chethan Kumar / TNN

DownToEarth

Choking slowly to death

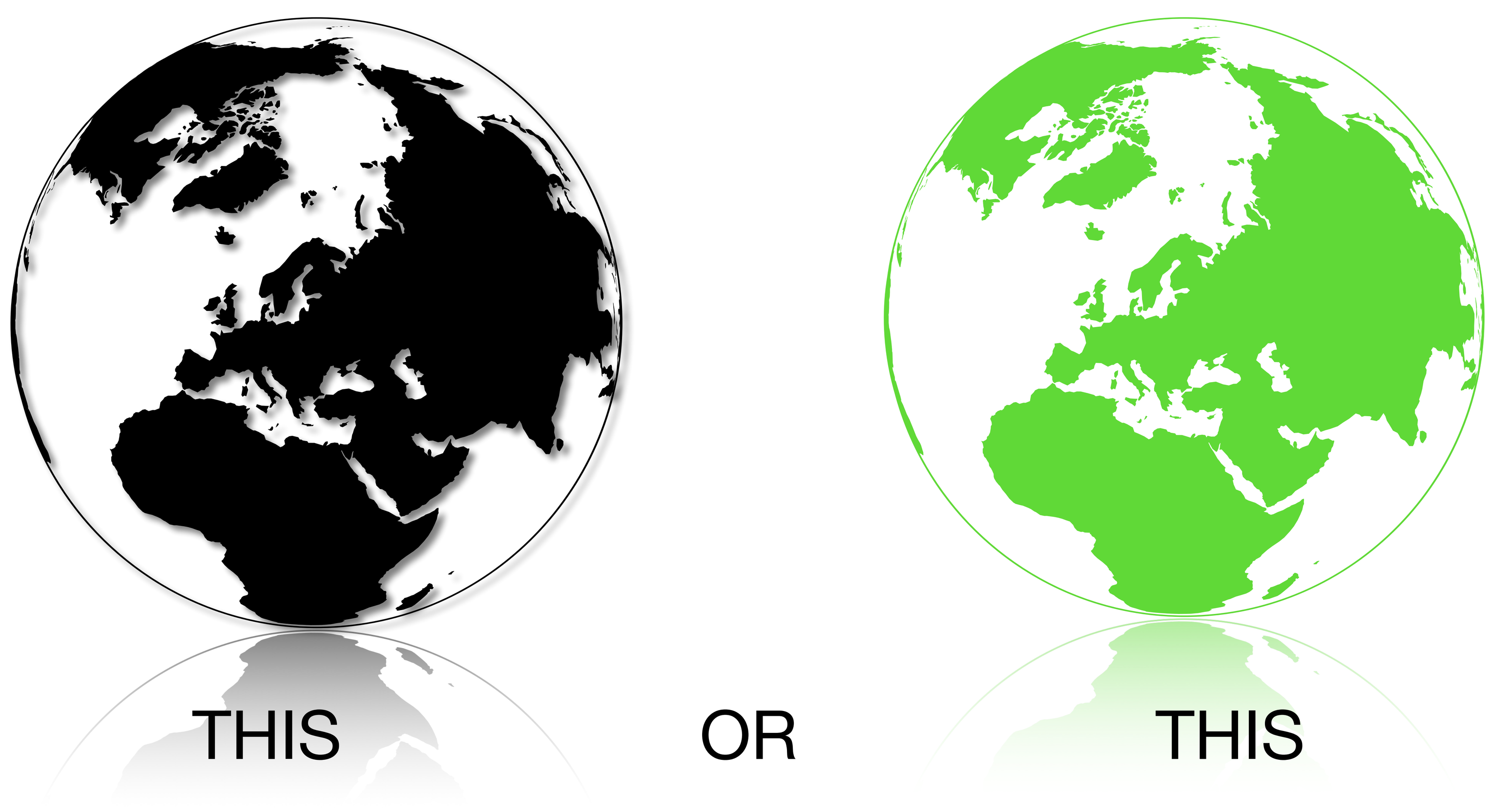
The Damodar is the most polluted river in the country today, thanks to the several industries that have sprouted on its mineral-rich banks. Experts say the only way to save the Damodar valley is for these highly polluting industries to make massive investments in clean-up technologies or to switch to a new generation of cleaner technologies, but the industrialists exploiting the area's resources are not willing to make the change.

North Koel river(Jharkhand) :Water Sample Analysis(pre monsoon and post monsoon)

Parameters	Unit	Safe limits as per BIS Norms	WS1		WS2		WS3		WS4		WS5		WS6		WS7		WS8		WS9	
			Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M
pH value	pH	6.5-8.5	7.77	6.65	**8.65**	7.05	**8.3**	7.15	8.04	7.43	7.82	7.54	**8.25**	7.45	**8.44**	7.53	8.28	7.62	8.21	7.29
Conductivity	us/cm	_	195	165.6	322	248	219	159.2	275	297	298	230	288	228	342	278	280	252	312	372
Total Dissolved solids	mg/l	1500	124	82	206	128	132	80	160	156	180	120	178	118	216	143	168	127	192	200
Calcium(as Ca2+)	mg/l	75	24	15.2	54.4	25.6	23.2	16	28.8	28	27.2	23.2	27.2	21.6	19.2	28.8	25.6	24.8	31.2	31.2
Magnesium(as Mg2+)	mg/l	30	4.37	4.76	0.48	6.36	6.8	4.36	8.74	6.92	11.7	6.04	10.2	5.96	**21.38**	6.52	10.2	6.28	11.7	7.24
Sodium(as Na+)	mg/l	_	17	9.04	27	11.76	18	9.08	25	12.64	26	11.56	25	11.76	30	12.08	25.3	11.6	28	12.32
Potassium(as K+)	mg/l	_	2	2.64	2	2.64	2	2.28	2	4.12	3	3.12	3	3.2	3	3.08	3	2.76	3	37.48
Phosphate(PO4-)	mg/l	_	0.04	0.37	ND(DL 0.003)	0.31	0.01	0.4	0.03	0.36	0.01	0.38	0.01	0.34	0.04	0.24	0.01	0.24	0.05	0.17
Iron (as Fe)	mg/l	0.3	ND(DL0.1)	**10.36**	ND(DL 0.1)	**13.29**	ND(DL0.1)	**8.76**	ND(DL0.1)	**4.41**	ND(DL0.1)	**8.56**	ND(DL0.1)	**5.49**	ND(DL 0.1)	**7.73**	ND(DL 0.1)	**5.28**	ND(DL0.1)	**3.81**

Remedial measures

- *Locate the point sources of pollution.*
- *Work against acid rain.*
- *Educate your community.*
- *Ensure sustainable sewage treatment.*
- *Watch out for toxins.*
- *Be careful what you throw away.*
- *Use water efficiently.*
- *Prevent pollution .*
- *Think globally, act locally.*



CHOICE IS YOURS.......THINK AGAIN !

Spatial variability and residence time of beryllium isotopes in the Indian Ocean: Role of oceanic processes

Partha Sarathi Jena[1], Ravi Bhushan[1], Shivam Ajay[1], A K Sudheer[1]

[1]Geosciences Division, Physical Research Laboratory, Ahmedabad 380009, INDIA

ABSTRACT:

The cosmogenic produced beryllium-10 (^{10}Be, half-life - 1.39 Ma) has proven to be an essential tool for building chronology and understanding millennial-scale earth surface processes. Prior to application of beryllium isotopes for deciphering the past processes, it needs understanding of processes controlling the present distribution of ^{10}Be/^{9}Be in global oceans. Multiple attempts have been made to understand beryllium isotopic distribution in the global ocean based on water column measurements and authigenic fractions derived from various archives (such as surface sediments and Fe-Mn nodules), though Indian Ocean remains poorly explored. This study based on beryllium isotopic measurements by AMS attempts to address the processes controlling beryllium isotopic distribution in surface sediments from the central and northern Indian Ocean.

In the Bay of Bengal, the sediments show higher ^{9}Be concentration and lower ^{10}Be/^{9}Be ratio because of higher terrestrial flux. Whereas for the open ocean locations, a negative correlation observed between $CaCO_3$ concentration and the beryllium isotopes suggests processes such as scavenging by particles affects both isotopes in well-mixed open ocean waters. The residence time of beryllium estimated for the Indian Ocean shows large basin-wise variation. The higher residence time of beryllium was observed in the central Indian Ocean, indicating lower scavenging of beryllium in the water column due to limited scavenging particles such as clay in the open oceans. Significantly lower residence time was observed in the Bay of Bengal implies enhanced scavenging of beryllium due to large terrestrial flux.

AIM OF THE STUDY:

- To understand role of oceanic processes controlling the ^{10}Be/^{9}Be distribution and behaviour of beryllium in the Indian Ocean water column.

METHODOLOGY:

- ^{10}Be and ^{9}Be was measured in the authigenic fraction derived from surface sediments covering central and northern Indian Ocean.
- ^{10}Be was measured using the 1MV Accelerator Mass Spectrometer at PRL (AURiS).

RESULTS:

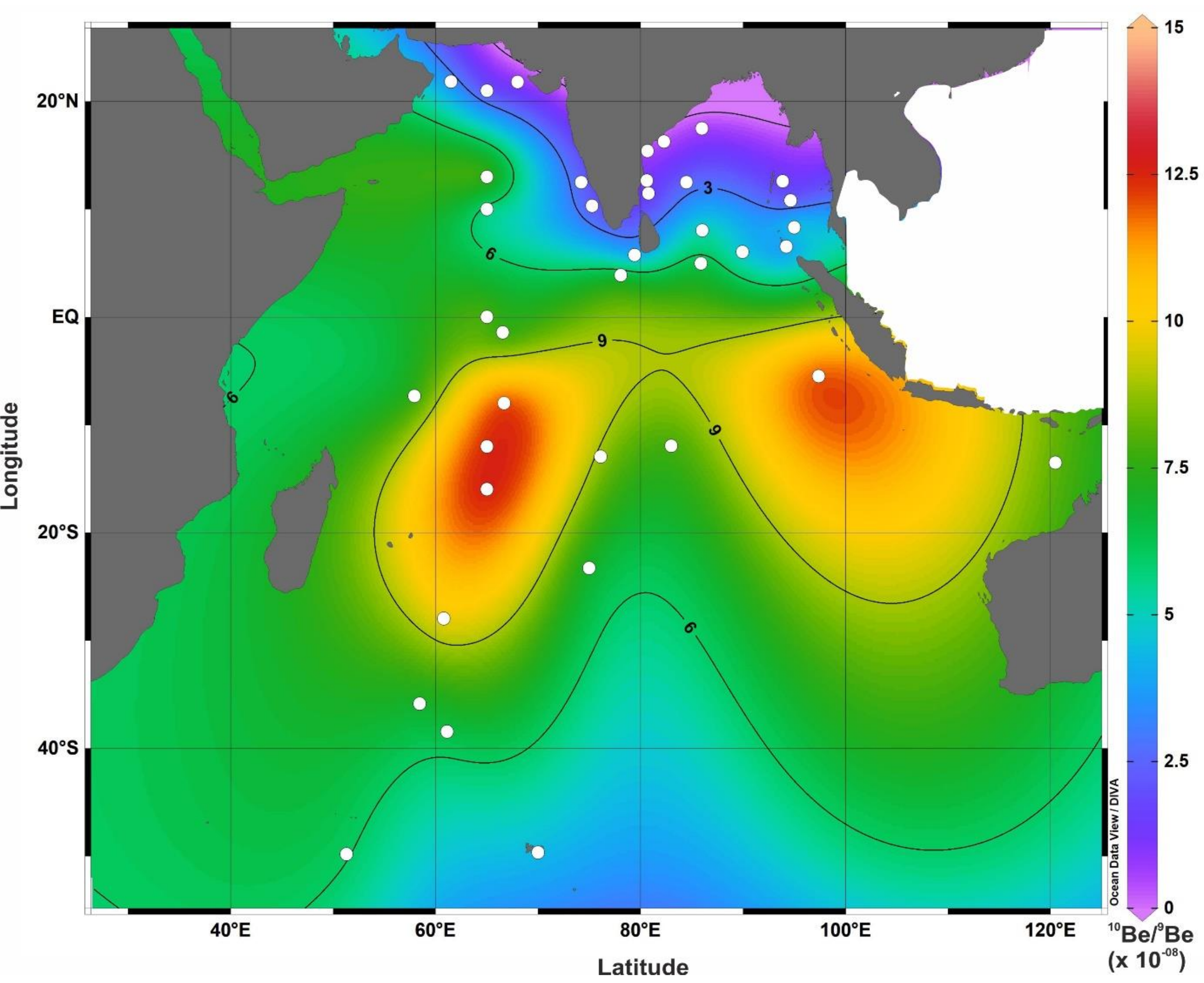


Figure 1: The distribution of ^{10}Be/^{9}Be ratio (x 10^{-08}) in the deep-water column of the Indian Ocean. The values are derived from different archives such as surface sediments (Bourles et al., 1989; present study) and Fe-Mn crusts (von Blanckenburg et al., 1996). The sample locations are represented by white circles.

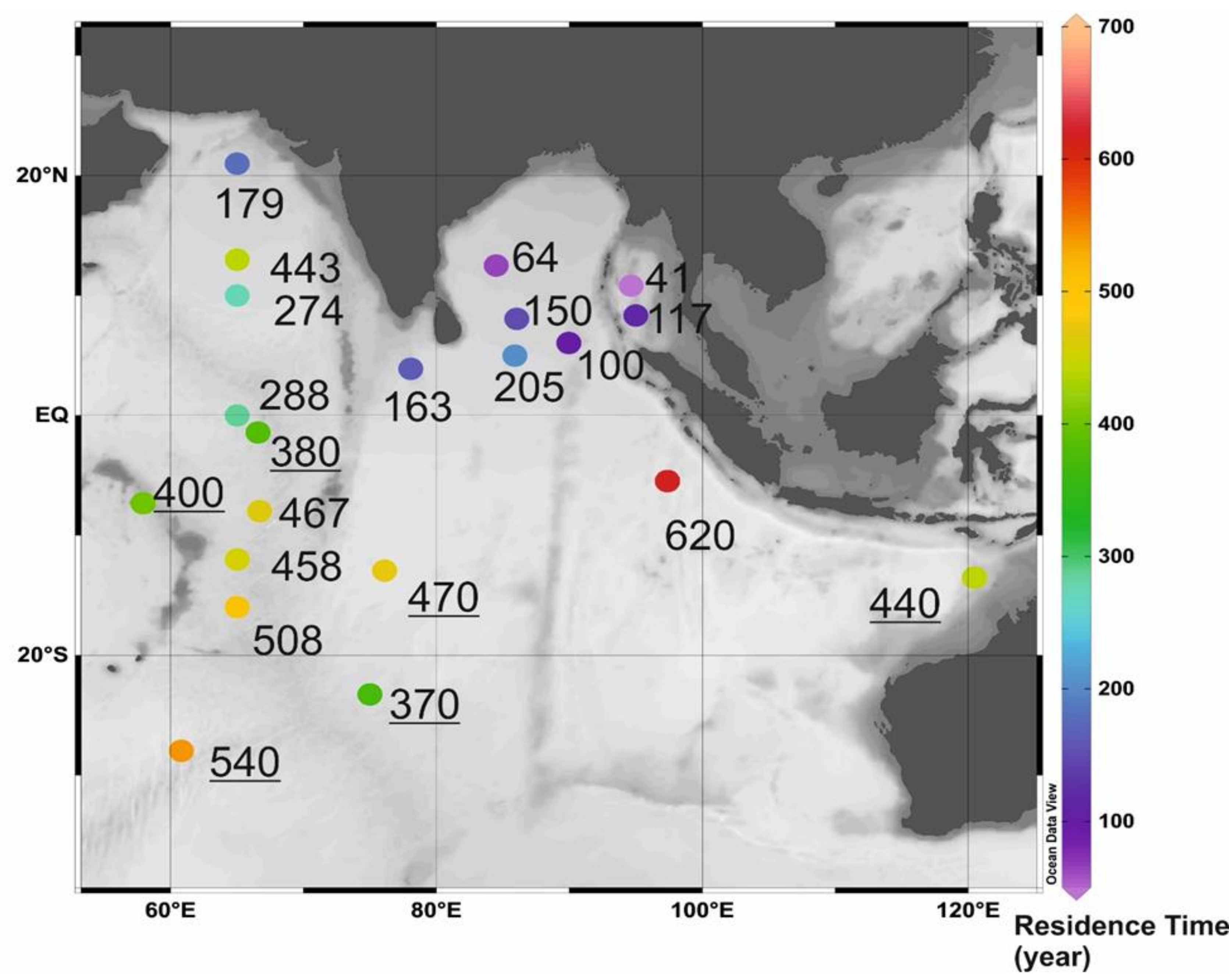


Figure 2: The estimates of residence time (in years) of beryllium in the Indian Ocean water column. The figure also includes Be residence time estimated (shown as underlined texts) by von Blanckenburg et al. (1996).

SUMMARY:

- A lower ^{10}Be/^{9}Be ratio observed from the northern Indian Ocean reflects higher terrestrial sediment input through various large rivers. Among all the basins, the Bay of Bengal receives maximum sediment load, which results in a higher ^{9}Be concentration and lower ^{10}Be/^{9}Be ratio.
- The lower residence time of Be in the Northern Indian Ocean has been attributed to the active scavenging of beryllium by sediment particles. Higher residence time in the central Indian Ocean, where sediments are characterized by higher carbonate concentration, implies that clay particles are more efficient in scavenging beryllium from the water column than carbonates.

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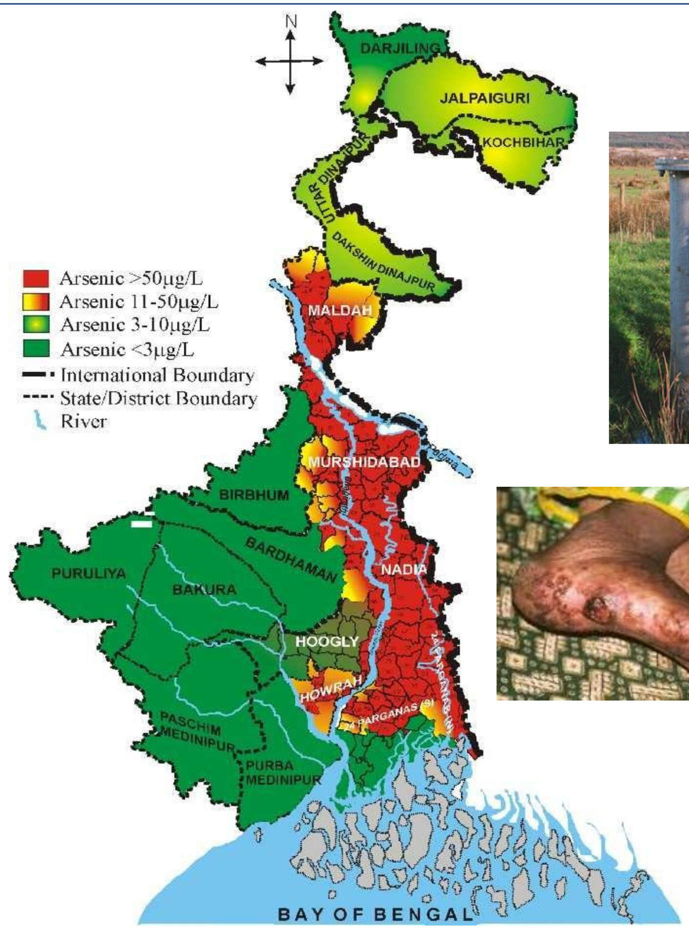
Evaluation of the role of carbon and sulfur bio-geochemical cycles on the seasonal arsenic mobilization process in the shallow groundwater of the Bengal aquifer

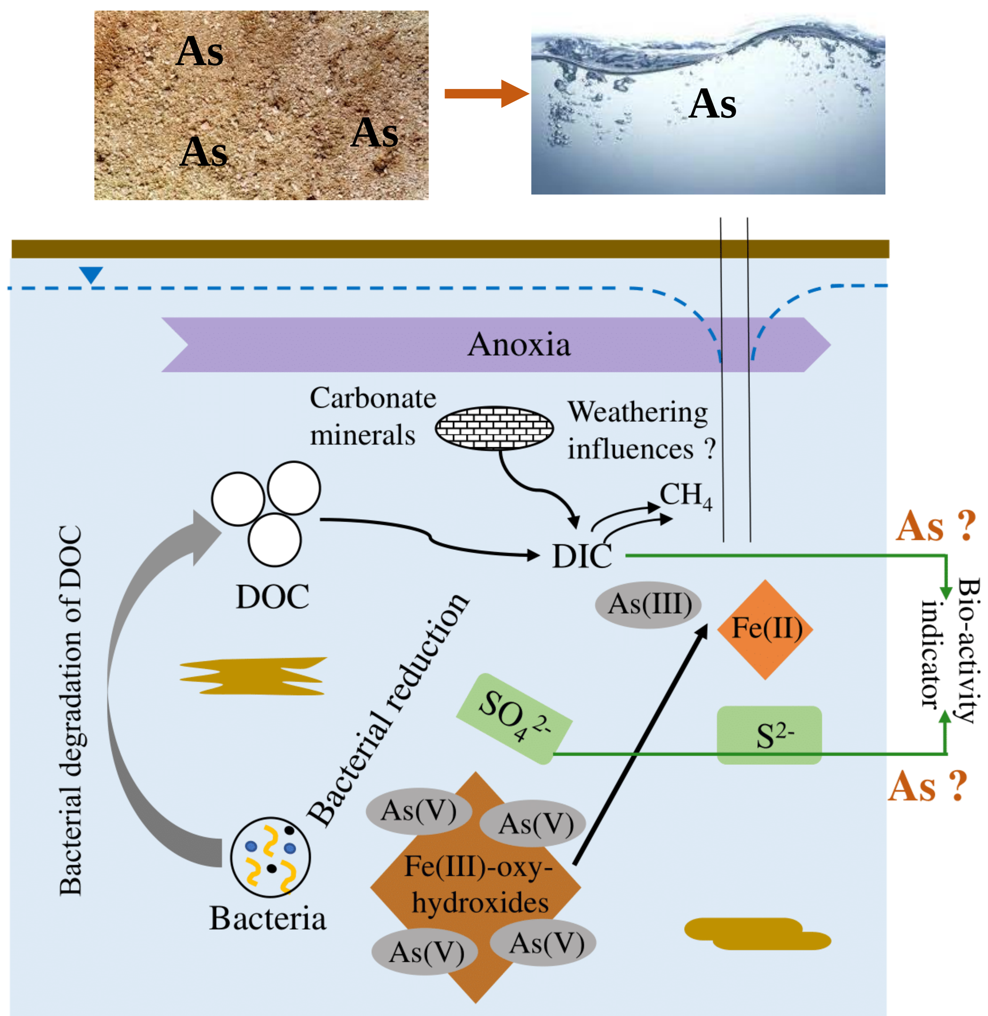
[1]Pousali Pathak, [1,2]Prosenjit Ghosh, [1]Ankit Swaraj, [3,5]Tsai-Luen Yu, [3,4]Chuan-Chou Shen

[1]Centre for Earth Science, Indian Institute of Science, Bangalore 560012, India; [2]Divecha Centre for Climate Change, Indian Institute of Science, Bangalore 560012, India; [3]High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University, Taipei 10617, Taiwan ROC; [4]Marine Industry and Engineering Research Center, National Academy of Marine Research, Kaohsiung 806, Taiwan ROC; [5]Research Center for Future Earth, National Taiwan University, Taipei 10617, Taiwan, ROC

THREAT OF ARSENIC CONTAMINATION IN GROUNDWATER OF WEST BENGAL



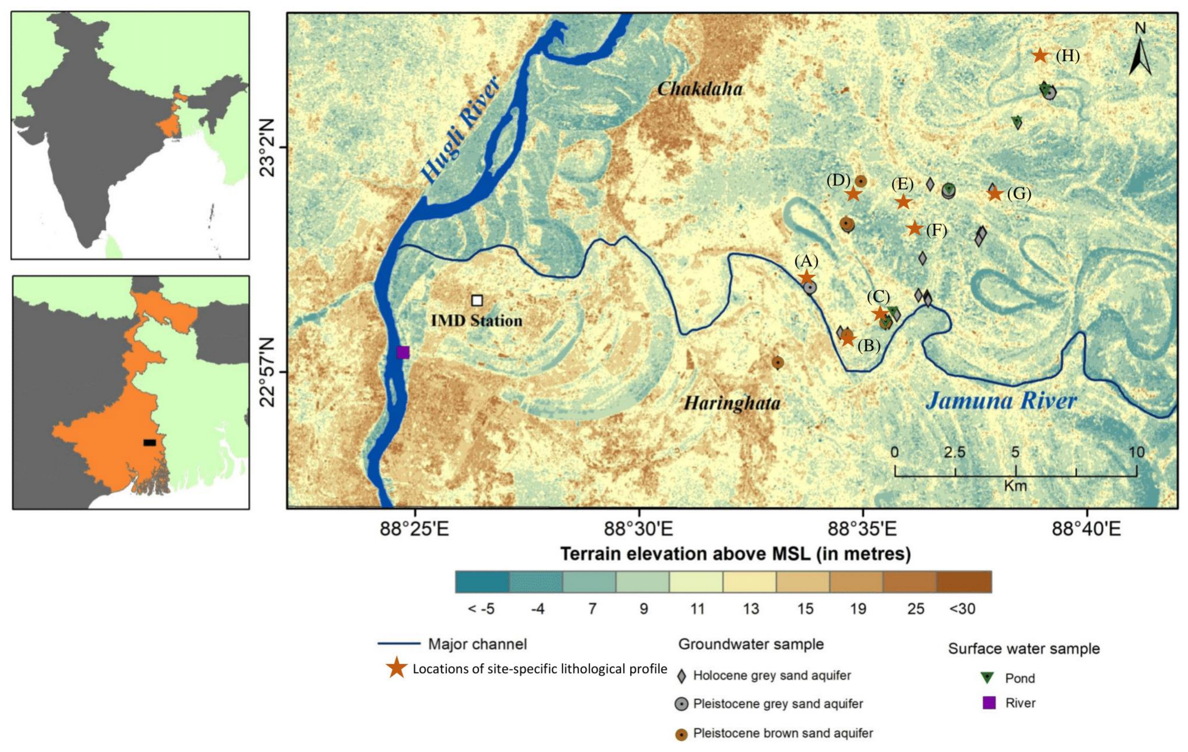
Mobilization mechanism of arsenic (As) from aquifer sediment into the groundwater

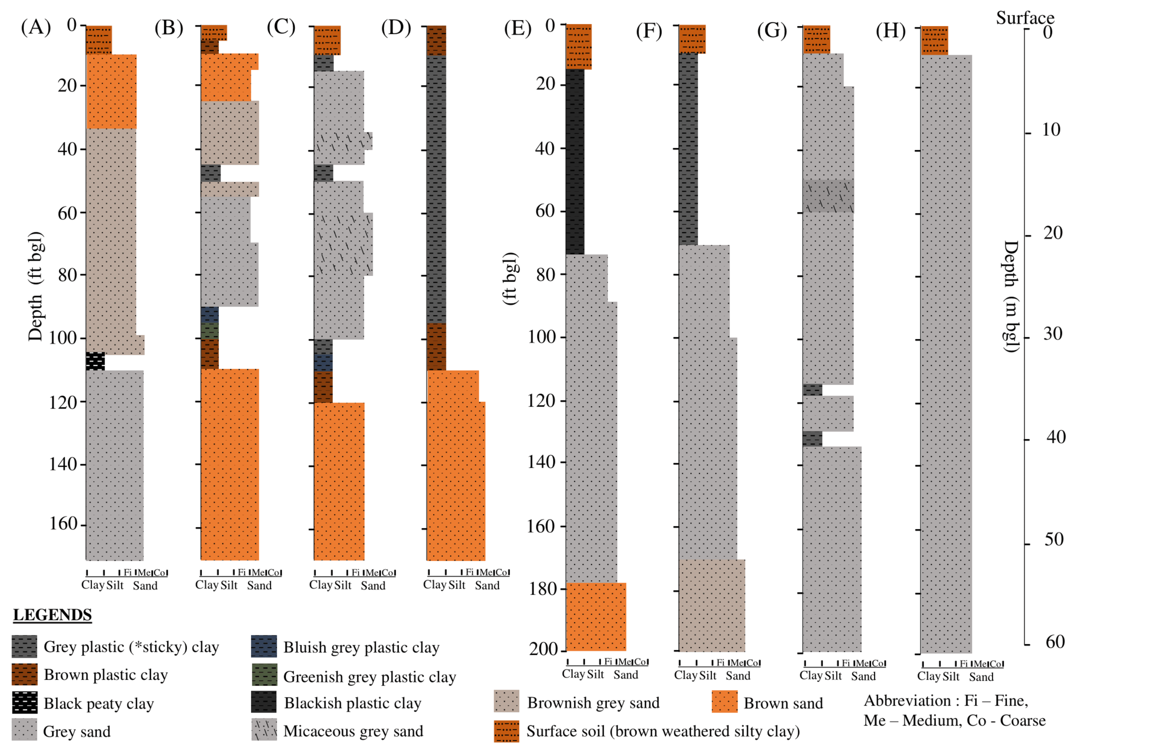


(Not to scale) Abbreviation : As – Arsenic, DOC - Dissolved organic carbon, DIC - Dissolved inorganic carbon.

- Arsenic (As) is a carcinogenic metalloid; exposes > 26 million people in the West Bengal region potentially at high risk of As toxicity
- WHO defined acceptable guideline value of total As concentration in drinking water is 10 µg/L

STUDY AREA AND SUB-SURFACE LITHOLOGY





MAJOR SCIENTIFIC QUESTION ADDRESSED

How the interplay between C-Fe-S biogeochemical cycles driving seasonal As mobilization in the shallow groundwater (and a few deep groundwater)?

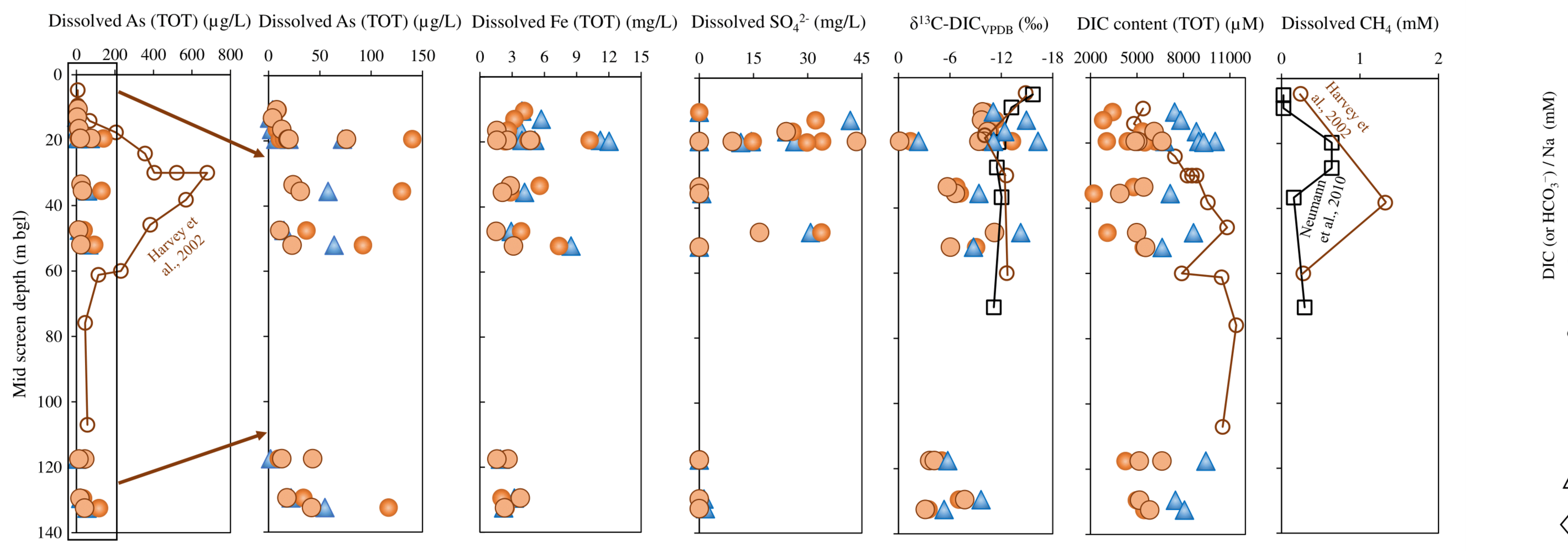
Sampling and Analytical measurements

11 bore-wells water from shallow GSA and 4 bore-wells water from deep GSA during Post-monsoon and Pre-monsoon periods over multiple years (i.e., Nov-16, Apr-17, Feb-18) (GSA- Grey Sand Aquifer)

pH, conductivity
Dissolved total As, Fe, SO_4^{2-}, Na, Ca, DIC content
δ^{13}C-DIC, δ^{34}S-SO_4^{2-} stable isotopes

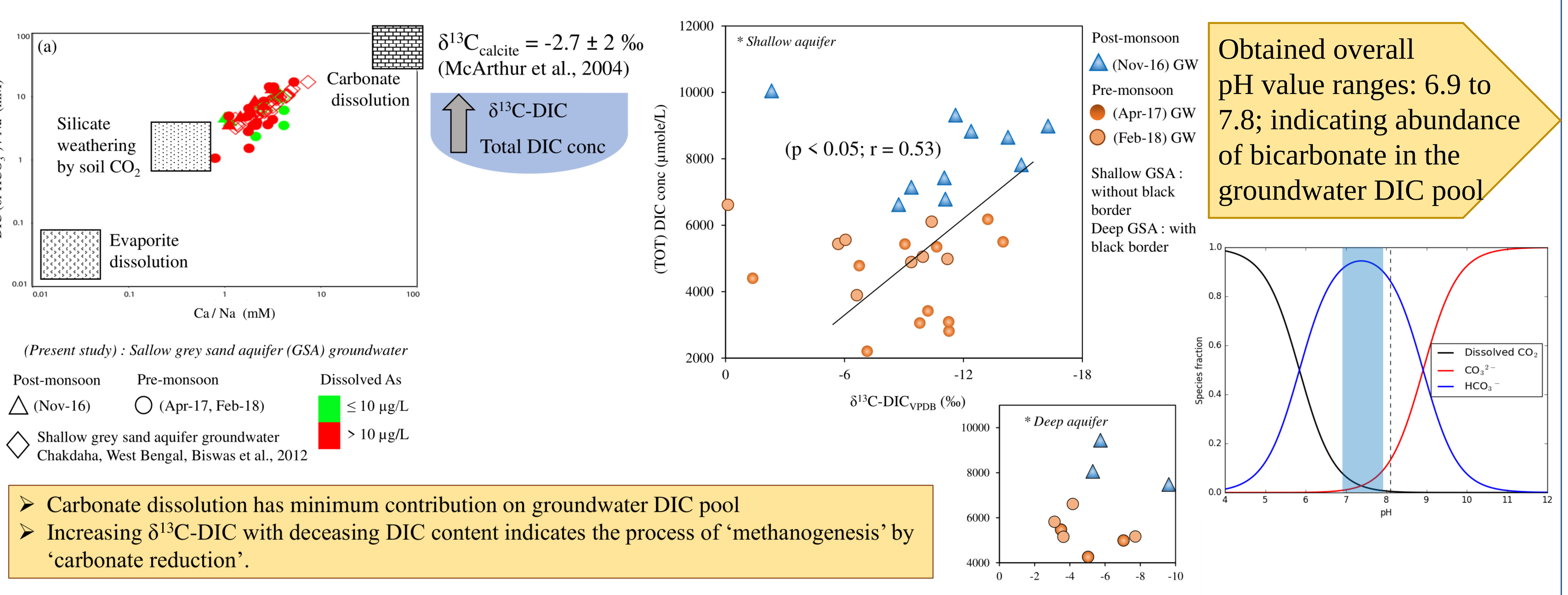
MAJOR FINDINGS IN THE CURRENT STUDY

1 Vertical distribution and seasonal pattern in As containing GSA groundwater chemistry



- Increasing dissolved total As contents, δ^{13}C-DIC composition, and decreasing total DIC content is prominent during winter and pre-monsoon periods from post-monsoon period.
- Dissolved total Fe, SO_4^{2-} contents in the limited samples show no prominent inter-seasonal pattern.

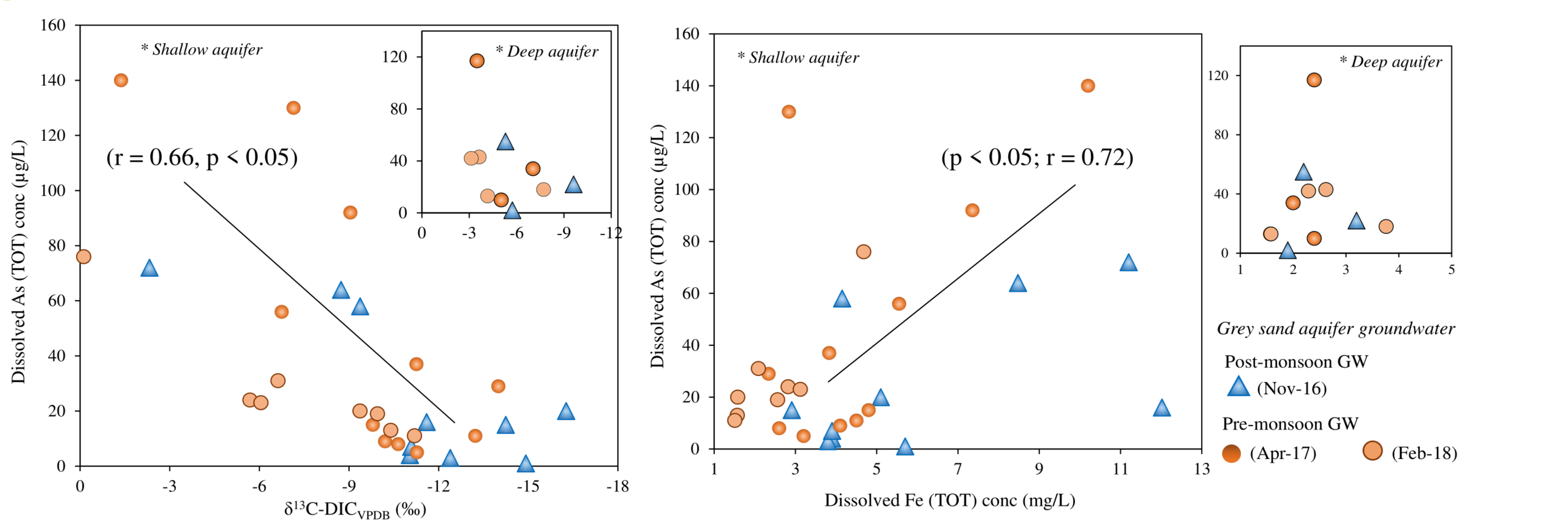
2 Abiotic and biotic influence on groundwater (GSA) DIC composition at seasonal time intervals



Obtained overall pH value ranges: 6.9 to 7.8; indicating abundance of bicarbonate in the groundwater DIC pool

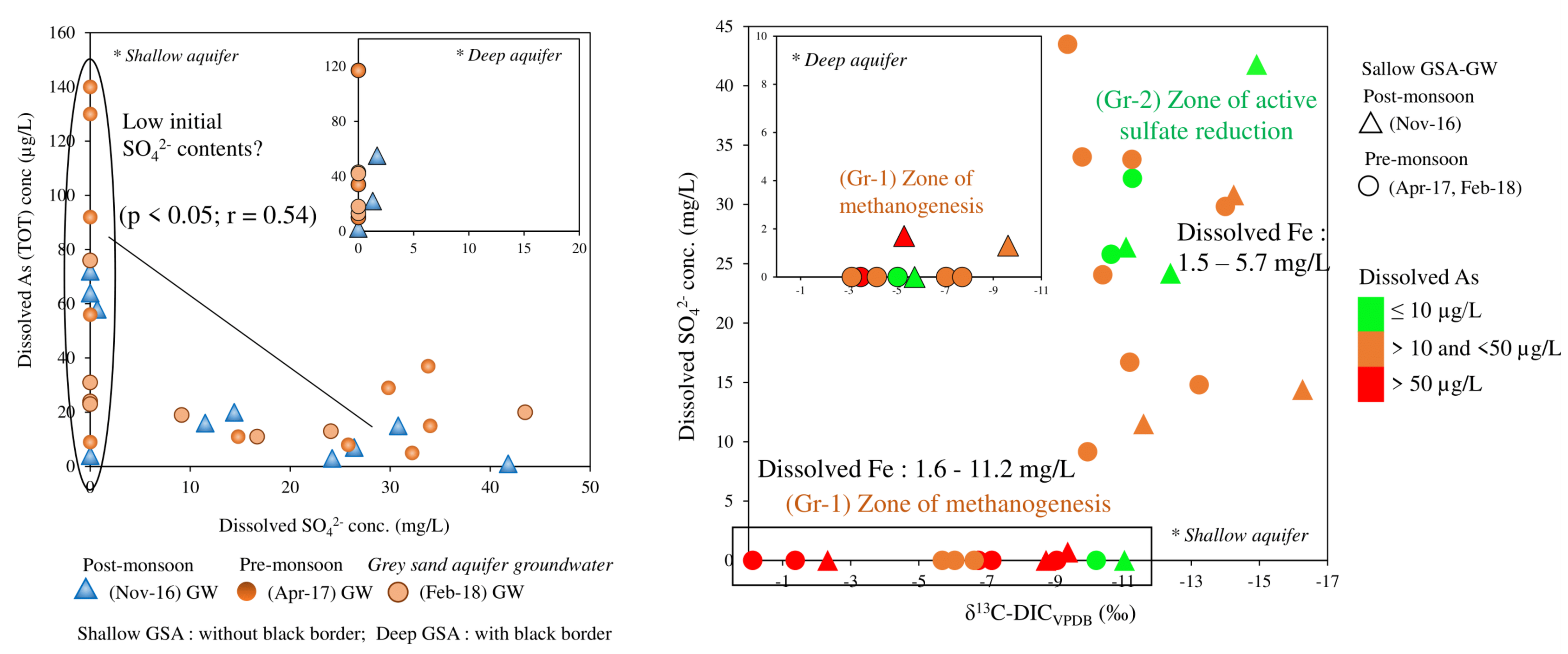
- Carbonate dissolution has minimum contribution on groundwater DIC pool
- Increasing δ^{13}C-DIC with deceasing DIC content indicates the process of 'methanogenesis' by 'carbonate reduction'.

3 Evaluation of the mechanism driving As mobilization in the seasonal groundwater



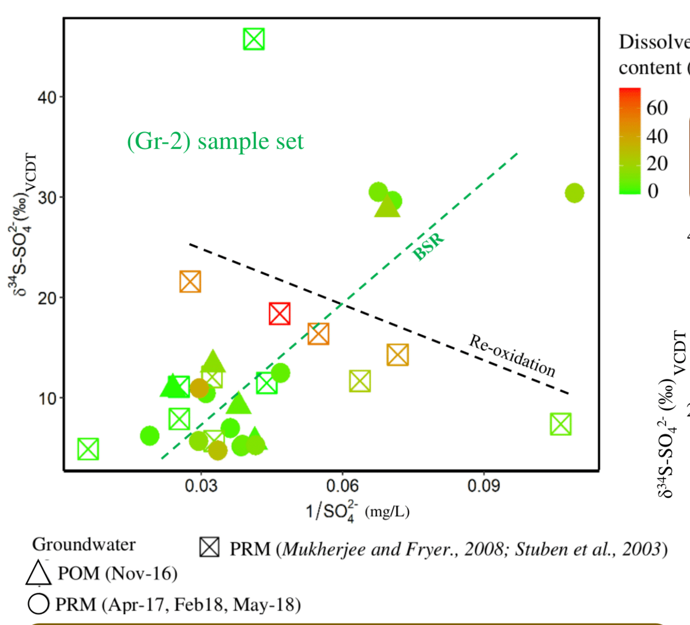
- Increasing δ^{13}C-DIC with increasing dissolved As content indicates methanogenesis promotes As mobilization in groundwater
- Dissimilatory reductive dissolution of As-coated Fe(III)-oxy-hydroxides coupled to microbial metabolism of DOC is the principle mechanism of As release in the shallow groundwater

4 Interplay between C-S-As-Fe bio-geochemical cycles indicating redox zonation in the GSA aquifer

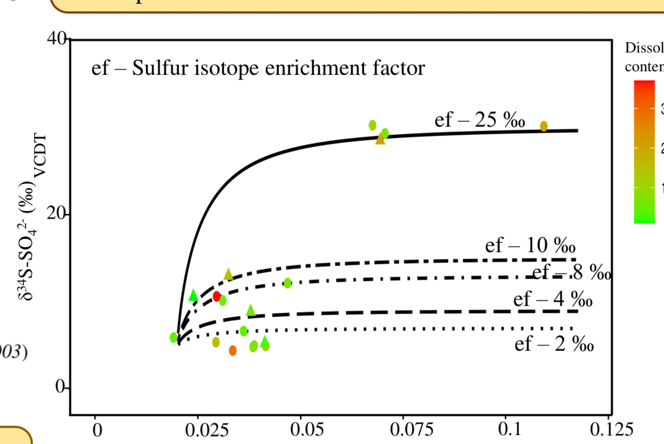


- 'Zone of methanogenesis' promotes higher As mobilization in the groundwater; actively during dry pre-monsoon periods.
- 'Zone of active bacterial sulfate reduction (BSR)' drives lower As mobilization in the shallow groundwater.

5 Evidence of active BSR from δ^{34}S-SO_4^{2-} isotope ratio and evaluation of differential BSR intensity by Rayleigh fractional model with the role of BSR intensity on the total As contents in the Gr-2 seasonal GSA groundwater set



- Differential intensity of BSR is prominent in Gr-2 seasonal groundwater sample set over multiple years; however independent of the dissolved As contents



- Positive correlation between δ^{34}S-SO_4^{2-} isotope ratio and dissolved 1/SO_4^{2-} contents in Gr-2 seasonal groundwater sample set, further indicates active BSR state

CONCLUSION

❑ Multiple years of seasonal observations on stable δ^{13}C-DIC and δ^{34}S-SO_4^{2-} isotope ratio in selected shallow and a few deep groundwaters (Gr-1) show the process of methanogenesis by 'carbonate reduction'; coupled to the microbially-mediated reduction of As-coated Fe(III)-OOH with limited BSR, promotes higher As mobilization in the groundwater, actively participate during dry pre-monsoon periods.

❑ Few selected shallow groundwaters (Gr-2) showing active BSR state with differential intensity of BSR, result in low As mobilization. Differential intensity of BSR (with sulfur isotope enrichment factor ranging <2 ‰ to ~25 ‰) in the selected groundwater is simulated by Rayleigh fractional model with fractionation of stable δ^{34}S-SO_4^{2-} isotopes, found independent of the groundwater total As contents.

Acknowledgement

- Dr. Abhijit Mukherjee for providing the required site-specific subsurface lithological information (sediment-core data) of the study area.
- Indian Institute of Science PhD fellowship for supporting the field-work and analytical expenditure.
- Grants from the Science Vanguard Research Program of the Ministry of Science and Technology (MOST), Taiwan, ROC (109-2123-M-002-001 to C.-C.S.), the Higher Education Sprout Project of the Ministry of Education, Taiwan, ROC (109L901001 to C.-C.S.), the National Taiwan University (110L8907 to C.-C.S.) for supporting the stable sulfur isotope analysis.

Fresh and recirculated submarine groundwater discharge through Indian coastline: A review

Yovan Lino[1], Harikripa Narayana Udayashankar [1], D. S. Suresh Babu[2], Keshava Balakrishna[1]

[1]Department of Civil Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal 576104, INDIA.

[2]Marine Geoscience Group (MGG), National Centre for Earth Science Studies, Thiruvananthapuram, Kerala, India

Email: lino.yovan@outlook.com; udaya.shankar@manipal.edu; dss.babu@ncess.gov.in; k.balakrishna@manipal.edu

Abstract

Submarine groundwater discharge (SGD) studies along the Indian coastline are very scarce, with only 0.2% of the coastline accounted for discharge so far. Here we present the status of the studies done in India and evaluate probable SGD zones along the Indian coastline using other published data. Reported estimates point out that the west coast of India, especially Kerala, Karnataka and Goa coasts, discharge more fresh groundwater to the sea than the east coast. This is due to the elevated topography of coastal alluvial aquifers, low electrical conductivity in coastal groundwater, high rainfall (>3000mm) and a higher number of rainfall days. Thermal images could be able to better identify discharge on the west coast than the east due to higher temperature differences between the groundwater and seawater. The discharge of recirculated seawater to the sea could be more Gujarat and West Bengal due to the high tidal range (~3-5m) and large intertidal zones in these areas. Based on the synthesis of literature and published data, probable SGD zones along the Indian coastline are marked and presented in this work. The implications of the population to the coastal ecosystem through the discharging groundwater is also discussed.

Methodology

A total of 19 peer-reviewed studies concerning SGD in India are reviewed here. GIS (raster) layers of precipitation (NOAA), sea surface temperature (GHRSST), ambient air temperature (NOAA), population (Balk et al.2020), wind (Global Wind Atlas 3.0), tides (Matthias 2017), intertidal zones (Murray et al., 2019) were synthesized and used to display variations of these parameters along the coast. These data were sampled near the coastline using QGIS to plot figures 3-6. Monthly average datasets (12 layers, one for each month) of precipitation was processed to acquire the annual total precipitation dataset. For globally estimated SGD rates (Zhou et al. 2019, Luijendijk et al., 2020), the data was acquired and clipped to the Indian coastline. Then, the data was converted to m3/kilometre/year. SRTM DEM data was used to generate the ground elevation plot by sampling at ~1km inland from the coast. The digitized data for geology (CGWB, 2014), aquifers (Dineshkumar et al. 2006) and electrical conductivity (CGWB 2010) variations along the coast are processed using illustration software

Inferences from previous studies

- In India, SGD studies are conducted on West Bengal, Odisha, Tamilnadu, Kerala and Gujarat states.
- Odisha and Kerala coast reported high SGD rates.
- Mass balance estimate suggests that the west coast of India discharges more SGD than the east coast.

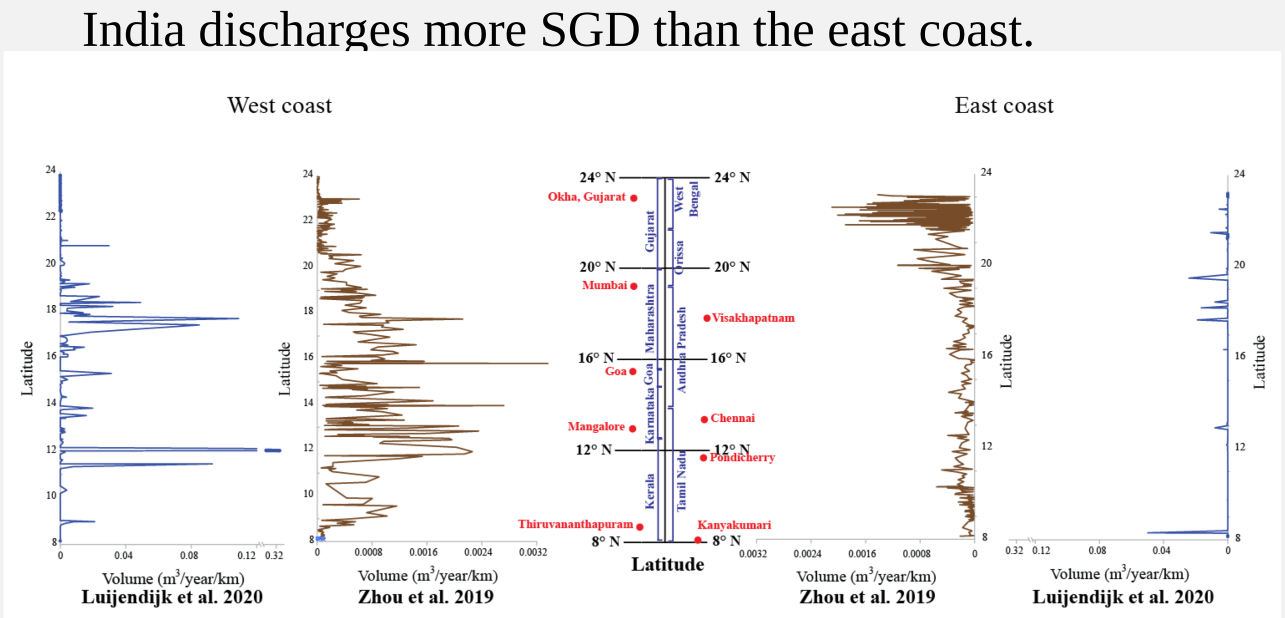


Fig. 1 SGD fluxes along Indian coastline quantified by Zhou et al., 2019 and Luijendijk et al., 2020. (Data cropped from global estimates)

Probable SGD zones along the coasts of India

Published datasets were synthesized to assess the probable SGD zones along the Indian coastline. Temperature and wind speed information is used to identify spots for thermal anomalies in the sea; tides and intertidal zone data were used to delineate the probable rSGD zones; geology, aquifers and electrical conductivity variations in coastal groundwater information is used to delineate the probable SGD and SWI zones; rainfall and topography data is used to assess the recharge and topographic gradient along the coast; and published data on SWI studies along the coast is used to identify SWI zones, a counterpart of SGD. The variations these parameters throughout the Indian coastline is given below.

Temperature

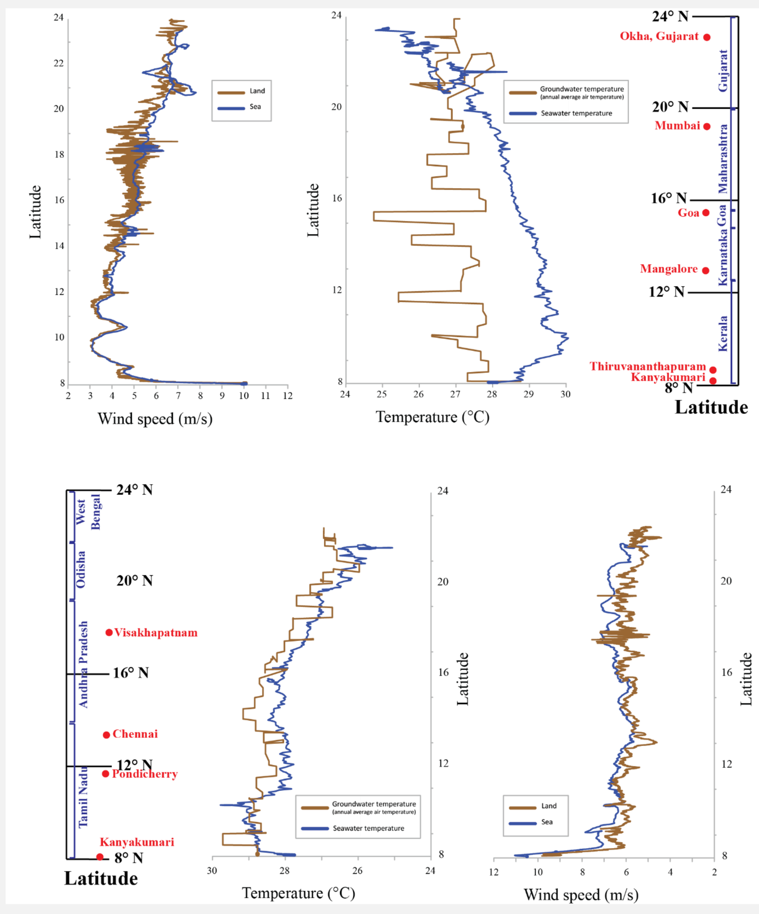


Fig. 2 Annual average seawater and groundwater temperature and wind speed in the sea and inland: changes along the coastline.

Electrical Conductivity, Geology and Aquifer

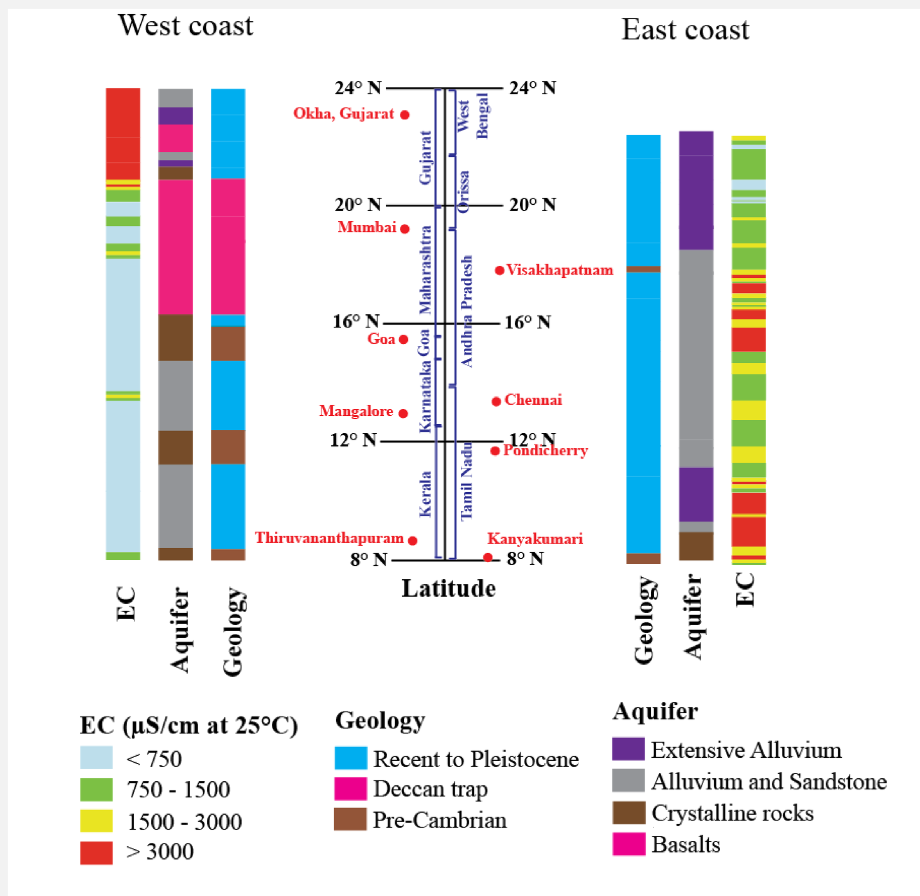


Fig. 3 Electrical conductivity in coastal groundwater, aquifer, and geology along the coastline of India.

Tides and intertidal zones

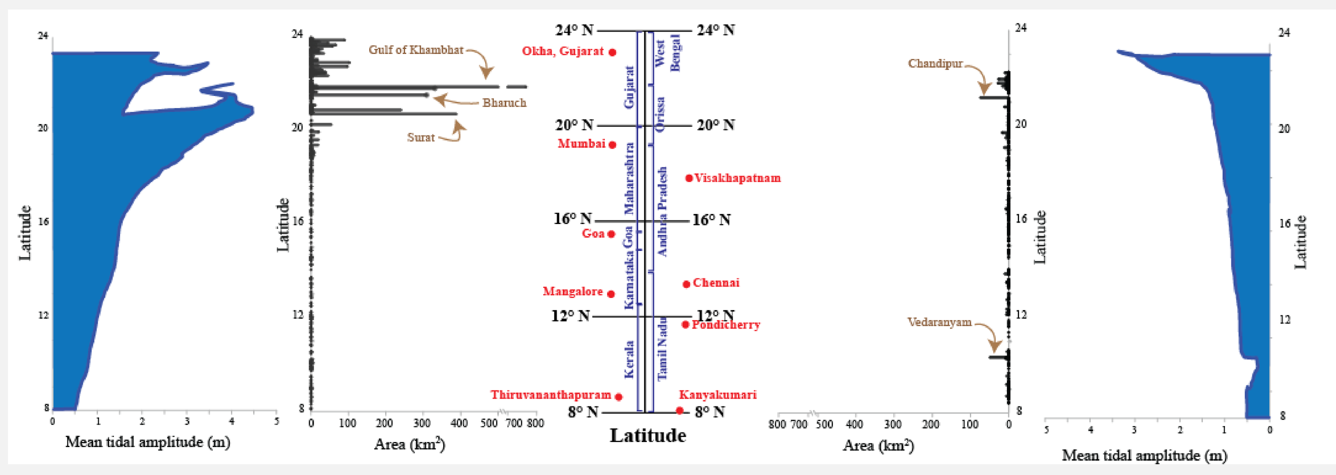


Fig. 4 Mean tidal amplitude and area of intertidal zones along the coastline.

Rainfall and Elevation

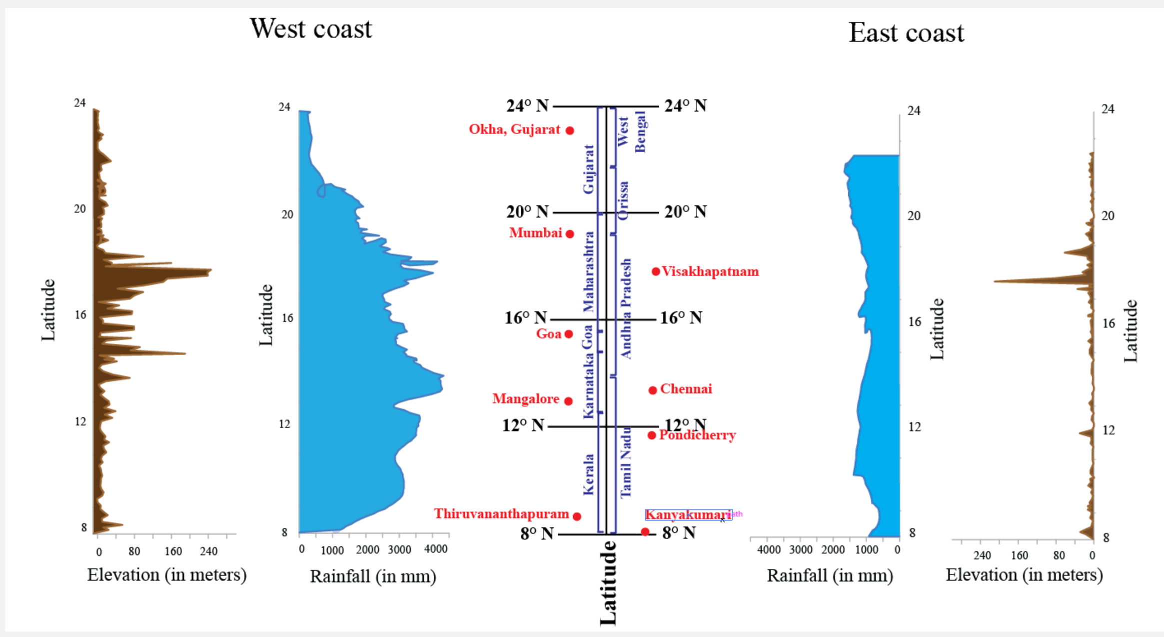


Fig. 5 Annual rainfall and ground elevation near the coasts of India.

Results and Conclusions

- The southwest coast of India discharges maximum fresh SGD to the coast.
- The northwest and northeast coasts discharge more of recirculated SGD.
- The high tidal range and the extensive intertidal zone between 20°N and 24°N latitudes promote more seawater recirculation.
- Thermal images can isolate the probable SGD zones in the West coast

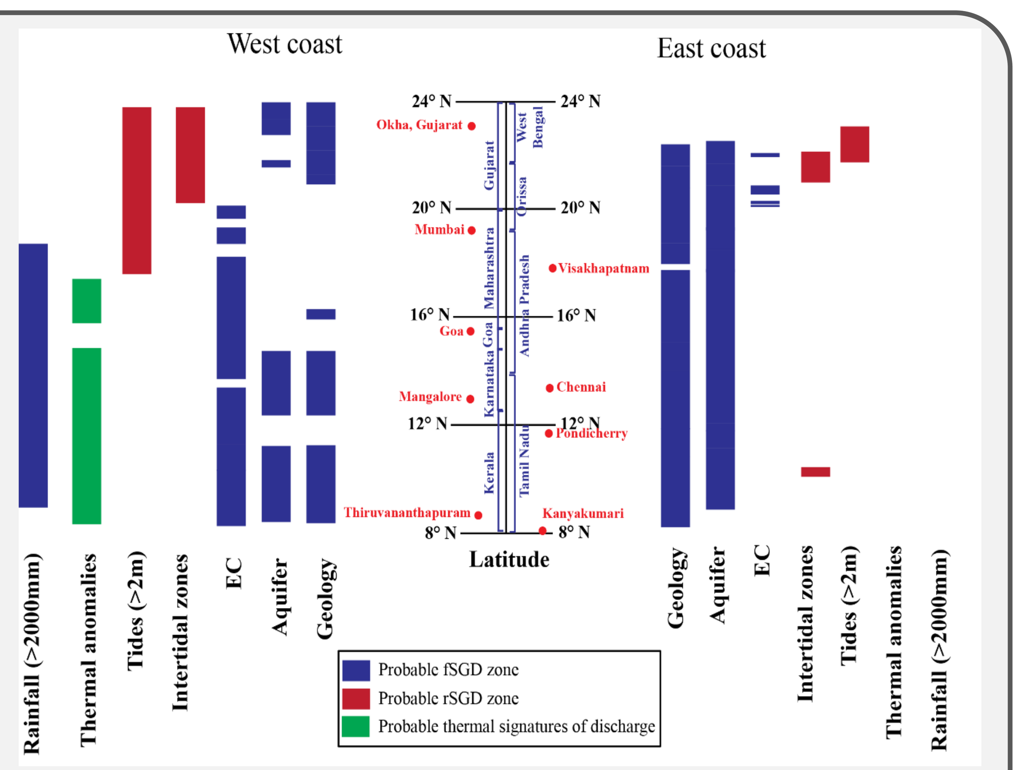


Fig.6 Qualitative representation of probable SGD zones throughout the Indian coastline

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