APN
ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

FINAL REPORT

The impacts of Himalaya's glacier melting on arsenic mass balance and its mobility in Mekong and Salween sub-region groundwater

CRECS2020-03MY-SEAH

2022

CHULALONGKORN UNIVERSITY

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1. Summary

Rivers originating in the high mountains of Asia are among the most meltwater-dependent river systems on Earth. Reducing the glacier area in the Himalayas is expected to change the land use and climate events in Asia. The Mekong, Salween, Indus, and Ganges-Brahmaputra-Meghna transboundary river basins, among others, contribute significantly to tying Asia's rich tapestry of cultures and incredible ethnic diversity together. In this project, Southeast Asia's main international rivers, i.e. Mekong and Salween Rivers regional water pollution were put to focus. An unexpected political crisis outbreak in Myanmar has refrained the connection thus we lost contact with the Myanmar team. Due to the unstable political environment occurred in Myanmar, the Salween River (connected from Myanmar to the boundary of Thailand) sampling plan was terminated. The main purpose of this project is to identify arsenic contamination levels in the Mekong River in the hope of helping the regional government understand the risk of As in groundwater and integrating As risks identified through climate change adaptation and disaster risk reduction into regional planning in the near future. Sampling was conducted in May and August 2022 in Cambodia and Laos, respectively. The water samples analysis including ion chromatography, inductively coupled plasma mass spectrometer (ICP-MS), and, isotope-ratio mass spectrometer (IRMS) were applied. The findings revealed that the topography of certain areas in Cambodia has exposed significantly high concentration of arsenic in groundwater compared to Laos. More research on climate change and arsenic hydrology at regional levels should be included.

IERI is one of the Climate Technology Centre and Network (CTCN) members which is the operational arm of the UNFCCC. We are actively involved in the CTCN-TA technology transfer project providing an engineering-based solution to developing countries. We are pursuing UN sustainable development goals covering clean water and sanitation, affordable and clean energy, climate action, life below water and partnerships for the goals. Through the research in this study, we promoted the regional government to include arsenic as one of the monitoring parameters in drinking water sources. The data obtained through this study has provided a precise database for appropriate climate change adaptation and mitigation strategies in regional planning especially on the clean water and sanitation sector. Therefore, we are preparing to extend the Phase I CTCN pro bono project collaboration with the Department of Climate Change, Ministry of Environment, Cambodia to Phase II where high arsenic risk villages in Cambodia based on the results obtained through this study will be targeted. We strongly support open data access for scientists worldwide to utilize the project data for future research. All information "collected/acquired and manipulated/processed" and/or "generated" as a result of this financing is publicly available. Lastly, we continuously shared the data obtained through workshops and seminar presentations. (455 words)

2. Objectives

The objectives of this study are 1) To identify the arsenic contamination in Mekong sub-region soil, sediment, and groundwater. The background concentration of regional-arsenic was collected in Laos and Cambodia. Several parameters that affect the release of arsenic will be analyzed in order to understand the release of As into the groundwater. 2) Policy consultation and data sharing on the findings from this study.

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
Database and background arsenic concentration for the Mekong River in Laos and Cambodia.	High arsenic risk villages are located in certain areas in Cambodia compared to Laos.	The information gathered served as a resource or supporting documentation for mitigation policies. Installation of water filtration systems in communities with significant arsenic risks (CTCN pro bono Phase II project).
Data sharing and management through scientific publications and policy consultation workshops.	Data sharing and management through CCOP database platform, international conference and regional workshop.	Raise local communities' awareness of the risks of using groundwater. Support the government in making more specific regulations and solutions regarding the drinking water issues in their countries.

4. Key facts/figures

- Significantly higher concentrations of heavy metals such as, As, Ba, Mn and Fe were found in Cambodia compared to the Laos sampling area indicating that Cambodia is more vulnerable to heavy metal pollution.
- The sediment samples were collected in Cambodia. The sediment profile showed that the concentration of heavy metals decreases along with the depth. The concentration of metals showed the highest at 10-20m depth.
- Part of the findings in this study are shared in the 19th International Conference of the Pacific Basin Consortium (PBC) for Environment and Health CCOP, the 58th CCOP Annual Session and the 79th CCOP Steering Committee Meeting, and Food Control Conference 2022 where the policy brief was discussed.

1. Database and background arsenic concentration for the Mekong River in Laos and Cambodia.

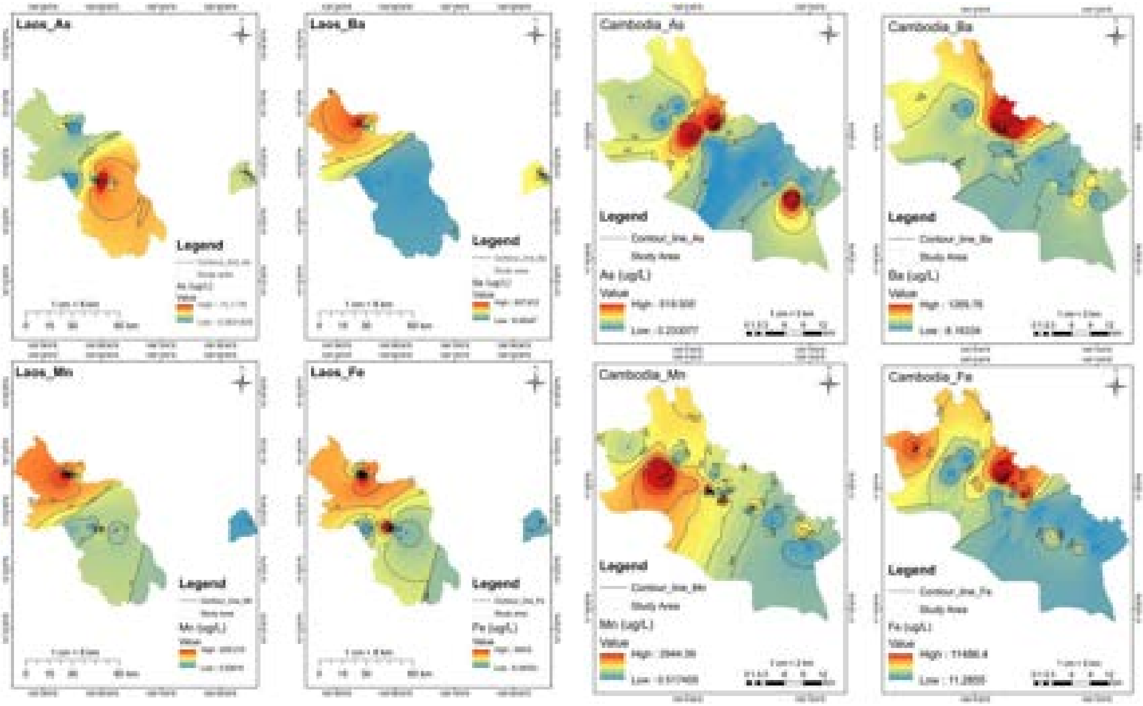


Figure 1. Spatial distribution map of the study area.

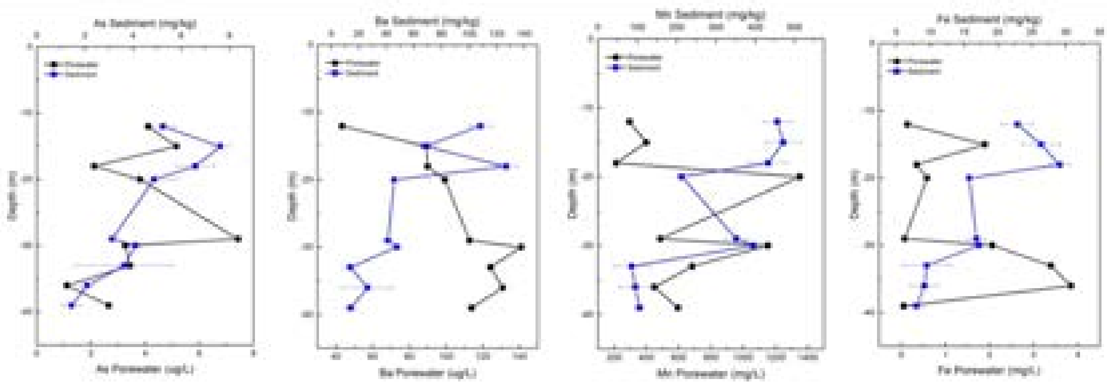


Figure 2. Sediment profile and porewater concentration in the samples collected nearby the Mekong River Basin, Cambodia.

2. Data sharing and management through scientific publications and policy consultation workshops.

Data Sharing

Name of data: Arsenic concentration in Southeast Asia (2003 – 2019)

Brief description of data: The average and range of arsenic concentration in rivers and groundwaters of Southeast Asia including, Thailand, Cambodia, Vietnam, Philippines, Nepal, and Bangladesh.

Access link (data hosting site or repository):
https://ncloud.dotdream.co.th/index.php/s/3zTxjeGEMjfZYQ5

Publisher/owner: Coordinating Committee for Geoscience Programmes in East and Southeast Asia / International Environmental Research Institute

2. Policy consultation workshop in Cambodia
Workshop: 2022 Annual Workshop on the Capacity Building of the Department of Environmental Engineering
Date: 2022.12.20 – 2022.12.22
Content discussed: The workshop was organized in a closed format with participants and speakers from the government of the Kingdom of Cambodia including MoEYS and the Ministry of Environment (MoE), Korea International Cooperation Agency (KOICA), Royal University of Phnom Penh (RUPP), Universities in the Kingdom of Cambodia, and IERI, GIST. The interactions between human actions and environmental effects were discussed. Identifying and addressing environmental challenges by adopting widely used or state-of-the-art approaches and technologies in the near future.

5. Publications

Not available

6. Media reports, videos and other digital content

1. 19th International Conference of the Pacific Basin Consortium (PBC) for Environment and Health in Jeju, South Korea / https://pacificbasin.org/conferences-2/2022-international-meeting

2. The 58th CCOP Annual Session and the 79th CCOP Steering Committee Meeting in Indonesia / https://ccop.asia/event/101 / https://www.youtube.com/watch?v=ihARspcdbQA

3. Food Control Conference 2022 in Vietnam / https://nifc.gov.vn/en/fcc /

7. Pull quotes

Not available

8. Acknowledgments

We thank the research teams in Cambodia and Laos for their valuable contribution to collecting water samples. The International Environmental Research Institute (IERI) affiliated with the Gwangju Institute of Science and Technology has played a significant role in supporting the data for this project.

9. Appendices

Appendix 1. Arsenic concentration in Southeast Asia (2003 – 2019)
Appendix 2. PBC presentation materials
Appendix 3. CCOP presentation materials
Appendix 4. Food Control Conference presentation materials
Appendix 5. 2022 Annual Workshop on the Capacity Building of the Department of Environmental Engineering presentation materials

8. Appendix 1

Report	Year	Part No.	Title	Authors	Sources	Total arsenic
Science and Technology for Sustainability Vol.1 Env Monitoring and Sustainability	2003	Part I 1.	Analysis and monitoring of arsenic contamination in groundwater in Rautahat disctrict, Nepal	Sushil Raj Kanel, Heechul Choi, Kyoung-Woong Kim	GW	1 - 62 ug/L (n=101)
Science and Technology for Sustainability Vol.2 Advanced Technologies for Monitoring and Remediation of Env Pollution	2004	Part I 10.	International Network Project on environmental monitoring and remediation for arsenic contamination in the Asian region (I) - enviromental monitoring for As contamination in the northern Vietnam	Kyoung-Woong Kim	GW Soil GW Soil GW Soil	0.5 - 280.7 ug/L (n=21) 4.9 - 34.6 mg/kg (n=16) 0 - 188.3 ug/L (n=13) 4.3 - 7.6 (n=13) 5.1 - 642.6 ug/L (n=15) 4.5 - 10.5 (n=9)
Science and Technology for Sustainability Vol.3 Hazardous Chemicals Contamination in Asian Countries	2005	Part I 1.	Mitigation of arsenic pollution in drinking water through geo-chemical mapping and hydrated ferric oxide (HFO) based	M. Khabir Uddin, M. Majibur Rahman, A.H.M. Saadat, G. Ahmed	tubewell	0 - 0.50 ppm (n=200) 60 - 70ft highly polluted

			on adsorption-filtration and inter-basin comparison of arsenic occurrence in groundwater			
		Part 1 4.	Environmental monitoring and remediation of As contamination in the Asian region	Kyoung-Woong Kim	GW	280 74 - 445 ug/L (n=11) 154 27 - 246 ug/L (n=11) 205 108 - 323 ug/L (n=15) 18 0-102 ug/L (n=15)
Science and Technology for Sustainability Vol.4 Sound Management of Hazardous Chemicals	2006	Part I 1.	Contamination by arsenic and other trace elements in tube well water in Prey Veng and Kandal Provinces, Cambodia	S. Sthiannopkao, Kyoung-Woong Kim, S. Sotham, S. Choup	GW	534.91 250 - 900 ug/L (n=5) 25.41 10 - 20 ug/L (n=2) 173.18 (n=1) 203.45 0 - 600 (n=13) 90.21 0 - 100 (n=3) 49.34

						0 - 150 (n=3)
						nill (n=1)
		Part I 2.	The relationship between water pollution sources and surface water quality at the Angkor Area, Cambodia	Young Geun Lee, Seo Jin Ki, Yun Seok Lee, Joon Ha Kim	GW	0.01 - 0.12 (n=7)
Science and Technology for Sustainability Vol.5 Environmental Monitoring and Ecosystem Restoration	2007	Part I 2.	Arsenic risk assessment through drinking water pathway in Hanam Province, Vietnam	Van Anh Nguyen, Sunbaek Bang, Kyoung-Woong Kim	GW	365.85 (n=9) 13.26 - 582.35 219.02 (n=9) 112.28 - 350.10 322.49 (n=7) 237.50 - 438.65
Science and Technology for Sustainability Vol.6 Environmental Monitoring and Sustainability	2008	Part I 1.	Arsenic and other trace elements contaminated groundwater in Kandal Province of Cambodia	Suthipong Sthiannopkao, Kyoung-Woong Kim	GW	965.5 (n=5) 6.11 - 1375.68 198.24 (n=5) 4.55 - 789.22 350.05 (n=5) 210.41 - 539.81 0.76 (n=4) 0.37 - 1.38

		Part I 5.	Arsenic and heavy metals survey of rural groundwater in Nigeria	Edu Inam, Godwin Ebong, Kyoung-Woong Kim	GW	0.16 - 3.03 (n=16)
Science and Technology for Sustainability Vol.7 Environmental Monitoring and Biotechnological Approaches	2009	Part I 1.	Arsenic and toxic trace elements: silent killing through groundwater consumption in the Mekong River Basin, Cambodia	Vibol San, Suthipong Sthiannopkao, Kyoung-Woong Kim, Kongkea Phan	GW	935.26 (n=30) 321 - 1672 789.75 (n=16) 569 - 1569 2.48 (n=7) 0.5 - 3.0 2.44 (n=13) 0.5 - 5
		Part I 4.	Characterization of arsenic contaminated groundwater in the Mekong River Delta of Vietnam: development of nanofiltration membrane unit for groundwater treatment	Hoang Thi Hanh, Sunbaek Bang, Kyoung-Woong Kim	GW	423 (n=22) 52 - 1150 467 (n=16) 44 - 693
		Part I 5.	Correlation of arsenic concentrations in groundwater and	Doungkamon Phihusut, Suthipong Sthiannopkao, Kongkea Phan, Kyoung-Woong Kim	GW	965.95 (n=297) 247.08 - 1841.50

			human hair of Kampong Kong commune in Kandal province, Cambodia			
		Part II 11.	Assessment of arsenic exposure in children in Thailand	Navasumrit P., Chaisatra K., Chanjamsai S., Tiemyuyen S., Hinhumpet P., Ruchirawat M.	Drinking water	1.63 (n=44) 0.26 - 9.34
					Non DW	21.69 (n=43) 0.45 - 82.87
					Drinking water	0.77 (n=36) 0.0003 - 1.37
					Non DW	0.99 (n=36) 0.02 - 1.21
Science and Technology for Sustainability Vol.8 Assessing Ecosystem Health in the Mekong River Basin	2010	1	Assessing health risks from inorganic arsenic intake by residents in the Mekong River Basin, Cambodia	Kongkea Phan, Suthipong Sthiannopkao, Kyoung-Woong Kim	GW	846.14 (n=46) 247.08 - 1841.50
						22.22 (n=12) 0.12 - 140.60
						1.28 (n=18) 0.12 - 2.37
		7	Assessing the quality of surface water and sediments in canals of HCM city	Sunbaek Bang, Dang Ngoc Thuy	river (no filtration)	0.94 - 46.06 (n=19)
					sediment	4.86 (n=5) mg/kg 3.73 - 6.90
						10.62 (n=3)

				7.25 - 13.39
				9.83 (n=3) 4.77 - 14.89
				9.05 (n=3) 8.56 - 9.45
8	Agricultural impacts on levels of pathogenic E.coli and Salmonella sp. In the Saigon River, Vietnam	Nguyen Cong Thanh, Kenneth W. Widmer	GW	1.0 - 46.9 (n=27)
10	Occurrence of selected metals in the Saigon River-canal system:implications for risk assessment of safety water supply to Ho Chi Minh City, Vietnam	Nguyen Thi Van Ha, Nguyen Thi Tuyet Nam, Suthipong Sthiannopkao	river	0.74 (n=18) 0.67 - 6.42
13	Groundwater quality and water access surveying, indexing, and reporting in Svay Rieng province, Cambodia	Andrew Shantz	GW	3.83 (n=823) 0 - 200

Science and Technology for Sustainability Vol.9 Assessing Ecosystem Health in the Mekong River Basin	2011	5	Risk assessment of arsenic intake via drinking water pathway of residents living in Prey Veng and Kandal provinces of Cambodia	Suthipong Sthiannopkao, Kyoung-Woong Kim, Kongkea Phan	Tube well	150.98 (n=13) 74.18 (n=3) 26.42 (n=3) 0 (n=1) 448.51 (n=5) 25.41 (n=2) 173.18 (n=1)
		8	Source and risk assessment of heavy metal in urban surface water in Ho Chi Minh City, Vietnam	Nguyen Thi Van Ha, Nguyen Thi Thu Tinh, Nguyen Thi Ngoc Quyen, Penradee Chanpiwat, Suthipong Sthiannopkao	Suburban canal, urban canal, river	0.008 (n=88) 0.010 - 14.3
		9	Contamination of arsenic in groundwater of Tien Giang and Long An, Mekong Delta provinces, Vietnam	Bui Xuan Thanh, Sunbeak Bang, Nguyen Thi Nhu Khanh, Nguyen Thi Kim Yen, Nguyen Phuoc Dan	GW	1.0 - 46.9 (n=21)
		11	Groundwater quality and water access	Andrew Shantz, Chaing Chanthea, Hok Phalla, Thang Makara, Thorn Sokha	GW	5.45 (n=1947) 0 - 200

			surveying, indexing, and reporting in Svay Rieng and Takeo province, Cambodia			2.91 (n=126) 0 - 107.72
		15	Groundwater quality verification for construction of arsenic treatment technology in Cambodia	Kok Sothea, Chea Eliyan, Seng Bandith, Sovann Chansopheaktra, Sunbaek Bang	GW	250 - 500 (n=5) 70 - 1000 (n=6)
Science and Technology for Sustainability Vol.10 Transboundary Pollutants Issues	2012	1	Assessing daily intake of arsenic by residents in Prey Veng Province, Cambodia	Kongkea Phan, Savoeun Heng, Samrach Phan, Kyoung-Woong Kim	GW	118.312 (n=11) 0.97 - 351.50
		6	Groundwater quality and water access surveying, indexing, and reporting in Takeo province, Cambodia	Thang Makara, Chheang Malis, Hok Phalla, Thorn Sokha, Andrew Shantz	GW	1.69 (n=884) 0 - 107.72
		8	Laterite as an adsorbent material for removing arsenic from polluted groundwater in	Bunchoeun Pich		1210 1230

			Cambodia			
Science and Technology for Sustainability Vol.11 Multi-Pollutants Issues in our Environments	2013	10	Distribution of trace elements in the Tonle Sap Great Lake and its tributary in Cambodia	Kongkea Phan, Samrach Phan, Soknim Se, Laingshun Huoy, Savoeun Heng	river	0.686 (n=14) 0.588 - 1.306
					lake	1.155 (n=37) 0.703 - 1.784
		16	Monitoring trace metals in water and biota in Tien River, Vietnam	Dang Vu Bich Hanh, Nguyen Huu Viet, Lai Duy Phuong, Nguyen Phuoc Dan, Seunghee Han, Eunhee Kim, Yongseok Hong	river	0.22 - 0.86 (n=5)
Science and Technology for Sustainability Vol.13 Environmental Challenges for Urban Cities	2015	3	Arsenic in groundwaters and aquifers in the wetland areas of the Cambodian Mekong delta: focusing geogenic source of release mechanism for suggestion of appropriate remediation methods	Bunchoeun Pich, Seingheng Hul, Borey Oum, Spohy Beak	GW	(n=10) 950 - 1630
		8	Metal concentrations in	Penradee Chanpiwat, Suthipong Sthiannopkao	river	2.41 (n=9) 1.96 - 3.23

		surface water in two large Southeast Asian cities			0.73 (n=9) 0.24 - 1.26
IERI research project 2016	2016	Arsenic in groundwaters and aquifers in the wetland areas of the Cambodian Mekong delta: focusing geogenic source of release mechanism for suggestion of appropriate remediation methods	Bunchoeun Pich, Sreylin Cheath	GW of Bassac river	411.8 (n=34) 80 - 950
		Trace metals in hard clams (meretrix lyrata) from the coastal area of Saigon - Dongnai River Estuary, Vietnam	Tran Tuan Viet, Nguyen Duy Khanh, Dinh Quoc Tuc, Nguyen Phuoc Dan, Emilie Strady, Seunghee Han	seawater	0.91 0.74 - 1.34 0.74 0.38 - 0.88 0.96 0.72 - 1.25
IERI research project 2018	2018	Assessment of water quality and heavy metal contaminations in	Kongkea Phan, Samrach Phan, Huy Sieng	tubewell dug well	3.45 (n=31) ND - 10 12.63 (n=23) ND - 50

		the coastal area of Cambodia		pond	0 (n=5)
				tubewell	4.00 (n=11) ND - 30.00
				dug well	4.44 (n=12) ND - 30.00
IERI research project 2019	2019	Water Treatment Technologies for Adaptation and Resilience to Climate Change Impacts	Maria Pythias B. Espino, Yunho Lee	GW	1.62 (n=3) 0.52 - 3.41
				river	1.67 (n=8) 0 - 1.95
				rainwater	0.19 (n=1)
		Impact of climate changes on water quality and greenhouse gas emission of the Ganges-Brahmaputra River, Bangladesh	Shafi M Tareq		2.05 (n=12) 0.1 - 7.6
		Assessing salinity susceptibility and water quality in Koh Kong coastal area of Cambodia for climate change adaptation	Kongkea Phan, Chek Sotha, Chenda Eav, Sieng Huy	tubewell	6.25 (n=8) 0 - 30
				dugwell	6.67 (n=25) 0 - 30
				canal	1.67 (n=7) 0 - 10

pond	2.00 (n=5) 0 - 10
rainwater	0 (n=5)

2022.08.31 (Wednesday)

Arsenic mass balance and its mobility in Mekong sub-region groundwater : case study of Kandal province, Cambodia

Seah Kah Yee (Cary)
IERI, GIST

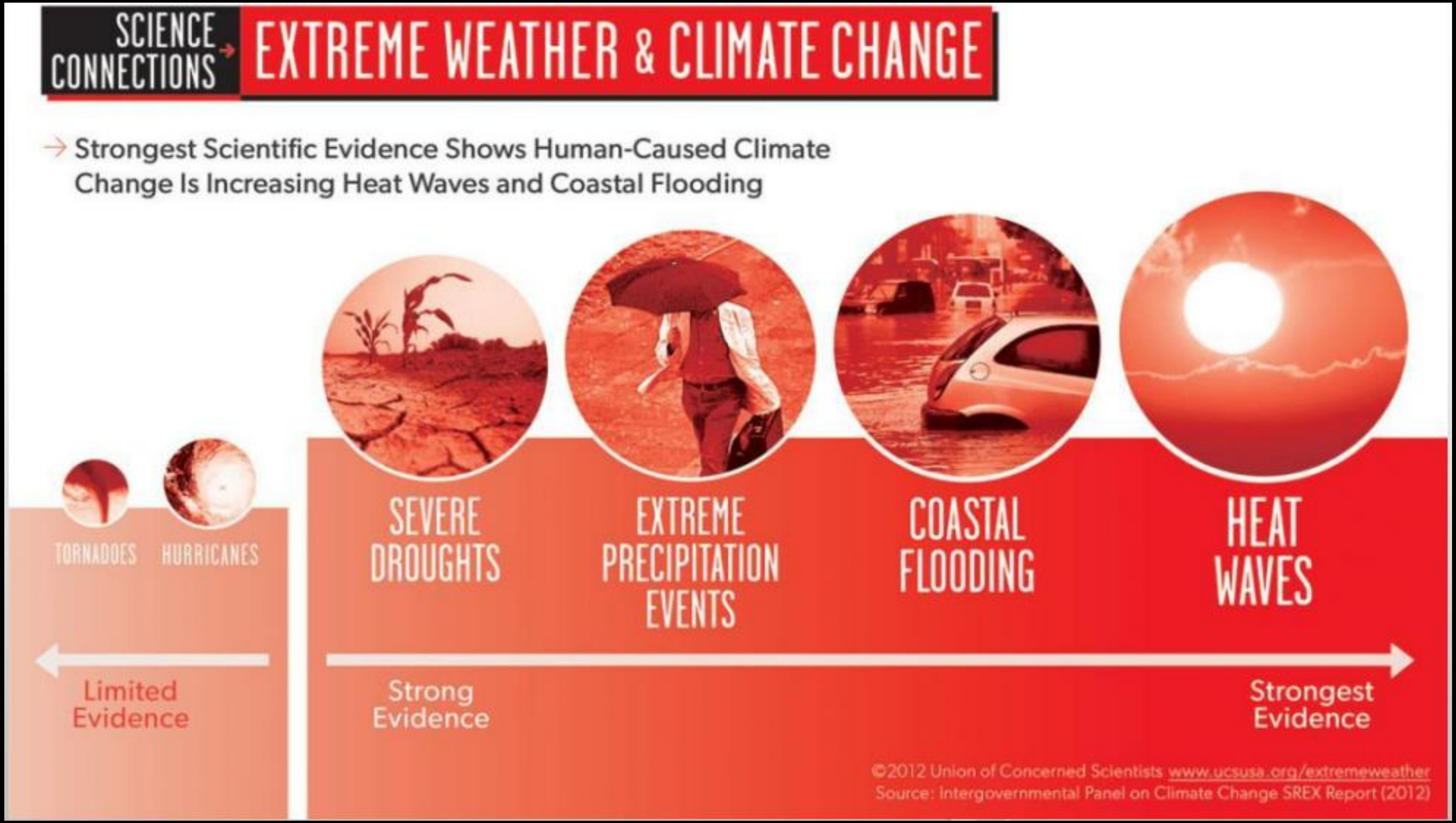
ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH
Collaborative Research for Early-Career Scientists (CRECS) Small Grants Programme

Outline

- Introduction
- Sampling
- Analysis
- Future Plan

Introduction

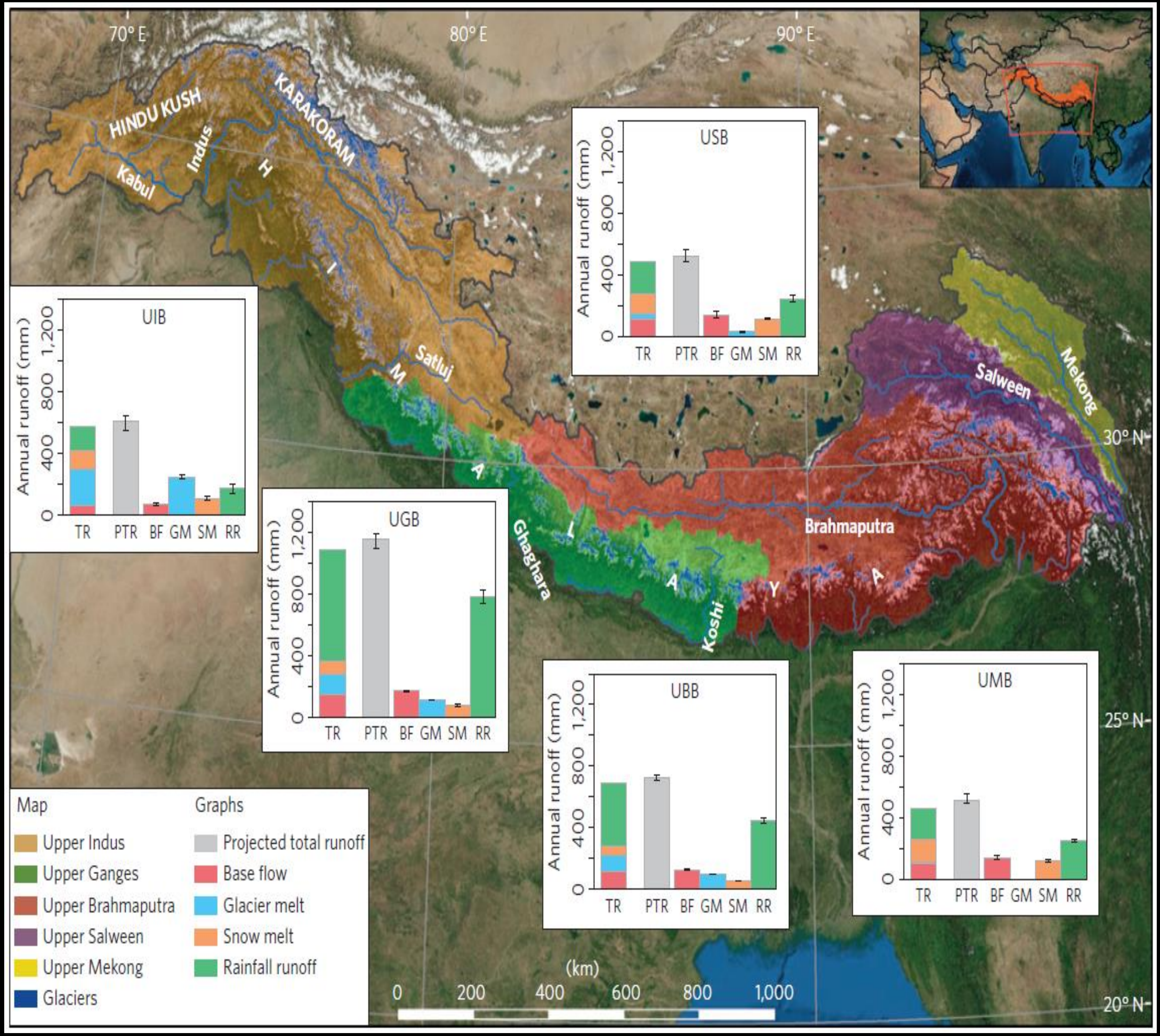
Climate change



Himalayan Mountains are home to the highest peak in Mount Everest at 29,029 feet, but also to the third largest deposit of ice and snow in the world, after Antarctica and the Arctic.

Rivers originating in the **high mountains of Asia** are among the most meltwater-dependent river systems on Earth

The 2007 IPCC report says: “Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate.”



DOI:10.1038/nclimate2237

The upstream basins of Indus, Ganges, Brahmaputra, Salween and Mekong. Bar plots show the average annual runoff generation (TR) for the reference period (1998–2007, REF; first column). The second column shows the mean projected annual total runoff (PTR) for the future (2041–2050 RCP4.5) when the model is forced with an ensemble of 4 GCMs. In the subsequent columns, PTR is split into four contributors (BF: baseflow, GM: glacier melt, SM: snow melt, RR: rainfall runoff). Error bars indicate the spread in model outputs for the model forced by the ensemble of 4 GCMs.

Why MEKONG?

Arsenic is naturally derived from eroded Himalayan sediments, and is believed to enter solution following reductive release from solid phases under anaerobic conditions.

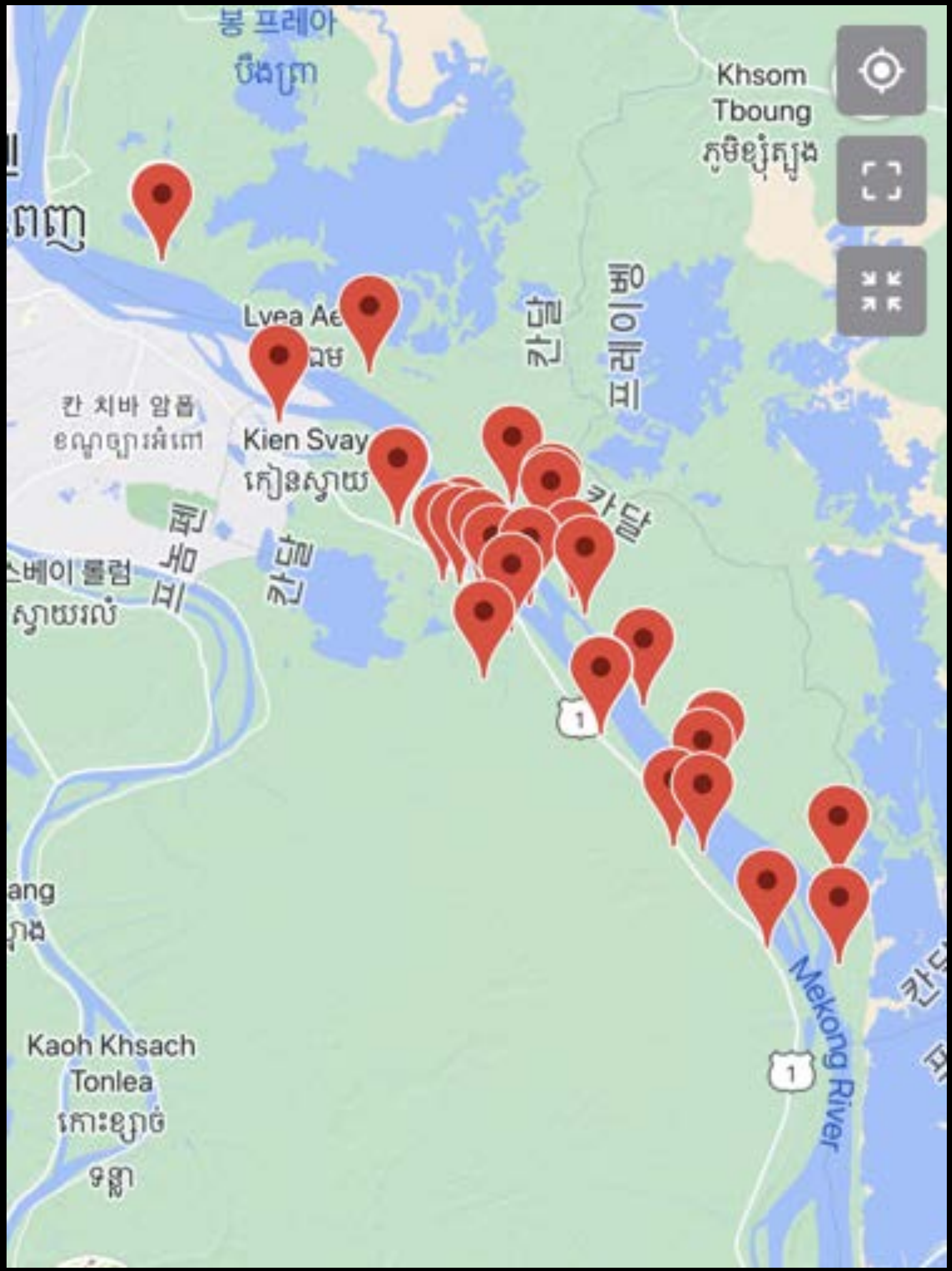
On the minimally disturbed Mekong delta of Cambodia, arsenic is released from near-surface, river-derived sediments and transported, on a centennial timescale, through the underlying aquifer back to the river.

To identify the arsenic contamination in Mekong river, its sub-region sediment, and groundwater

Sampling

- Sampling area: Kandal province
- Samples analysis

N11°24'40.90" E104°59'31.59"
N11°33'20.72" E105°14'50.22"



Tube well: 26, Dug well: 1, Rainwater: 3
River water: 7

Groundwater samples
pH, DO, conductivity, major ions, total arsenic, iron, sulfate, O, H, Sr isotope, Fe(II), As(III)

River water samples
pH, DO, conductivity, major ions, total arsenic, iron, sulfate, O, H, Sr isotope, Fe(II), As(III)

Sediment samples (XANES)
Arsenic, iron speciation

Analysis

Na^+
26.14 ppm
0.33 – 69.47

NH_4^+
3.59 ppm
0 – 28.06

K^+
2.48 ppm
0.32 – 4.37

Ca^{2+}
25.06 ppm
3.75 – 67.43

$(Mg^2)^+$
46.35 ppm
4.24 – 116.92

F^-
1.44 ppm
1.17 – 2.02

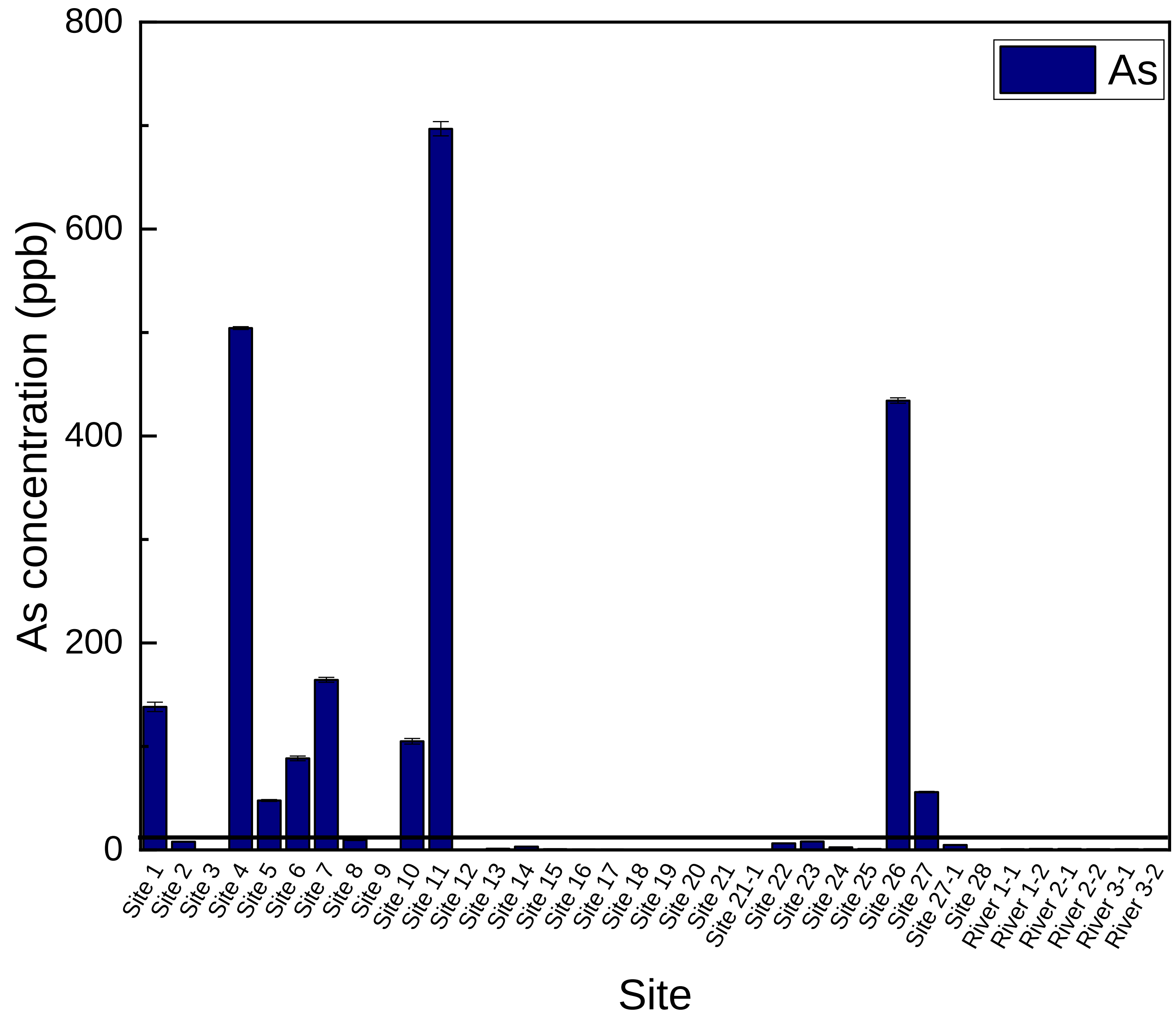
Cl^-
16.44 ppm
6.45 – 80.4

Br^-
4.60 ppm
4.14 – 4.81

SO_4^{2-}
19.37 ppm
4.36 – 62.89

NO_3^-
6.74 ppm
5.1 – 9.29

Physiochemical properties of water samples					
DO (mg/L)	Temperature (°C)	pH	EC (µS/cm)	TDS (ppm)	Salinity (ppt)
5.0	32.8	7.4	591.8	296.5	0.1
3.5 – 6.8	29.8 – 37.7	6.83 – 8.05	15.2 – 1787	7.6 – 901.3	0.00 – 0.51



35 – 65m depth
> 10ug/L As

EC
> 500 uS/cm

TDS
> 300 ppm

Table 3

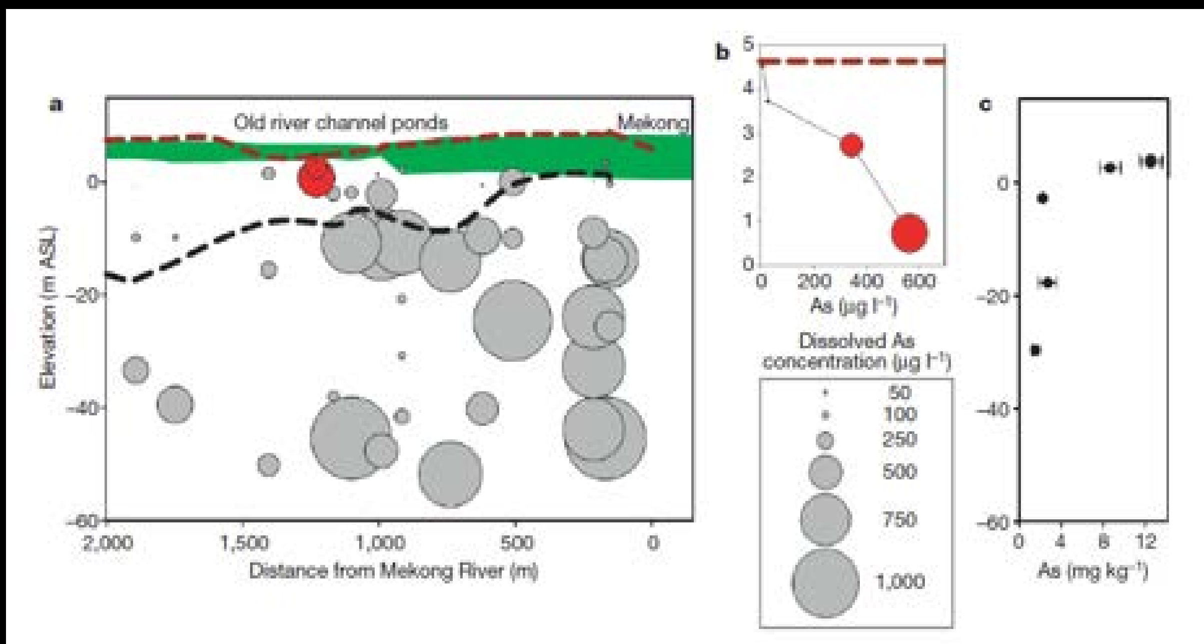
Cross-site comparison of seasonality in electrical conductivity (μS cm^{-1}) as a measure of dissolved ions. Bold values indicate significant seasonal differences at $P < 0.05$ at each site for each sampling year. ND stands for 'not determined'.

DOI:10.1016/j.jhydrol.2011.01.050

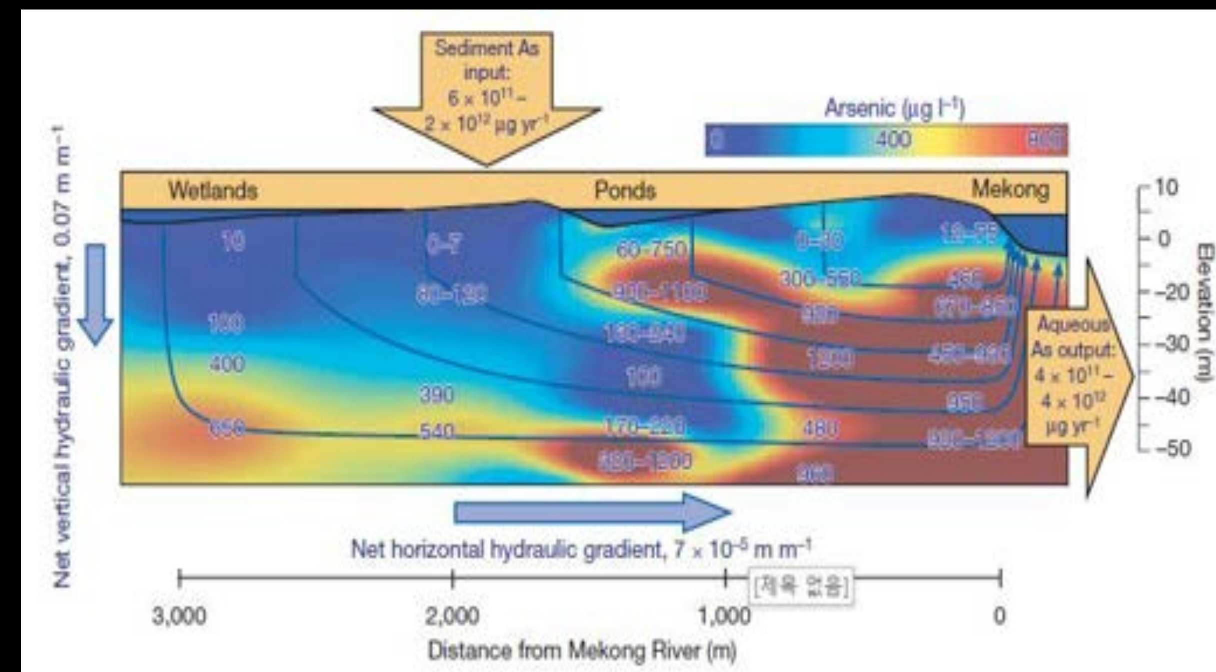
Site	Electrical conductivity (μS cm^{-1})			
	2006		2007–2008	
	Dry period Mean ± SE (Min–Max, *n*)	Wet period Mean ± SE (Min–Max, *n*)	Dry period Mean ± SE (Min–Max, *n*)	Wet period Mean ± SE (Min–Max, *n*)
Shanxi			**541** ± 34 (448–686, 9)	**344** ± 31 (262–510, 9)
Chuncheon			**103** ± 15 (54–197, 9)	**67** ± 12 (25–143, 9)
Gwangju	243 ± 86 (91–659, 6)	143 ± 33 (76–259, 6)		
Chiang Rai	**180** ± 32 (27–373, 15)	**127** ± 15 (14–209, 15)		
Luang Prabang			ND	268 ± 34 (226–402, 5)
Vientiane			293 ± 46 (136–537, 9)	178 ± 33 (5–259, 9)
Ubon Ratchatani	**241** ± 29 (89–467, 14)	**128** ± 21 (10–261, 14)	**209** ± 18 (105–265, 9)	**153** ± 28 (17–251, 9)
Phnom Penh	152 ± 16 (90–200, 11)	ND	85 ± 16 (12–123, 9)	86 ± 16 (12–128, 9)
Cantho			830 ± 607 (190–5682, 9)	164 ± 6 (142–209, 9)
Kota Kinabalu	74 ± 7 (53–156, 14)	70 ± 3 (51–85, 14)	**63** ± 2 (56–74, 9)	**37** ± 5 (0–49, 9)
Bogor			**22** ± 5 (9–44, 9)	**10** ± 1 (6–14, 9)

Thank you for your attention!

Future Plan



Dissolved and solid-phase arsenic profiles throughout the field area. a, Field area cross-section, showing groundwater arsenic concentrations (As, grey and red filled circles; concentrations are proportional to symbol size, see key). **Green**, zone of variable saturation; **red dashed line**, ground surface; **black dashed line**, clay/silt-sand transition. Well nest distances are normalized based on relative perpendicular distances from ponds and Mekong River. **b**, Lysimeter arsenic concentrations (red filled circles, see key for meaning of symbol size), showing increasing arsenic with depth at the near-surface during downward flow conditions. Data taken on 21 December 2005. **c**, Solid-phase arsenic concentrations. The highest values are found within the uppermost clay sediments; within the aquifer sands, values average 2.8 mg kg^{-1} (standard deviation, 1.65 mg kg^{-1}). Error bars, s.d. of replicate measurements.



Field area cross-section with groundwater flow paths and arsenic concentrations. Well water arsenic concentrations are depicted by the numbers within the cross-section, and these are contoured by kriging; temporal variations within wells are averaged, and ranges are representative of wells of equivalent depths and locations. Modelled net annual groundwater flow lines are depicted by blue arrows within the cross-section; net annual vertical gradients are 0.07mm^{-1} in the downward direction and net annual horizontal gradients are 7 x 10^{-5} mm^{-1} towards the river. Arsenic inputs to the field area via sedimentation are approximately
equivalent to arsenic outputs via groundwater discharge.

Doi:10.1038/nature07093

International Environmental Research Institute

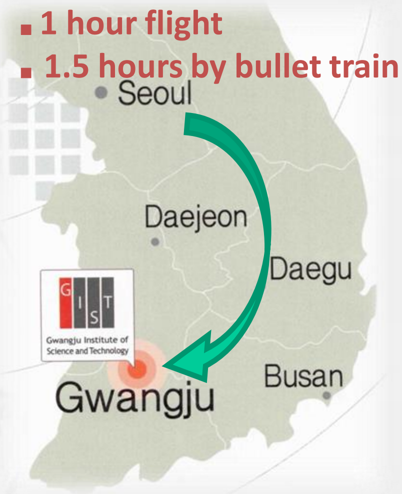
Past, Present and Future of IERI

Director, IERI
Prof. Kyoung-Woong Kim

International Environmental Research Institute

Gwangju: Hub City of Asian Culture & Art

- Located 200 miles south from Seoul
- Population: 1.5 million (5th largest in Korea)
- Also known for its modern industry, science and technology

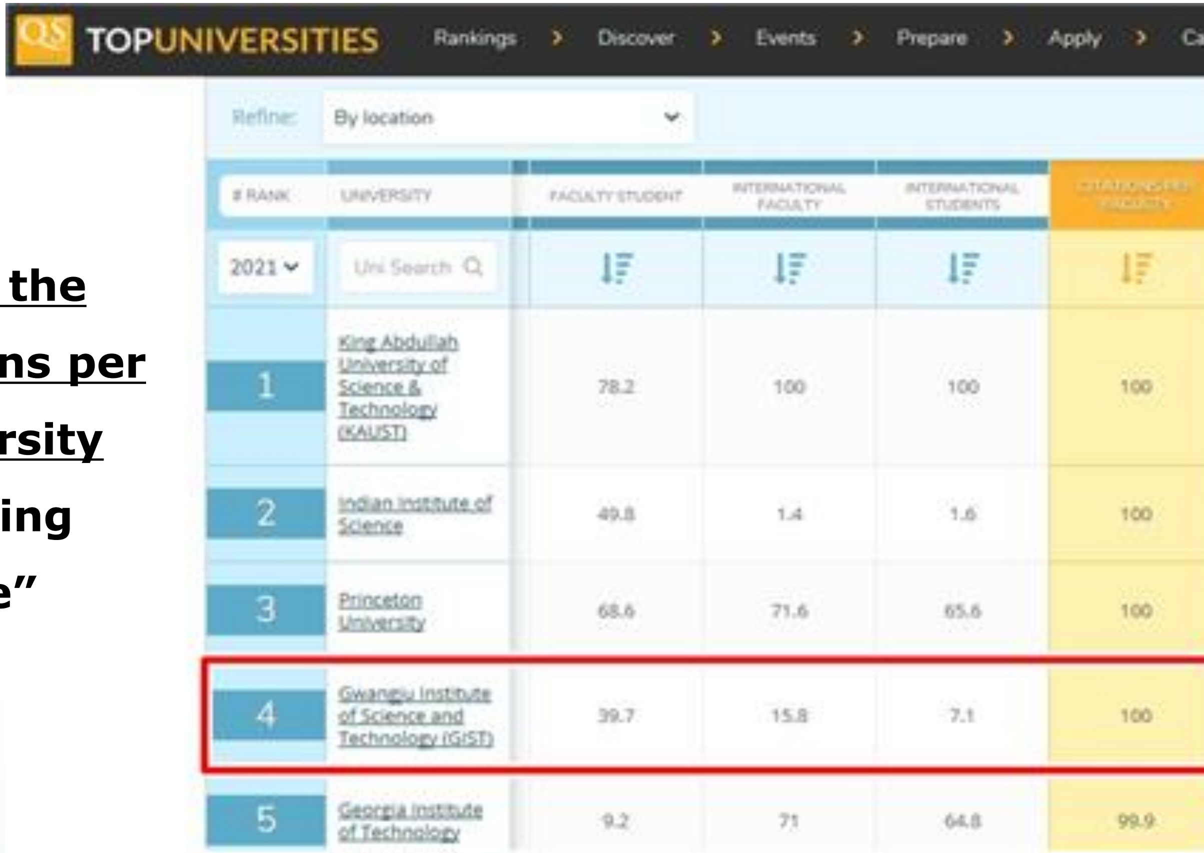


Soswaewon (Traditional Garden)

Dawn Redwood (*Metasequoia*)

Korean Traditional Museum

Global GIST : Research Oriented University supported from Korean Government



# RANK	UNIVERSITY	FACULTY STUDENT	INTERNATIONAL FACULTY	INTERNATIONAL STUDENTS	[illegible]
1	King Abdullah University of Science & Technology (KAUST)	78.2	100	100	100
2	Indian Institute of Science	49.8	1.4	1.6	100
3	Princeton University	68.6	71.6	65.6	100
4	Gwangju Institute of Science and Technology (GIST)	39.7	15.8	7.1	100
5	Georgia Institute of Technology	9.2	71	64.8	99.9

"GIST ranks the 4th in the world in terms of Citations per Faculty in World University Rankings 2020, showing academic excellence"

Goal of IERI

International Collaboration

- Sharing and propagating knowledge
- Formation of networks

Capacity Building

- Fostering environmental experts
- Building competence

Research

- Resolving environmental issues
- Building research capacity

Strategy

The Leader on Global Environmental Issue

Leader on global environmental issues
Institute for research excellency

Strengthening
Collaborations and networking

- Overseas universities, researchers and Research Institutes
- Nongovernmental organization (NGOs)
- Asian Development Bank (ADB), World Bank (WB), African Development Bank (AfDB)

Developing
New topics and programs

Research : Climate Change Adaptation, Sustainable Technology

Capacity Building : Workshops for advisory education and operating an internship program for developing countries

Climate Technology Centre and Network (CTCN) - member since Aug. 8, 2016

- Became the **200th member** of the Climate Technology Centre and Network (CTCN) which is the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) in working on developing climate change technologies and supporting developing countries
- As a CTCN member, **IERI is now eligible to bid for CTCN technical assistance (TA) work**
  - Playing the leading role in climate change response technologies including its transfer and adaptation

United Nations Climate Change Conference, Conference of the Parties (COP)

An international meeting about environmental issues since Paris Agreement in 2015

COP23 Nov 6 – 17, 2017 in Germany

COP24 Dec 3 – 14, 2018 in Poland

Forum and Conference

(International Forum on Climate Adaptation)

Achieving Sustainable Development Goals for the Environment

Purpose

- **Networking of policy makers and research experts in climate change within the Southeast Asian region**
- **Sharing current and future efforts of climate adaptation from their respective nation's perspective**
- **Discussing the ongoing environmental challenges Southeast Asia faces due to climate change**

Year	Topic	Location
2016	Achieving Sustainable Development Goals for the Environment	Siem Reap, Cambodia
2017	Bridging Carbon Action with Development in Southeast Asia	United Nations ESCAP, Bangkok, Thailand
2018	Induction and New Industries for Climate Adaptation in Southeast Asia	GIST, South Korea
2019	Showcasing latest climate resilience solutions and identifying priority actions for regional collaboration	Jeju, South Korea
2022	19th International Conference of the Pacific Basin Consortium (PBC) for Environment and Health	Jeju, South Korea

Research Project

- Regional collaborative research on climate change impacts on surface water quality in eastern monsoon As ia: Towards sound management of climate risks (APN, 2007-2009)

- Collaborative research on sustainable urban water quality management in southeast Asian countries: Analysis of current status (comparative study) and development of a strategic plan for sustainability (APN, 2009-2011)

- K-UNDP science and technical training for water quality monitoring and management of sustainable water resources (K-UNDP, 2013-2015)

- K-UNDP village empowerment project to build sustainable community development through innovative integration of science and technology (K-UNDP, 2017-2021)

- Application of the gravity-driven membrane (GDM) technology for supplying sustainable drinking water to rural communities in Cambodia (CTCN-TA Pro bono, 2020-2022)

- The impacts of Himalaya's glacier melting on arsenic mass balance and its mobility in Mekong and Salween sub-region groundwater (APN, 2020-2023)

GIST Water Purification Device

"Ong-Dal-Seam" Project

GDM (Gravity-driven Membrane) filtration process without power

Project Goal

- Sharing "Ong-Dal-Seam" to the villages damaged by tropical cyclone "Winston" in Fiji
- Collaboration with WHO in Fiji

Supply of GDM Units

- Quantity and Size of GDM Units for Fiji
  - 250 mm x 250 mm: 14
  - 250 mm x 180 mm: 9

- Quantity and Size of GDM Units for Kiribati
  - Pre-assembled GDM system: 1
  - 250 mm x 250 mm: 4
  - 250 mm x 180 mm: 1

Installation of GDM and Training Plan

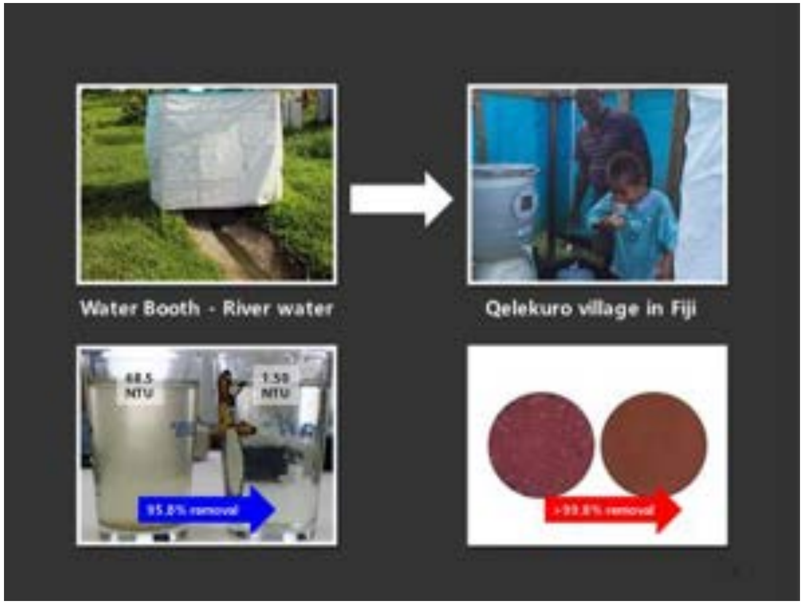
- Installation of GDM Filtration System in Fiji and Kiribati
  - Training for officers in the Ministry of Health
  - Distribute the installation manual
  - **Local officer will install the GDM to village**
  - **Continuous technical support will be conducted by E-mail**

<GDM units for Fiji>

<GDM units for Kiribati>


Qurekuro, Fiji


Tarawa, Kiribati


Water Booth - River water
Qelekuro village in Fiji
68.5 NTU
1.50 NTU
95.8% removal
>99.8% removal


Ulanbaataar, Mongolia

K-UNDP (Phase I)
2013 ~2015

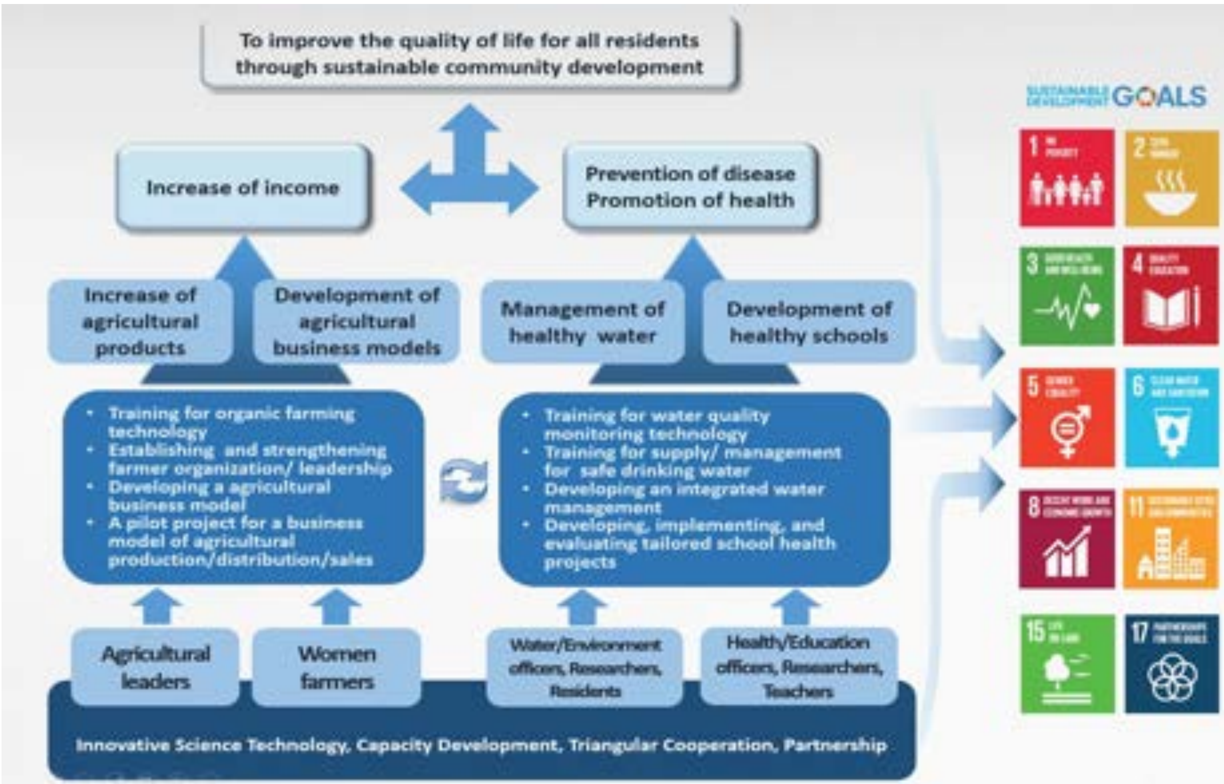
Project Goal

Transfer technical skills and theoretical knowledge on water quality monitoring to individuals involved in water resource management for developing economies
- both lectures and hands-on laboratory experiences

Science and Technical Training for Water Quality Monitoring and Management of Sustainable Water Resources

K-UNDP (Phase II)

2017~2021



Target Area

Strategies

Gwangju Institute of Science and Technology

Srei Santhor, Cambodia

Sukabumi, Indonesia

- After installation, training workshops were conducted for the school staff and local education officers for the operation & maintenance of the GDM systems.
- 3-month water quality monitoring after installation for physical, chemical parameters and fecal bacteria.

Country	Schools	No. Student	Installed	Systems	Production Rate	Remarks
Indonesia	SMP Naringgul	142	March, 2019	Underground water-Pre-sediment-GDM	20-30 L/h	Dirking
	SMPN 2 Cisolok	304	August, 2020	Surface water + Underground water -Pre-sediment-Activated carbon/quarts sand-Cartridge filter-GDM		Water Quality Monitoring
	SMP PGRI 1 Cisolok	293	August, 2020	Surface water + Underground water - Mn-Sand -Pre-sediment-Activated carbon/quarts sand-Cartridge filter-GDM		Source water is from Sewage – Digging the well
Cambodia	Tu Rey Secondary Scho ol	278	July, 2019	Rainwater harvest + Underground water-pre-sediment-GDM	50-60 L/h	Water Quality Monitoring
	Kbal Koh Secondary Sch ool	94	Nov., 2021	Rainwater harvest + River water-pre-sediment-GDM		Water Quality Monitoring
	Mean Chey High School	569	Nov., 2021	River water- pre-sediment-GDM		Water Quality Monitoring

CTCN-TA Pro bono

Project Goal

Funding for the development of technology to solve drinking water issues in Attapeu Province, Laos

42 GDM system units are donating to Karen, Kayah, and Shan refugee camps in Myanmar

Installation of nano-filtration membrane water purification system to refugee camps due to collapse of the Xe Pian-Xe Nam Noy hydropower dam and arsenic contamination in Attapeu Province, Laos

- Thahinh village, Samakkixay district **> 100pb As**
- Xai village, Xaysettha district **> 15 ppb As**
- Vongsamphanh village, Phouvong district **> 40ppb As**

CTCN-TA Pro bono

Achievement

- Monitoring Nanofiltration membrane water purifier

Nanofiltration membrane water purifier installation location	Xaisa-at village (Sammakkixay district)	Xay village (Xaysettha district)	Vongsamphanh village (Phouvong district)
			

A total of 3 units nanofiltration membrane water purifier was installed at the Attapeu province to solve the arsenic contamination in drinking water

CTCN-TA Pro bono

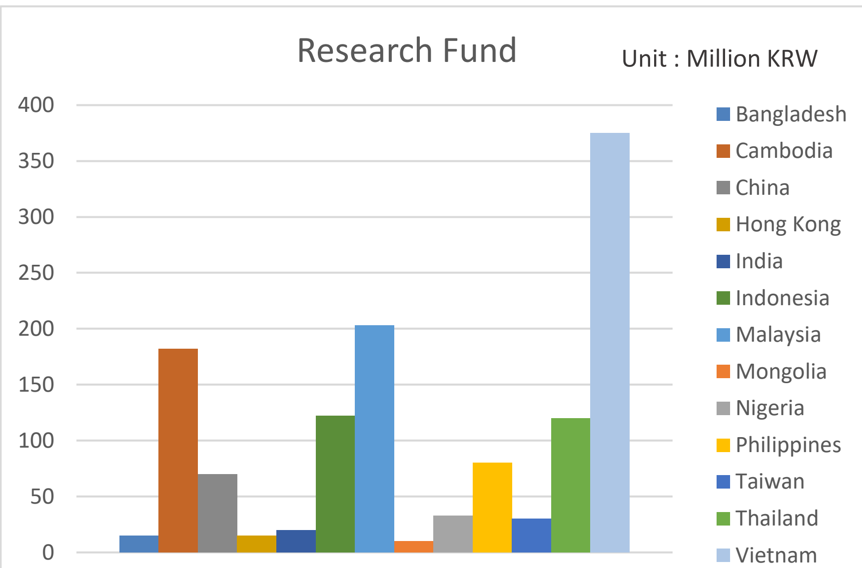
Achievement

- Field seminar pre-preparation
- Environmental safety training with WHO Laos and NUOL
- Water samples monitoring plan and arsenic contamination analysis

Cooperative Research Funding in Developing Countries

Project Theme

Funding for the development of technology to solve environmental issues in responding to climate change



Funded to 264 projects in 2004-2022

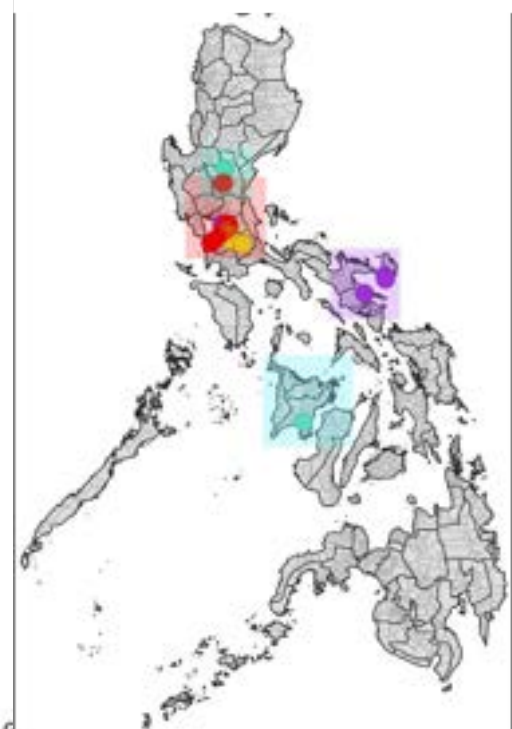
Project Report

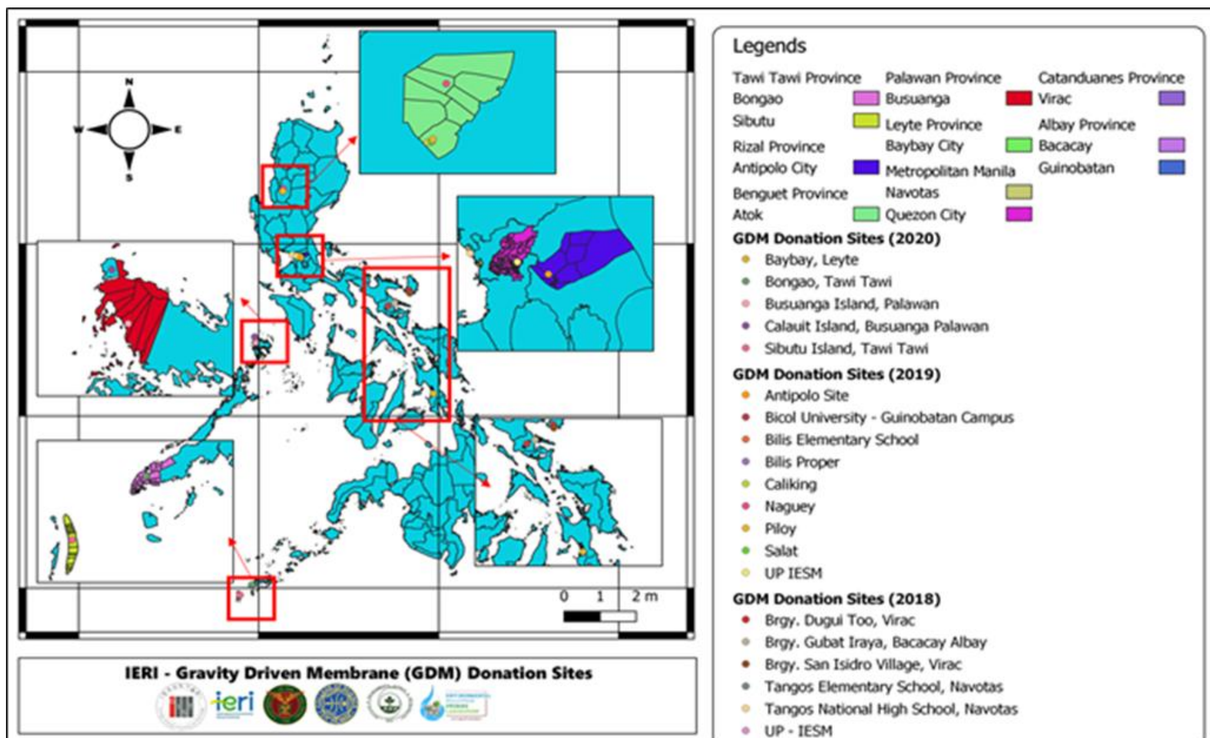
GIST Water Purification Device (Philippines)

GDM filtration technology for the treatment of domestic sewages in densely populated communities in Metro Manila

Project Goal

To develop, test and pilot a community-level sewage treatment facility for Maningning creek incorporating gravity-driven membrane filtration technology.

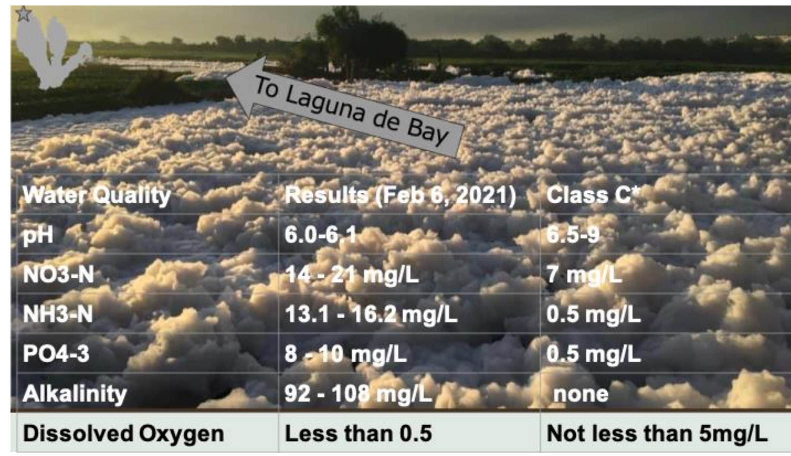




Science and Technology

International Environmental Research Institute

Location	Brgy. (Village)	GDM Installed
Metro Manila	UP Diliman	1 (Demo unit)
	Tangos Fish Port	2
Virac, Catanduanes	Dugui-too (Mountain)	1
	San Isidro (Resettlement)	1
Bacacay, Albay	Gubat-Iraga	1
TOTAL (2018)		6



Water Quality	Results (Feb 6, 2021)	Class C*
pH	6.0-6.1	6.5-9
NO3-N	14 - 21 mg/L	7 mg/L
NH3-N	13.1 - 16.2 mg/L	0.5 mg/L
PO4-3	8 - 10 mg/L	0.5 mg/L
Alkalinity	92 - 108 mg/L	none
Dissolved Oxygen	Less than 0.5	Not less than 5mg/L

The GDM technology may improve the quality of the surface water of Maningning creek before it reaches the Laguna de Bay.

GIST Water Purification Device (Thailand)

Application of Gravity Driven Membrane (GDM) Water Treatment System for Sustainable Access to Safe Drinking Water in Climate Change Vulnerable Areas in Thailand

Project Goal

Supply sustainable and safe drinking water to the vulnerable community in Tak Province by using the GDM water treatment system.

The district consists of six sub-districts under the health management of five health-promoting hospitals and Tha Song Yang District Hospital. The total population is about 60,000.

GIST Water Purification Device (Cambodia)

Investigating a gravity driven membrane (GDM) filtration system for supplying sustainable drinking water in rural communities of Cambodia impacted by climate change

Project Goal

Investigate the performance of community-based GDM filtration systems in rural communities of Cambodia impacted by climate change

Water sampling and quality analysis (25 Parameters)

Water Quality Standard		Metal Ions				Microbials	
DO	mg/L	As	Ppb	Total Fe	mg/L	*E. coli*	CFU/100ml
Temperature	^{0}C	Ba^{2+}	mg/L	Mg	mg/L	Total Coliform	CFU/100ml
pH		Ca	mg/L	Mn	mg/L		
ORP	mV	Free Cl_2	mg/L	NO_2-N	mg/L		
EC	µS/cm	Total Cl_2	mg/L	NO_3-N	mg/L		
TDS	ppm	Total Cr	mg/L	SO_4^{2-}	mg/L		
Salinity	%	Cu	mg/L	Zn	mg/L		
Turbidity	NTU	F^-	mg/L				

- Chemical Analysis: RUPP Lab
- Microbes: RUPP Lab

Four community-based GDM filtration systems installed at Kdol Senchey, Kampong Chhnang province



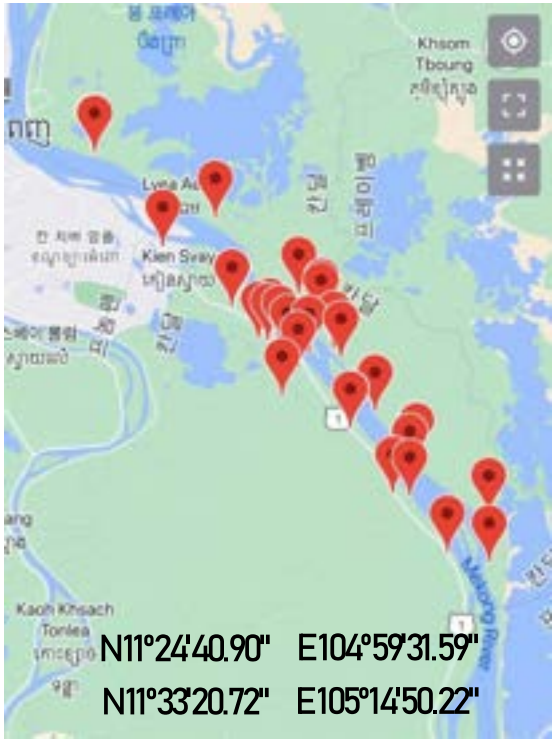


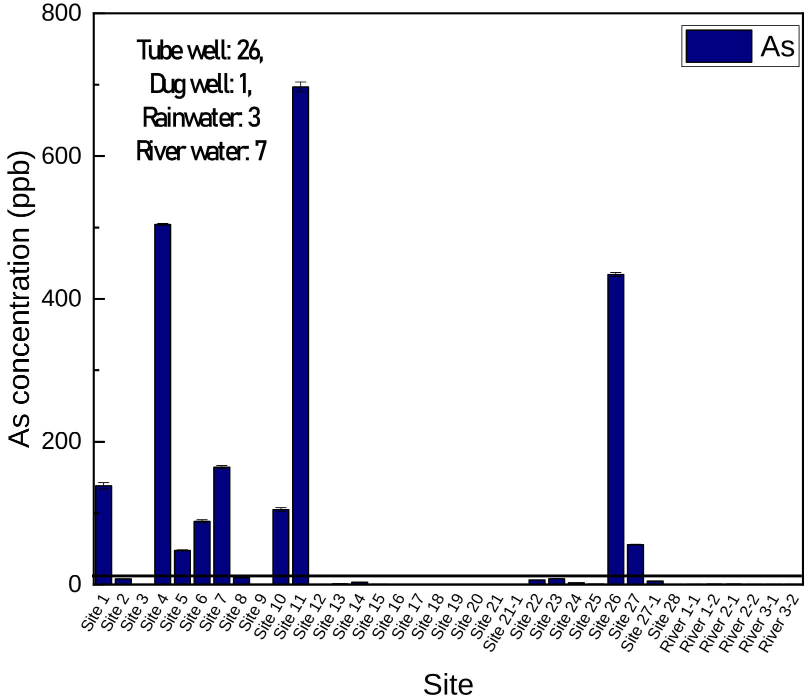
Asia Pacific Network CRECS Project

Project Goal

To identify the arsenic contamination in Mekong river, its sub-region sediment, and groundwater

Sampling area: Kandal province





The concentration of arsenic (ppb) in tube well (n=26), dug well (n=1), rainwater (n=3), and groundwater (n=7) nearby Mekong River, Kandal province.

International Internship Program

Purpose	Target	Benefits	Duration
Educational training for capacity building of government officials and researchers in developing countries	• Graduate students • Researchers in developing countries	• Round trip airfare • Monthly stipend • Dormitory • Health insurance	6 months

Number of participant Interns in 2004-2020 : 171 students from 27 countries

2019 Summer Intern

2020 Spring Intern

CCOP-IERI Internship Program

CCOP INTERN (Fall 2019)

Purnaning Tuwuh Triwigati, S.T.
Geological Engineering
Universitas Diponegoro
2014 - 2018

CCOP INTERN (Spring 2020)

Manussawee Hengsuwan, Ph.D.
Department of Groundwater Resources, Thailand
2011-present

CCOP INTERN (Fall 2020)

Nouvarat Prinpreecha
Geologist
Department of Mineral Resources
2012 - present

CCOP INTERN (Fall 2020)

Tseyenkhand Punsatsogvoo
Research assistant, IGG, MAS, 2016 – present
Master student at National University of Mongolia, 2019-2021

CCOP INTERN (Fall 2020)

Nguyen Quynh Anh
Researcher
Vietnam Institute Geosciences Mineral and Resources
2019 - 2020

CCOP-IERI Internship Program

EXPERIENCES

- Nature-based solutions for disaster and climate resilience, IHE Delft Institute for Water Education (October 2021, training)
- Natural Capital training hackathon co-organized by Stanford University and Wildlife Conservation Society (September 2020)
- Researcher training workshop, Nature Research, Springer (October 2018)
- Thin cloud-based database application development, MERIT and SESMIM project (February 2018, workshop)

ORGANIZATIONS

- Institute of Geography and Geoecology, Mongolian Academy of Sciences (November 2017 - recent)

ACHIEVEMENTS

- "Best young researcher" of the Institute of Geography and Geoecology, MAS for the years 2019 and 2020
- 3rd place of master's and doctoral students scientific conference, SEAS, NUM, 2019
- Published more than 15 scientific articles, one monograph, two recommendations as a first and co-author
- Participated in the two basic research projects concerning landscape ecology and ecosystem service as well as about 8 international and domestic scientific conferences

CCOP INTERN (Spring 2021)

Purevsuren Munkhtur
Junior researcher, IGG, MAS, since 2017
Master of Science in Environmental Science, SEAS, NUM, 2017-2019

CCOP-IERI Internship Program

Ms. Irina Ishan - Brunei

Research Experience

(02/20 – Present) Climate Researcher, Brunei Climate Change Secretariat (BCCS).

- Contributed author of the first Brunei National Climate Change Policy (BNCCP).
- Conducted stakeholder consultations with National Disaster Management Centre, Brunei Shell Petroleum, Brunei Darussalam Meteorological Department and Universiti Teknologi Brunei to assess Brunei's vulnerability to the impact of climate change.
- Took the role as a liaison officer to liaise with lead agencies and facilitators, and prepared work plans, stakeholder lists, terms of reference, logistics arrangements for BNCCP Operational Document Task Force Workshops.
- Proactive in climate action promotion by applying technical knowledge on climate issues.
- Multisectoral engagements; administrative work and general office support.

(06/19 – 08/19) Undergraduate Research Assistant, Lyell Work-Experience and Research Scholarship.
Supervisor: Dr. Rebecca Fisher, Department of Earth Science, Royal Holloway, University of London

- Research Project: Characterization of methane emission around a region of shale gas extraction.
- The data will contribute to ongoing NERC projects such as new methodologies for methane removal from the atmosphere and the global methane budget (MOYA).
- Experienced in campaign planning for mobile measurement campaign, air samples collection, and working with a large research group.
- Baseline surveying to identify sources around before development of the shale gas extraction.
- Lab analysis, data interpretation, GIS mapping of methane, keeling plot analysis for isotopic signature and Hysplit trajectories of air mass origin.

GIST-UNU Internship Programme

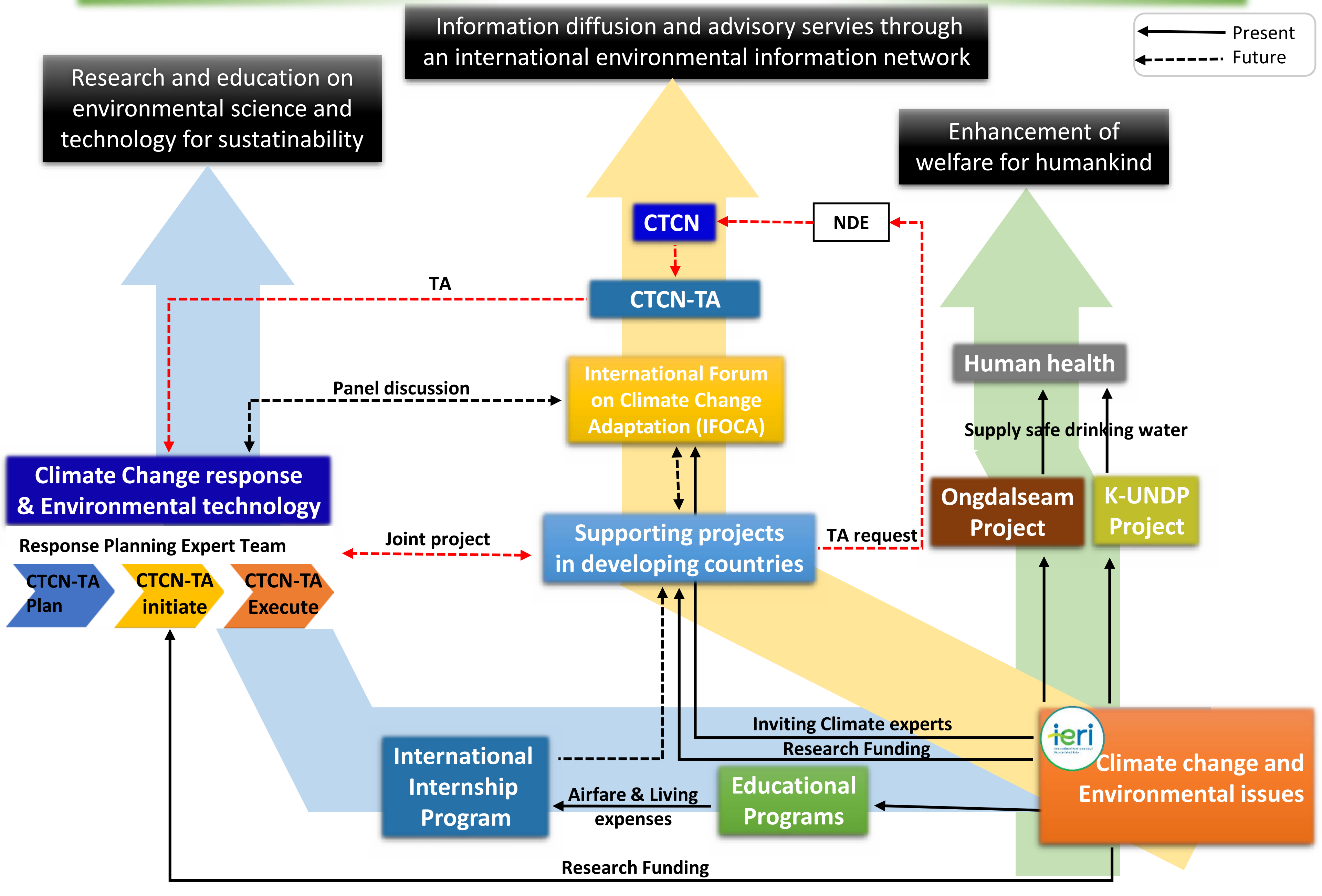
OUTBOUND !

- **Public relations ambassadors of UNU-GIST Joint Programme**
- **Dispatched interns to:**
  - **UNU-INWEH (United Nations Univ. Institute of Water, Environment and Health) in Ontario, Canada**
  - **UNU-FLORES (United Nations Univ. Institute for Integrated Management of Material Fluxes and of Resources) in Dresden, Germany**

Gwangju Institute of Science and Technology

ieri International Environmental Research Institute

Strategy for Enhancing Linkage in IERI Programs



R&D Project for Climate Change Response Technology

- Carbon Reduction Technology
- Carbon Recycling Technology
- Climate Change Adaptation Technology
- Customized Consumer Technology
- Policy of Climate Change Technology

Evaluation & Promotion of Climate Change Response Technology

2030 Changing to cope with the new climate system (Post-2020) after COP 21

The world's best low-carbon, green growth climate change technology

Thank you for your attention.

NỒNG ĐỘ KIM LOẠI NẶNG TRONG GẠO VÀ CÂY TRỒNG Ở KHU VỰC LÂN CẬN SÔNG MEKONG

Heavy Metal Concentrations in Rice and Crop Plants in the Vicinity Area of Mekong River

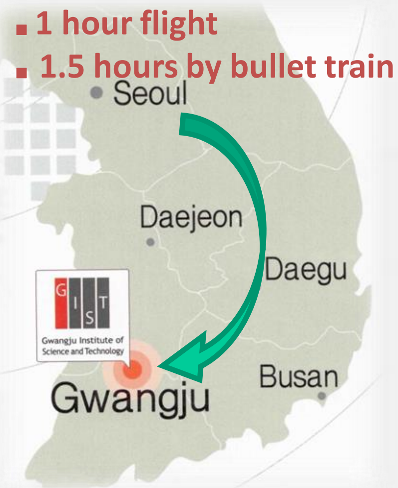
SOULIYAVONG THIPPHACHANH, HOANG THI PHUONG ANH
and KYOUNG-WOONG KIM

Gwangju Institute of Science and Technology (GIST), Korea
(Viện Khoa học và Công nghệ Gwangju, Hàn Quốc)

Gwangju Institute of Science and Technology

Gwangju: Hub City of Asian Culture & Art

- Located 200 miles south from Seoul
- Population: 1.5 million (5th largest in Korea)
- Also known for its modern industry, science and technology



Soswaewon
(Traditional Garden)

Dawn Redwood
(*Metasequoia*)

Korean Traditional Museum

Global GIST : Research Oriented University supported from Korean Government

GIST ranks the 4th in the world

in terms of Citations per Faculty

in QS World University Rankings 2022,

showing academic excellence ."

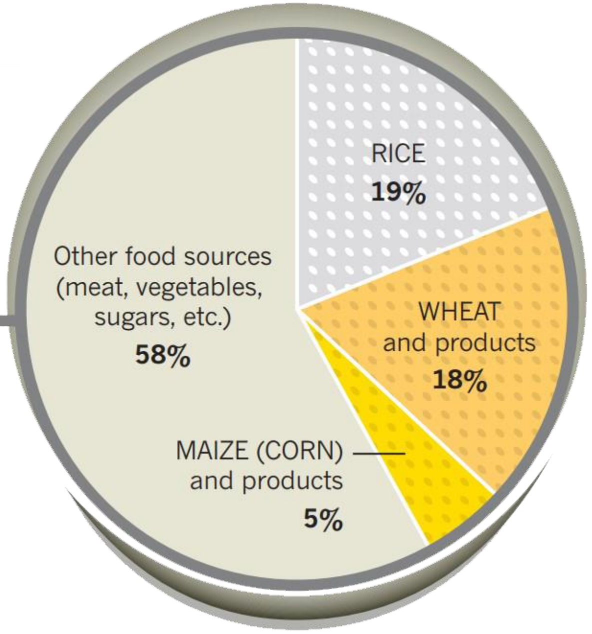
Rice: Importance for Global Nutrition

GLOBAL NUTRITION

On average, every day, each person in the planet consumes:

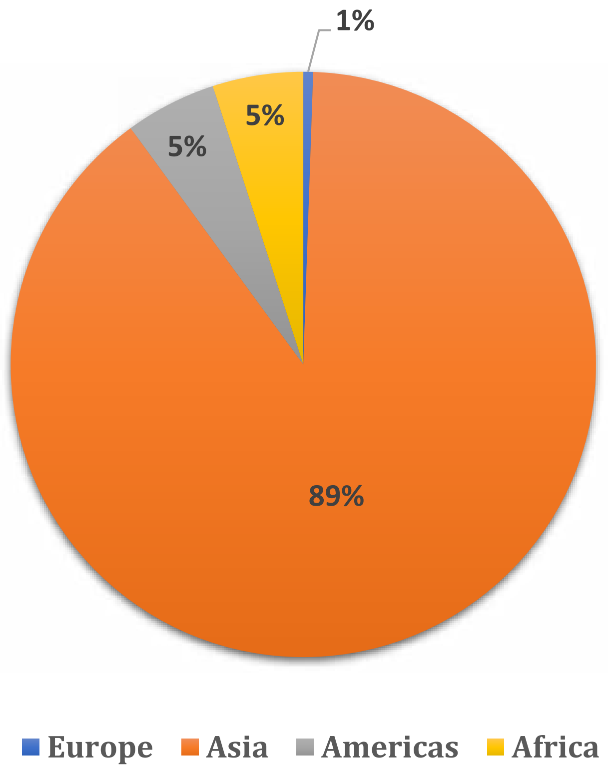
2,868 kcal

42% of our daily energy supply comes form cereal crops (rice, wheat and maize).



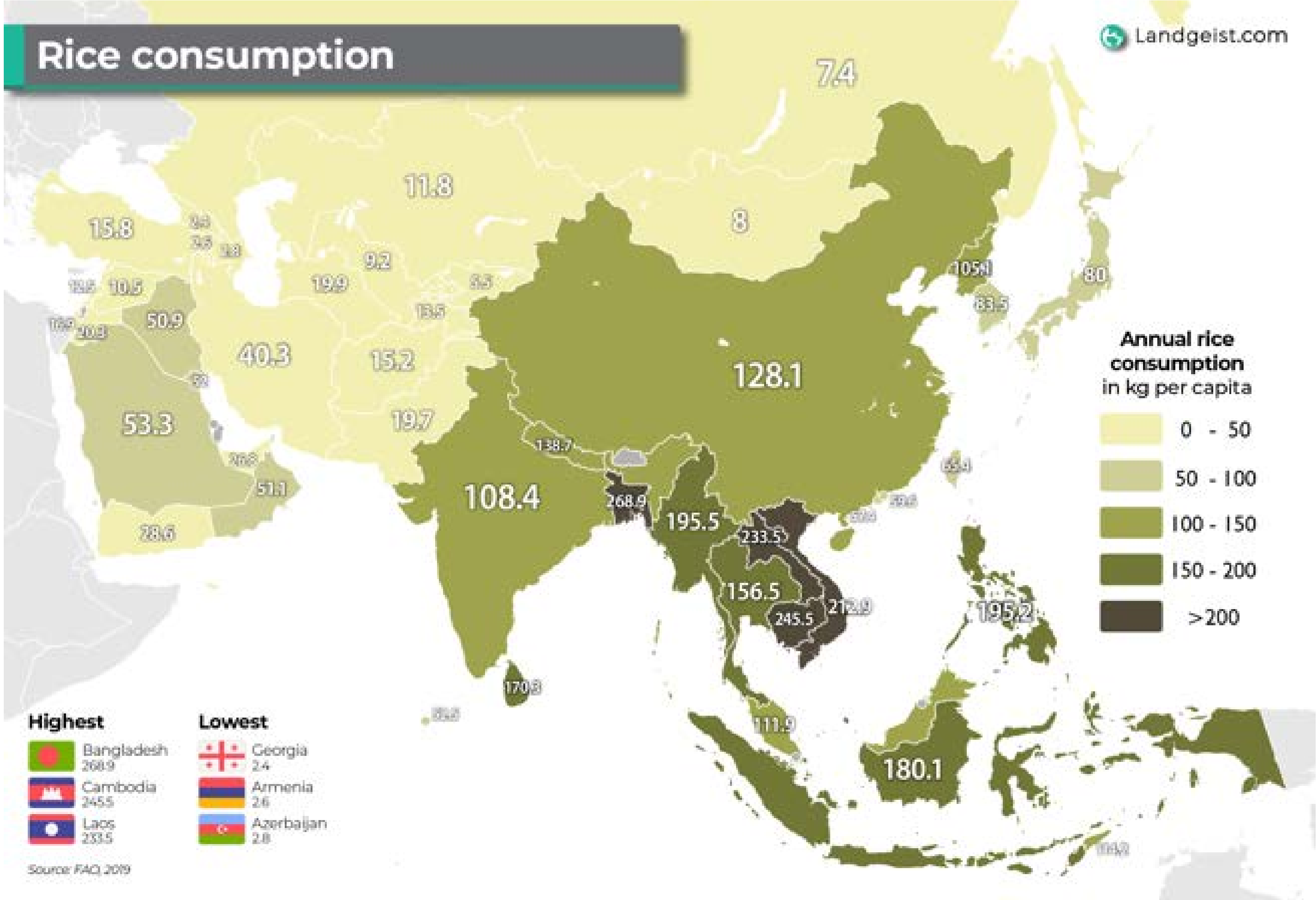
Data source: Food and Agriculture Organization of The United Nations, Statistics Division

Share of Global Rice Production (2020)

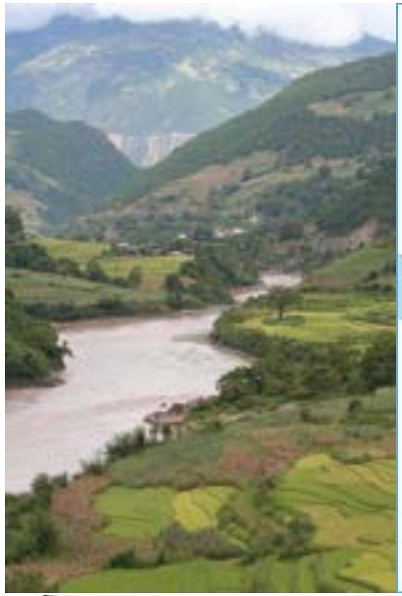


Data source: FAOSTAT

Rice: Importance for Global Nutrition



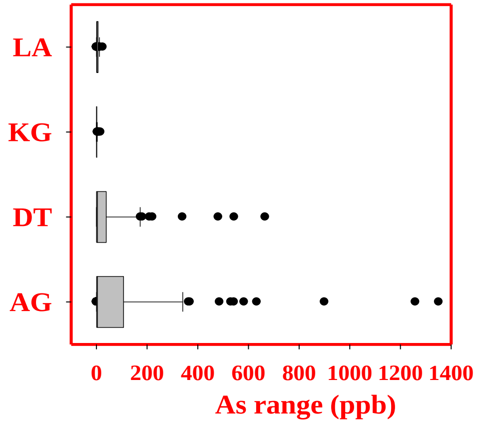
Mekong River in Southeast Asia



Mekong River

-Area: 790,000 km²
-Laos (25%), Thailand (23%), China (21%), Cambodia (20%), Vietnam (8%), Myanmar (3%)
-Length: 4,020 km
-Population: 250,000,000

Arsenic Disaster in Groundwater



WATER

Cambodia
(July, 2005)

Geochemical Hazard

King of Poison

As

- **Carcinogens (group A):**
- **Drinking Water Standard**
  : 0.01 mg/l
  (US EPA, WHO, EC, Japan)

- **As Speciation**
  - **Arsenite (+3)**
  - **Arsenate (+5)**
  - **Organic As**

- **Korean Standard**
  - **Drinking Water : 0.01 mg/l**
  - **Paddy Soil : 6 -> 25mg/kg**
  (2010) 15 -> 75mg/kg

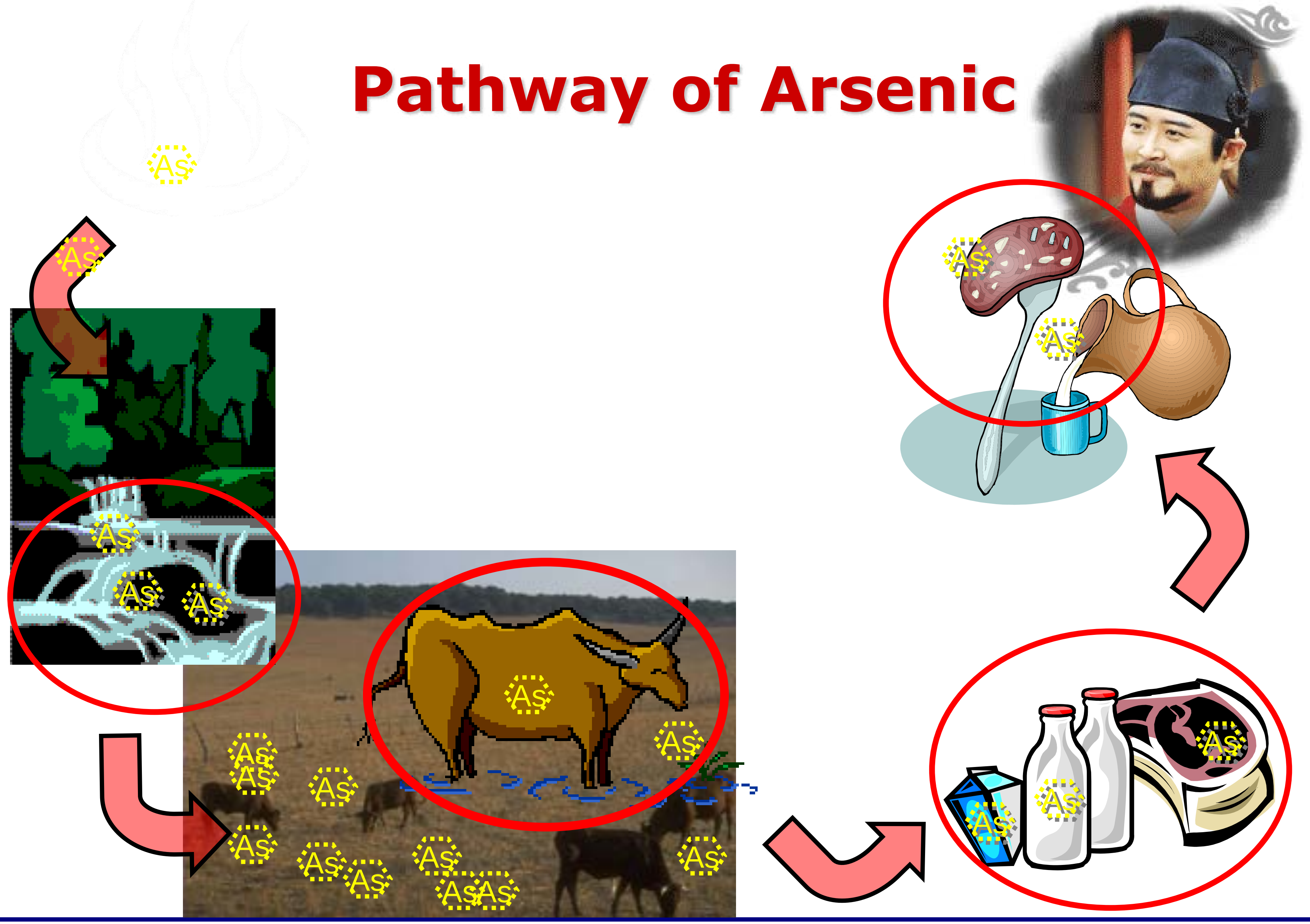
Arsenic: an issue in ancient history of Korea (大長今)

Arsenic: an issue in ancient history of Korea (大長今)

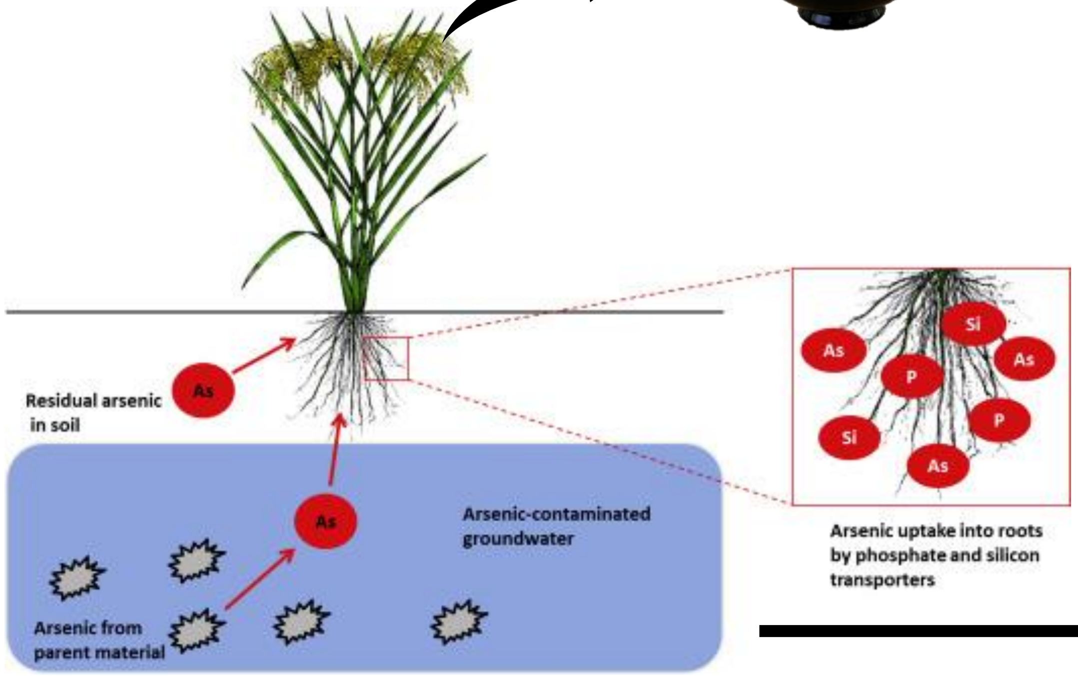
King 中宗 (Joong-Jong) suddenly lost his eyesight and suffered from skin hyperpigmentation. The medical doctor for King did not know the reason but chef 大長今 (Jang-gum) found out the reason. King went to spa (hot spring) and that water was contaminated with arsenic. Another main reason was that King used to drink milk which was produced from arsenic contaminated area.

ジュンジョン王は突然視力を失い、皮膚の色素沈着過剰に苦しみました。王様の主治医はその理由を知りませんでしたが、料理長のチャン・ガムは、その理由を見つけました。王様は温泉に行って、しかもその水がヒ素で汚染されていました。もう一つの主な理由は、王様がヒ素汚染地域で生産された牛乳を飲んでいたということでした。

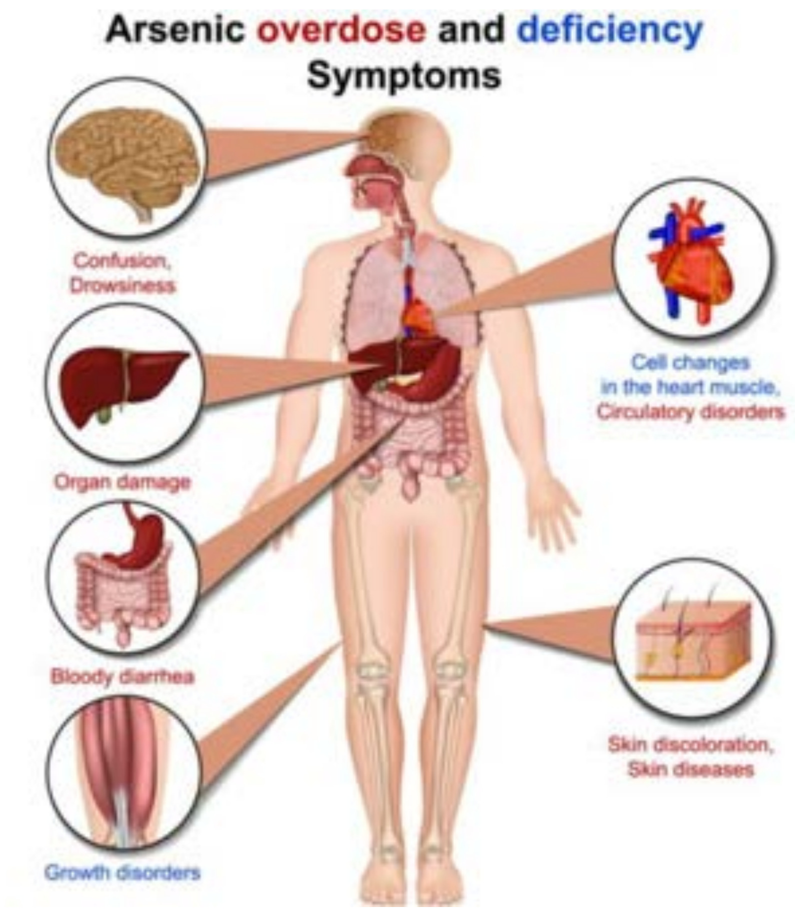
Pathway of Arsenic



Arsenic on Human Health



Muhammad et al., 2019



Arsenic and Heavy Metal Levels in Rice

Total arsenic concentration in rice (mg/kg) in contaminated areas

Plant type	Location	Contamination source	t_{As} (mg/kg)		Reference
			mean	range	
Rice	Xikhuanshan, China	**Mining activity**	0.517	0.235-0.750	Fan *et al.*, 2017
	Tonglushan, China		0.31	0.14-1.33	Cai *et al.*, 2015
	Gunung Pongkor, Indonesia		2.27	0.352-3.216	Rahman *et al.*, 2014
	Myungbong, Korea		**0.41**	**0.24-0.72**	**Lee *et al.*, 2008 (SEL)**
	Dalsung, Korea		0.314	0.212-0.454	Kwon *et al.*, 2017
	Ron Phibun, Thailand		0.682	0.291-1.361	Phimol *et al.*, 2017
	Ngan Son, Vietnam		**0.29**	**0.18-0.40**	**Tran *et al.*, 2020 (SEL)**
	Dai Tu, Vietnam		**0.4**	**0.2-0.9**	**Ko *et al.*, 2020 (SEL)**
	Bangladesh	As-enriched groundwater		0.058-1.83	Meharg 2003
	Mekong River Delta, Vietnam		0.18	0.08-0.56	Nguyen *et al.*, 2019
	Haringhata, India		0.54		Bhattacharya *et al.*, 2010
Leafy greens	Ha Thuong, Vietnam	**Mining activity**	0.37	0.05-1.06	Nguyen *et al.*, 2019
	Shizhuyuan, China	**Smelting activity**	0.59	0.14-1.42	Li *et al.*, 2017
Lettuce	Tuscania, Italy	Volcanic activity		0.689-1.271	Spognardi *et al.*, 2019
Purple basil	Malatya, Turkey	Industrial activity	0.297		Varol *et al.*, 2022
Water spinach	Chandpur & Jamalpur, Bangladesh	As-enriched groundwater	0.68	0.1-1.53	Das *et al.*, 2004
Spinach	Nadia, West Bengal	As-enriched groundwater	0.257	0.17-0.79	Bhattacharya *et al.*, 2010b

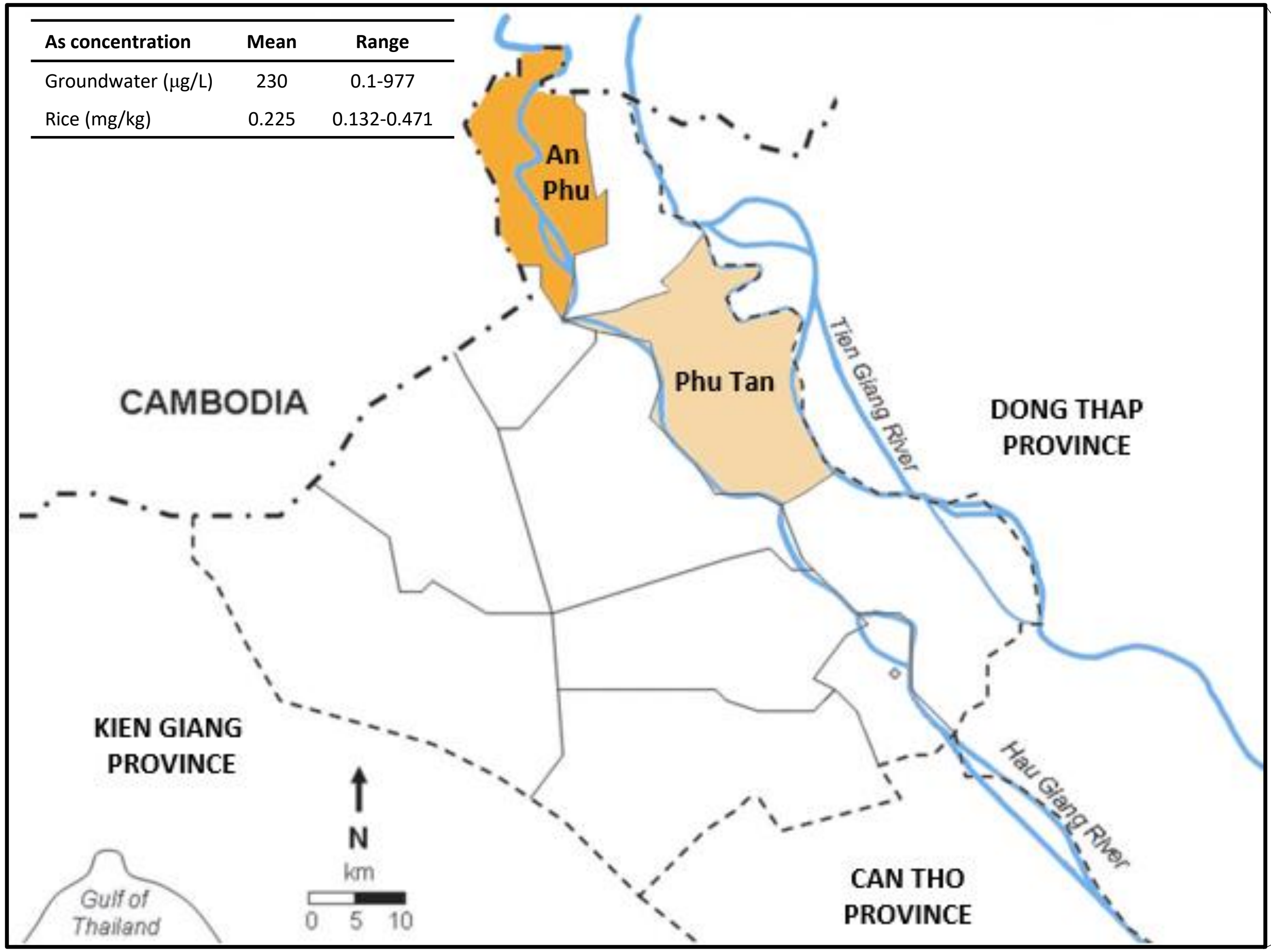
Cadmium concentration in rice and vegetable (mg/kg) in contaminated areas (from SEL studies)

Study areas	Contaminated sources	Types of crop	Mean	Range	Ref
Duckum, Korea	Au-Ag mine	Unpolished rice	0.38	0.19-0.74	Kim et al., 2001
		Vegetable	1.78	1.10-2.51	
Mae Tao, Thailand	Zn mine	White rice	0.288	ND-1.941	Suwatvitayakorn P et al., 2019
		Sticky rice	0.299	ND-2.597	
Dai Tu, Vietnam	W mine	Unpolished rice	0.3	0.1-0.6	Ko et al., 2020

SEL Researches in Vietnam

Hoang et al., J. Environ. Monit., 2011, 13, 2025

As concentration	Mean	Range
Groundwater (μg/L)	230	0.1-977
Rice (mg/kg)	0.225	0.132-0.471



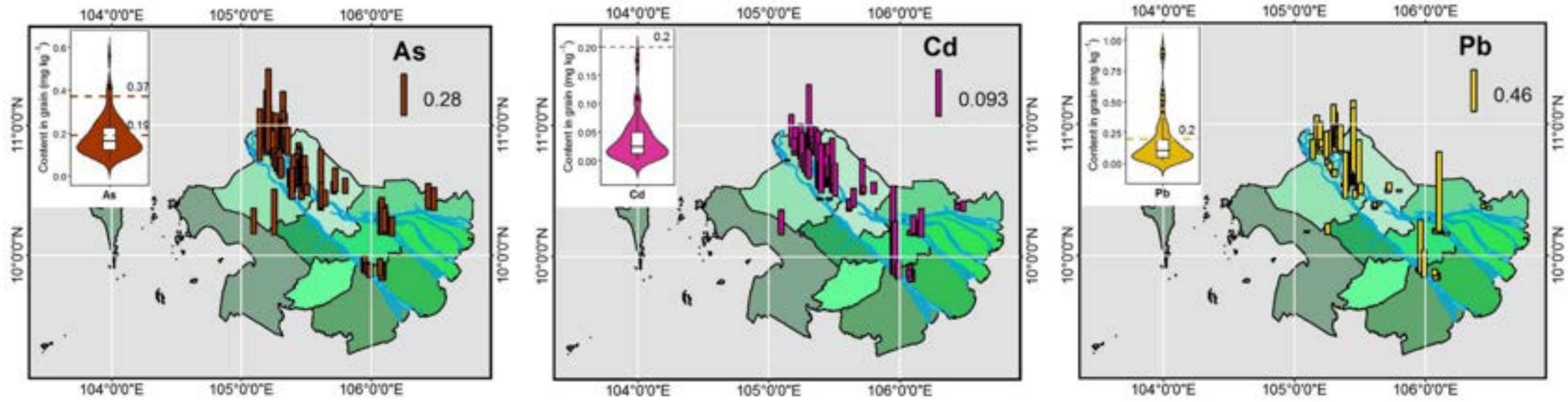
Sampling sites in An Giang, Vietnam

Beginning in 2008, residents of An Phu and Phu Tan district have been using alternative sources of drinking water (tap water, treated groundwater) that contain safe levels of As. Since then, rice consumption has become a major route of As exposure.

Other Researches in Vietnam

Nguyen TP et al. /Environ Geochem Health (2020) 42:2377–2397

Map of As-, Cd-, and Pb-concentration in rice grain in Mekong River Delta and their allowable maximum levels (in mg kg^{-1})



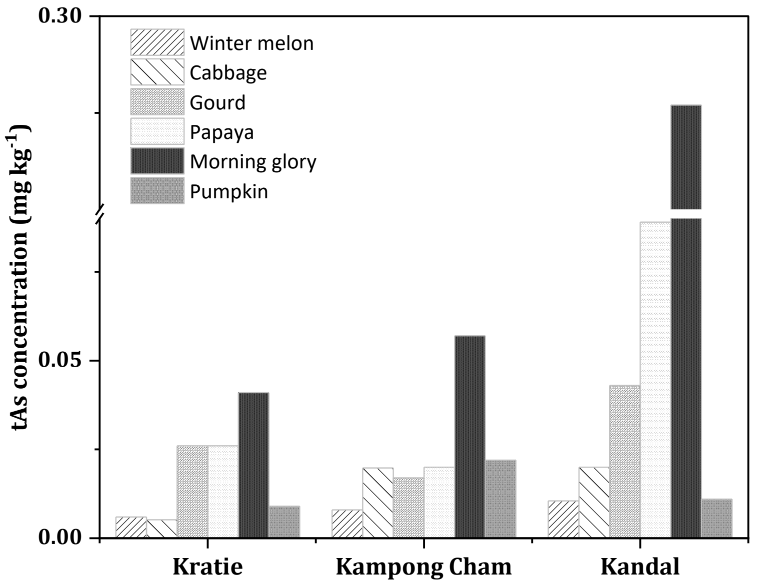
- 24% of the Mekong rice samples exceeded the MC (Permissible maximum concentration) of 0.2 mg Pb kg^{-1}, 10% contained more than twice as much
- All Cd-concentrations of Mekong and Huong River rice samples were lower than the MC of 0.2 mg kg-1
- MCs total As for adults and young children are 0.37 mg kg^{-1} and 0.19 mg kg^{-1}. Compared to these limits, 5% of the Mekong samples would pose a health risk to adults and about 37% to young children.

SEL Researches in Cambodia

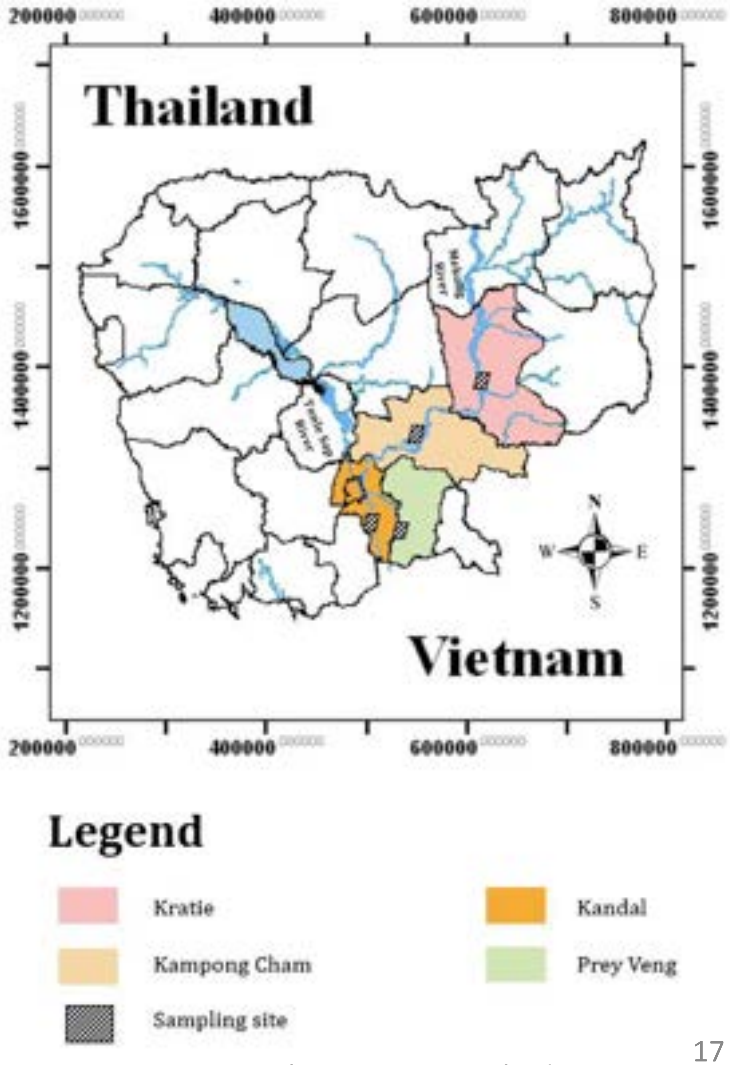
Cheng Z et *al.* / Chemosphere 92 (2013) 143-149
Wang HS *et al.* / *Environ Geochem Health (2013) 35:745–755*
Phan K et *al.* / Journal of Hazardous Materials *262 (2013) 1064–1071*
Phan K et *al.*/ Environmental Pollution *185 (2014) 84-89*

Total arsenic and mercury concentration in rice (mg/kg) in study areas

Province	Total As concentration (mg/kg)		Total Hg concentration (ng/g)	
	Mean	Range	Mean	Range
Kratie	0.075	0.012 - 0.171	12.7	9.90-16.7
Kampong Cham	0.024	0.014 - 0.048	8.14	6.16 – 11.7
Kandal	0.256	0.088 - 0.578	10.21	5.91-15.1
Prey Veng	0.201	0.091 - 0.285		



Total arsenic concentration in crop plants (mg/kg) in study areas



Sampling sites in Cambodia

- Health risk assessment suggested that the residents in Kandal are at risk of inorganic arsenic through daily food consumption
- Residents in Kratie and Kampong Cham are less likely to be exposed to arsenic through their daily intake

Arsenic and Health Issues in Cambodia

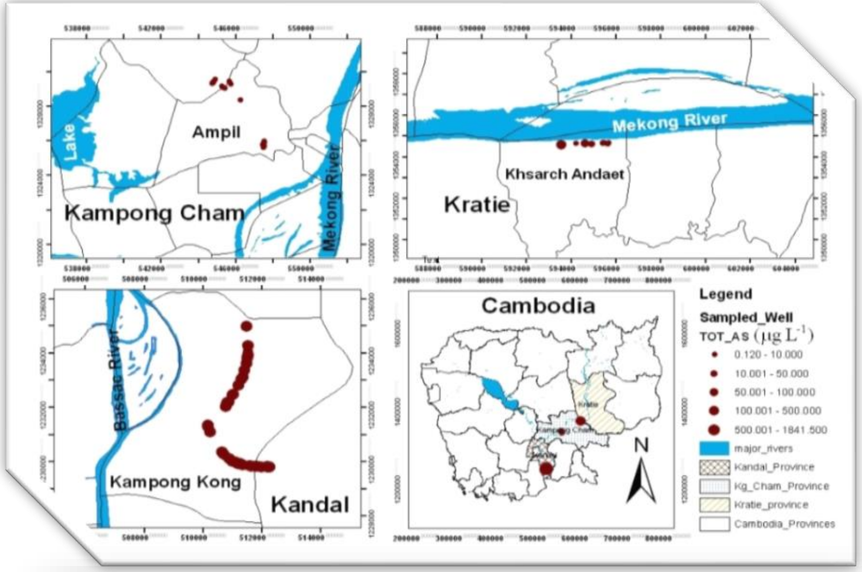
Kyoung-Woong Kim[1] and Kongkea Phan[2,3]

[1]School of Earth Sciences and Environmental Engineering, Gwangju Institute of Science and Technology, Gwangju 500-712, Republic of Korea

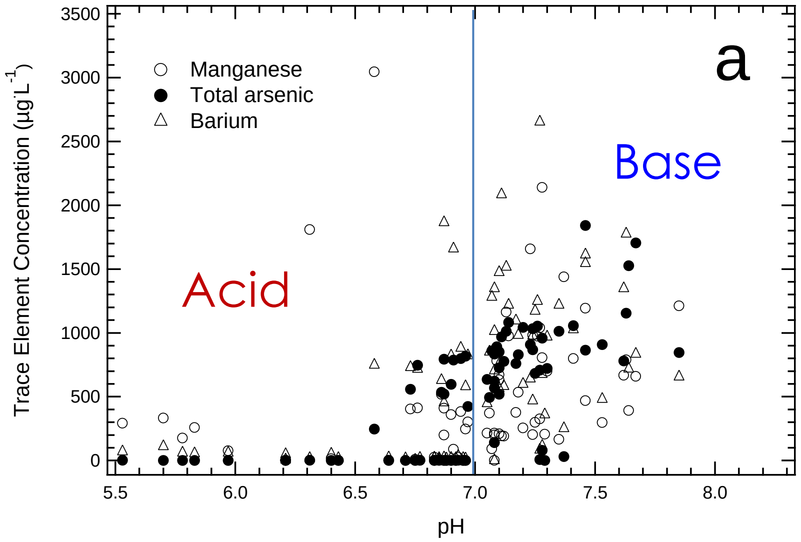
[2]Faculty of Science and Technology, International University, Phnom Penh 12101, Cambodia

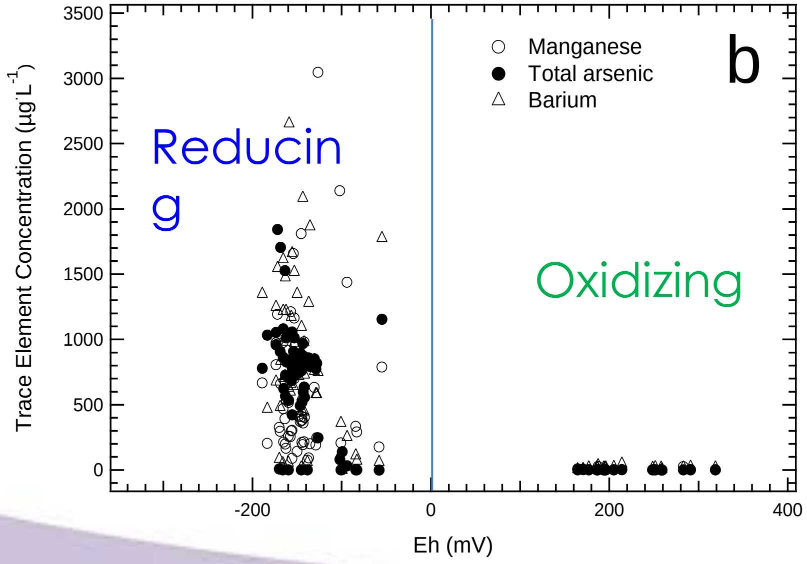
[3]Cambodian Chemical Society, Street 598, Phnom Penh, Cambodia

Study Areas & Fieldwork (Groundwater)



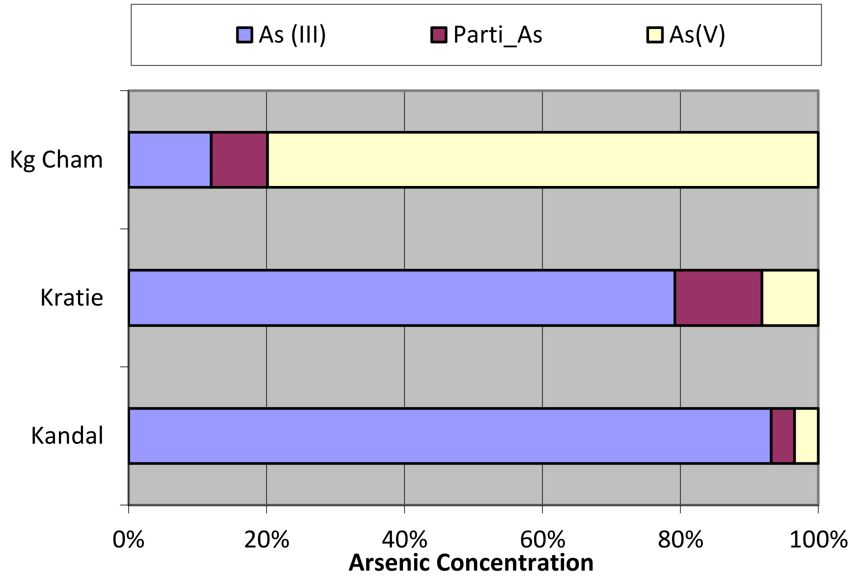
Groundwater Chemistry





Arsenic is released from solid phase to pore water through desorption process enhanced by alkaline condition

Arsenic is released to groundwater in reducing conditions



Groundwater & Human Health

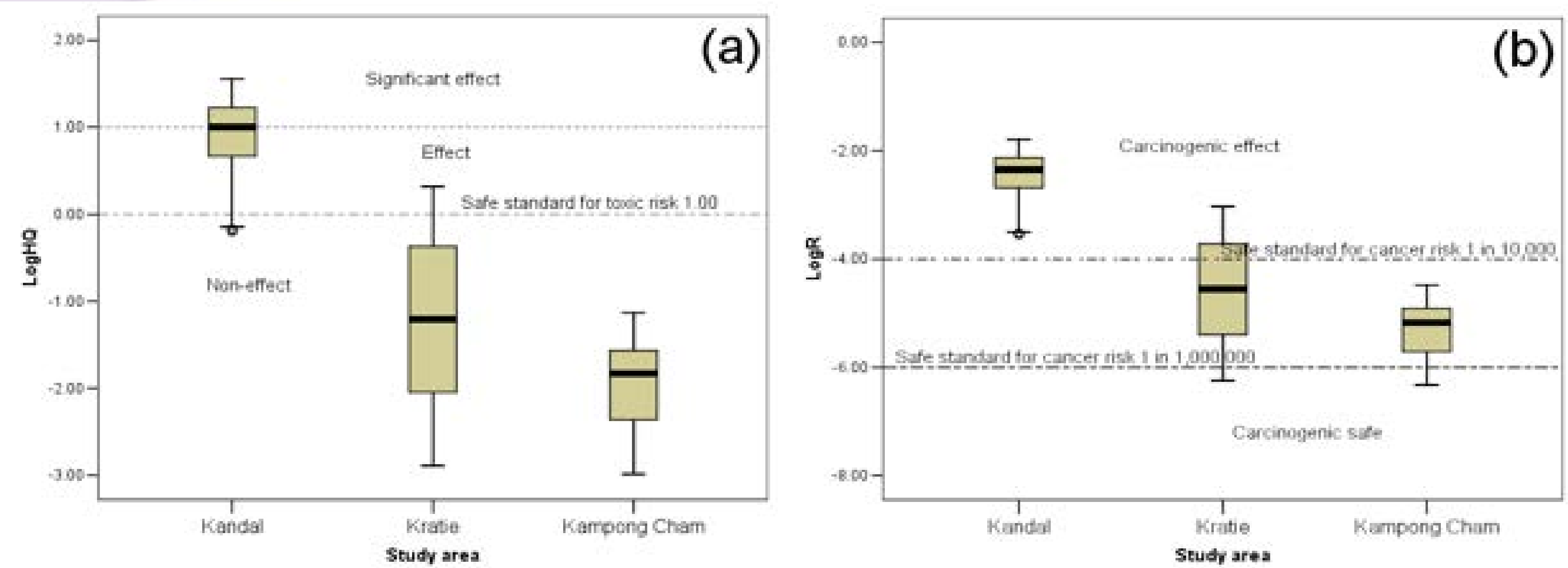
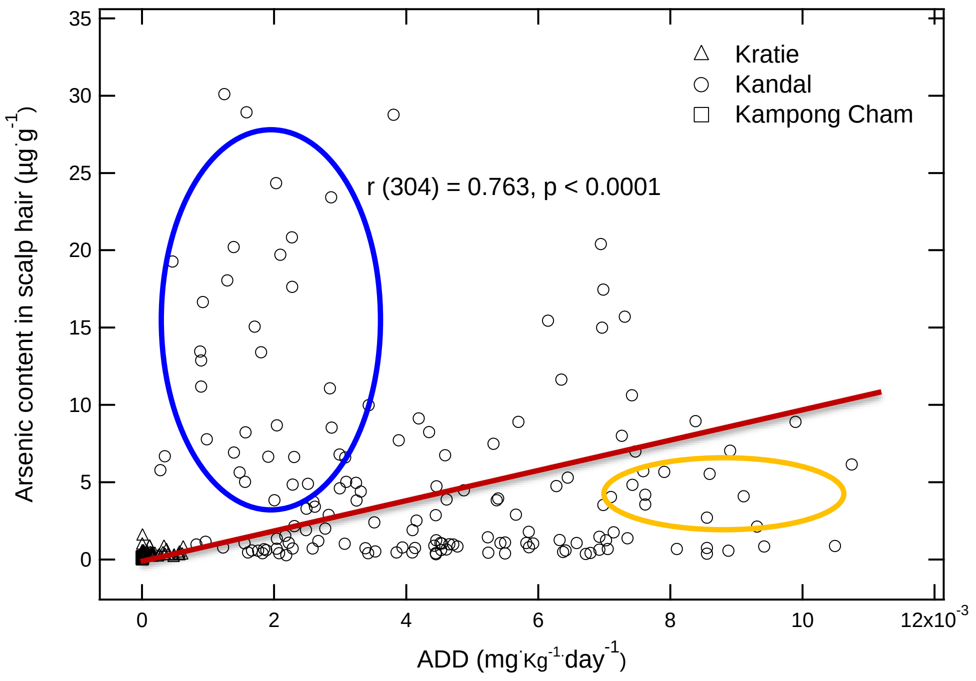


Table. Percentage of residents exposed to toxic and carcinogenic effects in each of the study areas (%)

Study area	HQ > 1.00	Cancer Risk Probability (R)			
		> 1 in 10^2	> 1 in 10^3	> 1 in 10^4	> 1 in 10^6
Kandal (n = 297)	98.65	13.80	92.59	100.00	100.00
Kratie (n = 89)	13.48	0.00	0.00	33.71	97.75
Kampong Cham (n = 184)	0.00	0.00	0.00	0.00	93.48

HQ: Hazard Quotient; R: Carcinogenic risk probability
1 in 10,000 is the highest safe standard for carcinogenic risk
1 in 1,000,000 is the safe standard for carcinogenic risk

Groundwater & Human Health



1) Residents in the Kandal province study area might be exposed to more toxic and carcinogenic risks than those of the Kratie and Kampong Cham province study areas.

2) Positive significant correlations between arsenic content in hair (As_h), arsenic levels in groundwater (As_w), and individual average daily doses (ADD) of arsenic was found

Study Areas & Fieldwork (Foodstuffs)

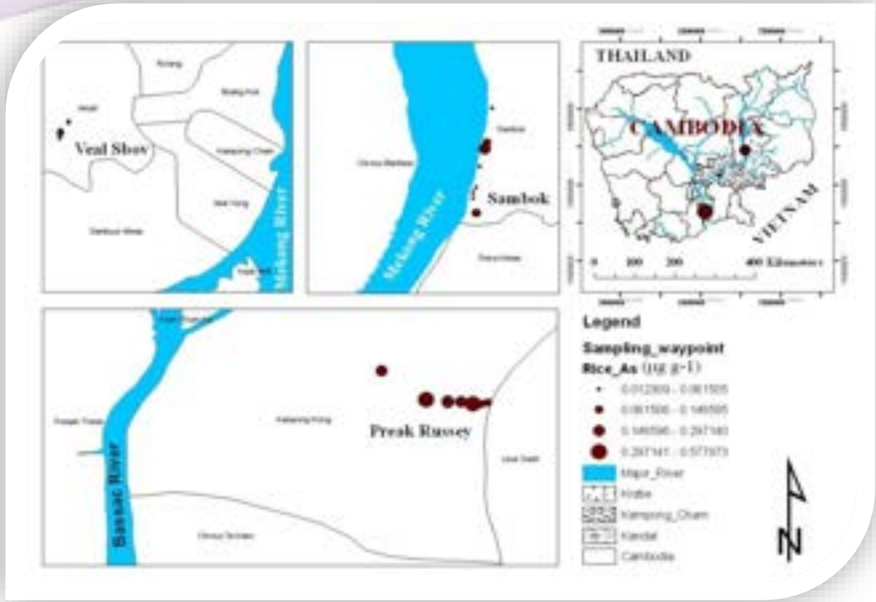
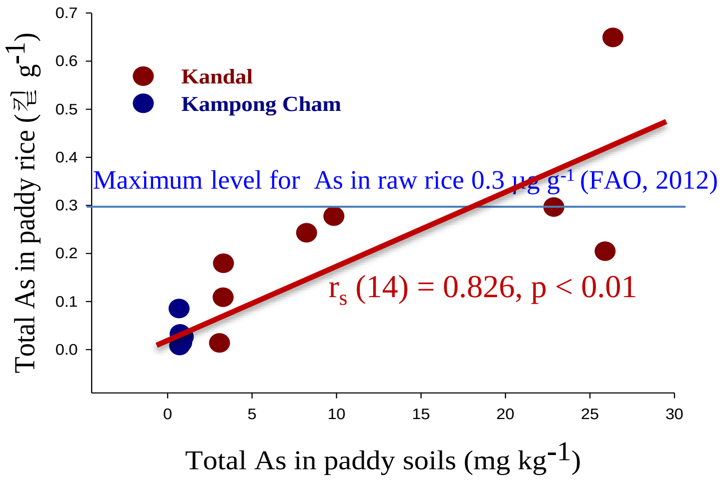


Table 3.1 Number of foodstuff samples

Sample	Kandal	Kratie	Kampong Cham	Total
Uncooked rice	10	10	10	30
Cooked rice	10	10	10	30
Vegetable	15	9	15	39
Fish	10	10	10	30
Total	45	39	45	129

All foodstuffs were washed with DIW and dried at 50 °C over night before digestion

Correlation between As in Paddy Soil and in Rice



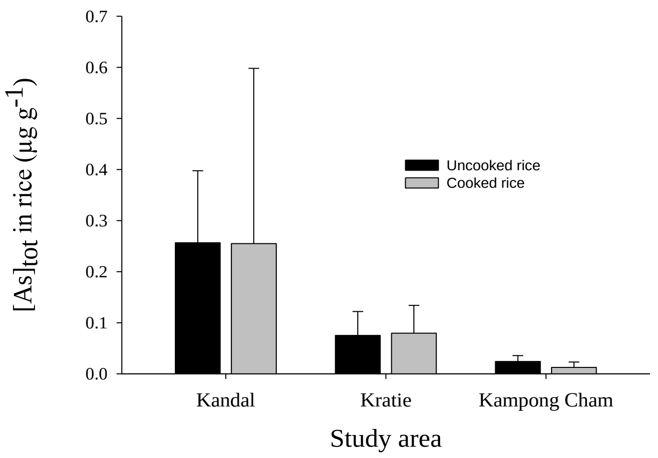
There is a significant positive correlation between arsenic in paddy soil and paddy rice

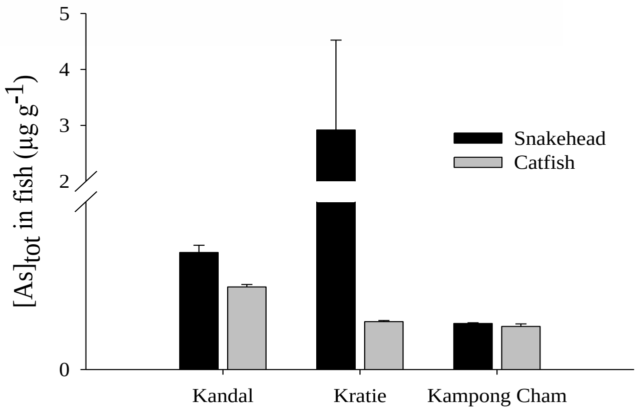
Table 3.2 A comparison of the total arsenic concentrations in paddy soil (mg kg^{-1}) and paddy rice (µg g^{-1}) in Kandal (n = 8) and Kampong Cham (n = 8)

Variables	Mean ± SD	Median	Range	*t*	*df*	*p*
Paddy soil				3.271	7.001	0.014
Kandal	12.9 ± 10.43	9.04	3.07 - 26.4			
Kampong Cham	0.79 ± 0.088	0.78	0.68 - 0.93			
Paddy rice				3.261	7.229	0.013
Kandal	0.247 ± 0.187	0.224	0.014 - 0.649			
Kampong Cham	0.029 ± 0.024	0.025	0.008 - 0.085			

The *t* and *df* were adjusted because variances were not equal, SD: Standard deviation

Foodstuffs & Human Health





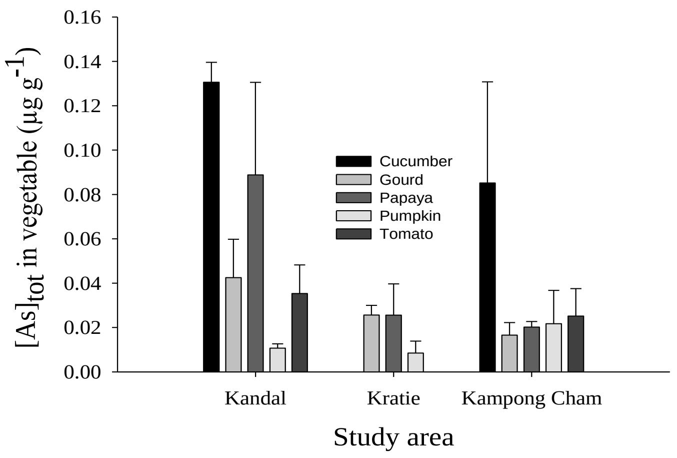
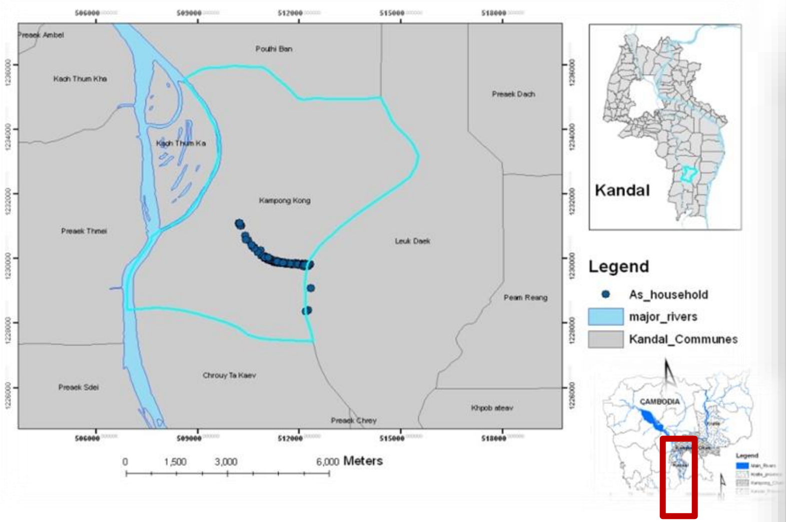


Table 3.4 One-Way Analysis of Variance comparing regional groups on the total arsenic concentrations in uncooked rice, cooked rice, fish and vegetable

Sources	df	SS	MS	F	*p*
Uncooked rice					
Between Groups	2	0.298	0.149	19.907	0.000
Within Groups	27	0.202	0.007		
Total	29	0.501			
Cooked rice					
Between Groups	2	0.314	0.157	3.889	0.033
Within Groups	27	1.089	0.040		
Total	29	1.403			
Fish					
Between Groups	2	12.607	6.303	5.604	0.009
Within Groups	27	30.372	1.125		
Total	29	42.978			
Vegetable					
Between Groups	2	0.011	0.006	4.173	0.023
Within Groups	36	0.048	0.001		
Total	38	0.059			

***df*: degree of freedom; SS: sum of squares; MS: mean square**

Study Areas & Fieldwork (Contributing Factors)



Map of the study area

Physical examination for arsenicosis symptoms is made by following WHO guideline (WHO, 2000)

Human Health Survey

Table 1 Prevalence of arsenicosis with various symptoms (Kandal province)

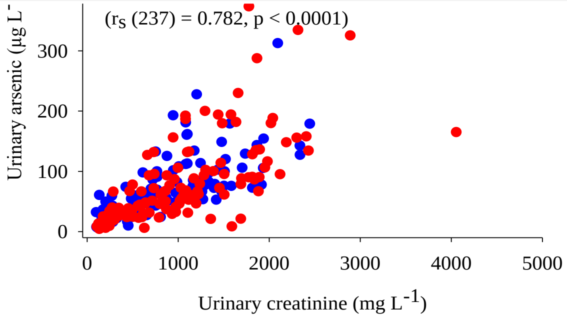
Symptoms[a]	Yes		No	
	N	Percent (%)	N	Percent (%)
Hyperkeratosis	56	9.09	560	90.91
Hypomelanosis	89	14.45	527	85.55
Hyperpigmentation	51	8.28	565	91.72
Diagnosed arsenicosis	138	22.40	478	77.60

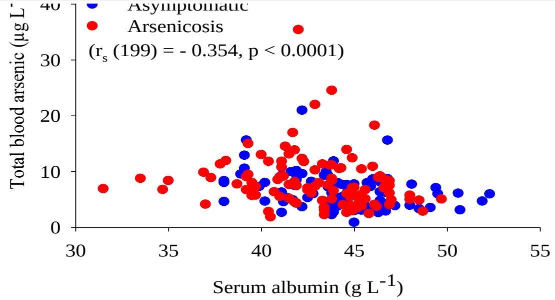
[a]Symptom was diagnosed following WHO's diagnostic guideline

Table 5.1 A comparison of total urinary arsenic (UAs), urinary creatinine (UCre), total blood arsenic (BAs) and serum albumin (SAlb) concentrations between arsenicosis patients and asymptomatic villagers

Variables	Mean ± SD	Median	Range	Mann-Whitney U	Z	*p*
UAs				6720	-0.267	0.790
Asymptomatic (n = 108)	73.04 ± 52.24	60.47	5.93 – 312			
Arsenicosis (n = 127)	78.74 ± 69.84	60.22	3.76 – 373			
UCre				6794	-1.231	0.218
Asymptomatic (n = 115)	944 ± 622	843	103 – 3097			
Arsenicosis (n = 130)	1058 ± 695	978	111 – 4058			
SAlb				3772	-2.932	0.003
Asymptomatic (n = 92)	44.28 ± 3.01	44.30	38.00 - 52.30			
Arsenicosis (n = 108)	42.63 ± 3.69	43.10	25.80 - 49.70			
BAs				3595	-3.366	0.001
Asymptomatic (n = 92)	6.30 ± 3.23	5.73	0.86 - 20.94			
Arsenicosis (n = 108)	8.53 ± 5.97	7.38	1.84 - 46.16			

SD, standard deviation; urinary total arsenic (µg L^{-1}); urinary creatinine (mg L^{-1}); total blood arsenic (µg L^{-1}); serum albumin (g L^{-1}); significance is considered in circumstance where $p < 0.05$.





Summary

1) Residents in the highly contaminated study area of Kandal are exposed to more toxic and carcinogenic risks than those in the Kratie and Kampong Cham provinces.

2) The daily dose of inorganic arsenic of the residents in Kandal province is higher than the lower limits on the benchmark dose for a 0.5% increased incidence of lung cancer ($BMDL_{0.5}$ equals to 3.0 µg kg^{-1} d^{-1})

3) Arsenic in rice is an additional source which is attributed to high arsenic accumulation in the residents' bodies in the Mekong River basin of Cambodia.

4) High arsenic concentrations are also found in blood and urine of arsenicosis patients and asymptomatic villagers of the highly contaminated study area of Kandal province.

5) Malnourished people with high blood arsenic are likely to rapidly develop arsenicosis as blood arsenic and serum albumin are keys factors contributing to the development of arsenicosis symptoms.

Local news on arsenic issue in Cambodia

Khmer Times (14 October, 2015)

Khmer Times (26 August, 2015)

The Phnom Penh Post (1 March, 2016)

The Effect of Climate Change on Heavy Metal Concentration in Food Chain

Case Study : Laos

INTRODUCTION

Climate Chang
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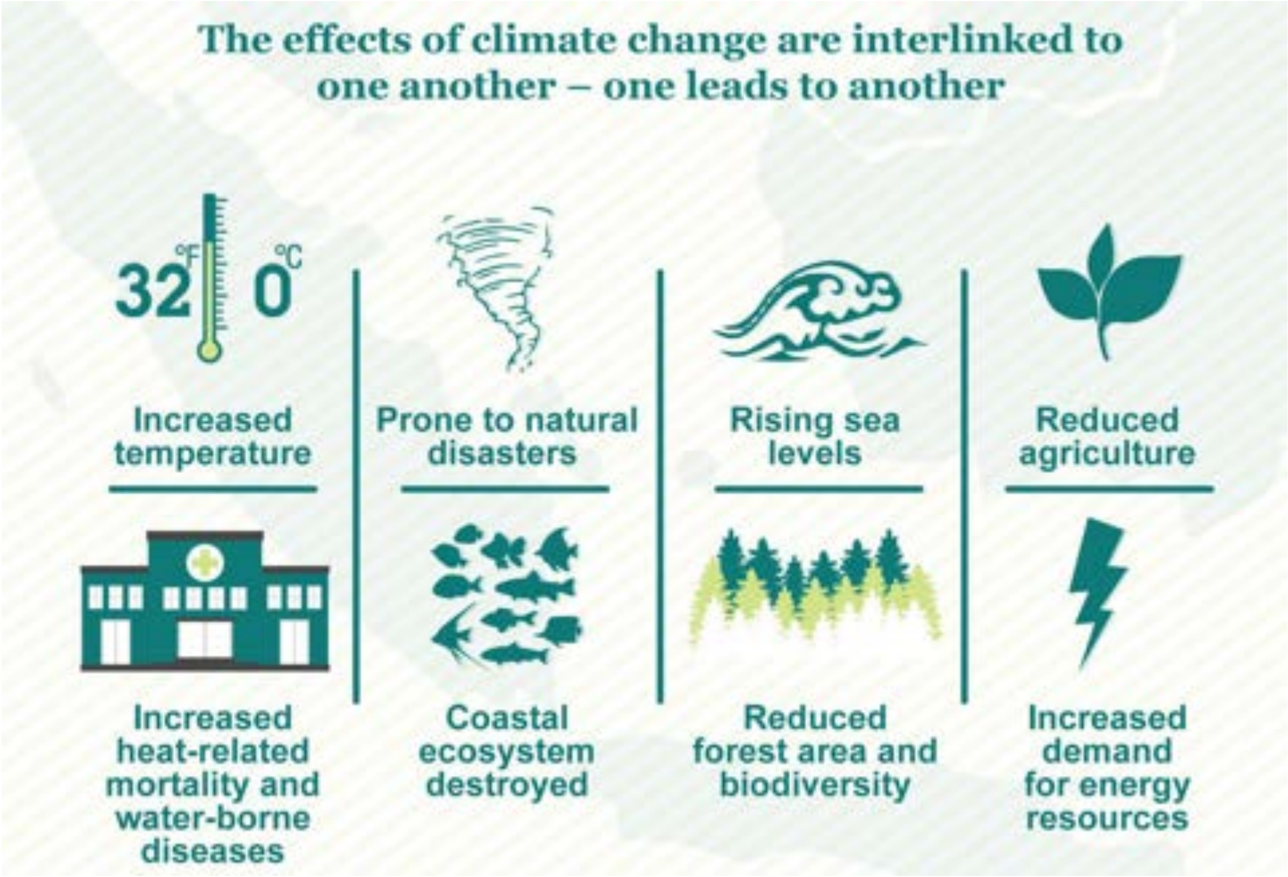
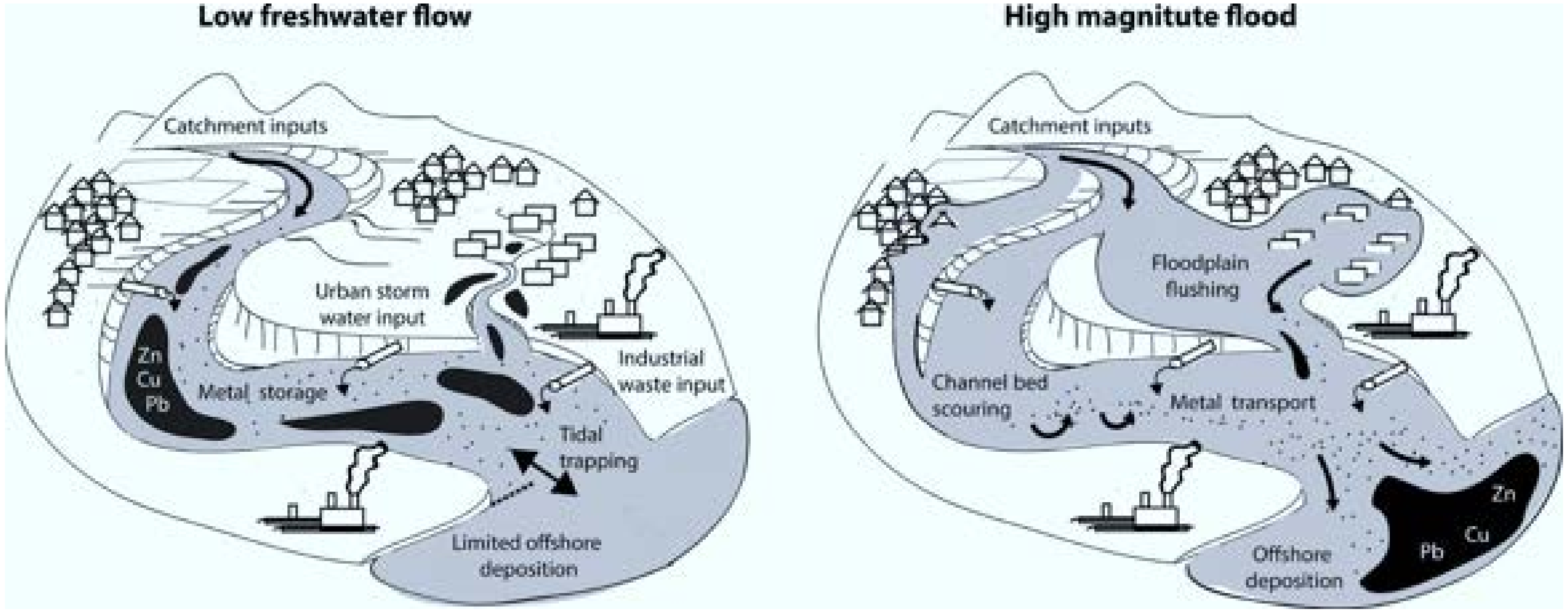


Climate Change vs Heavy Me tal



- Climate change can **affect both surface and groundwater quality**, It can particularly affect the diffuse or "non-point" sources of pollution.
- Climate change could **release heavy metals at enhanced rates from peatland wetlands**, which are important storehouses of heavy metals to the lowland catchment.

INTRODUCTION

Laos Demographic

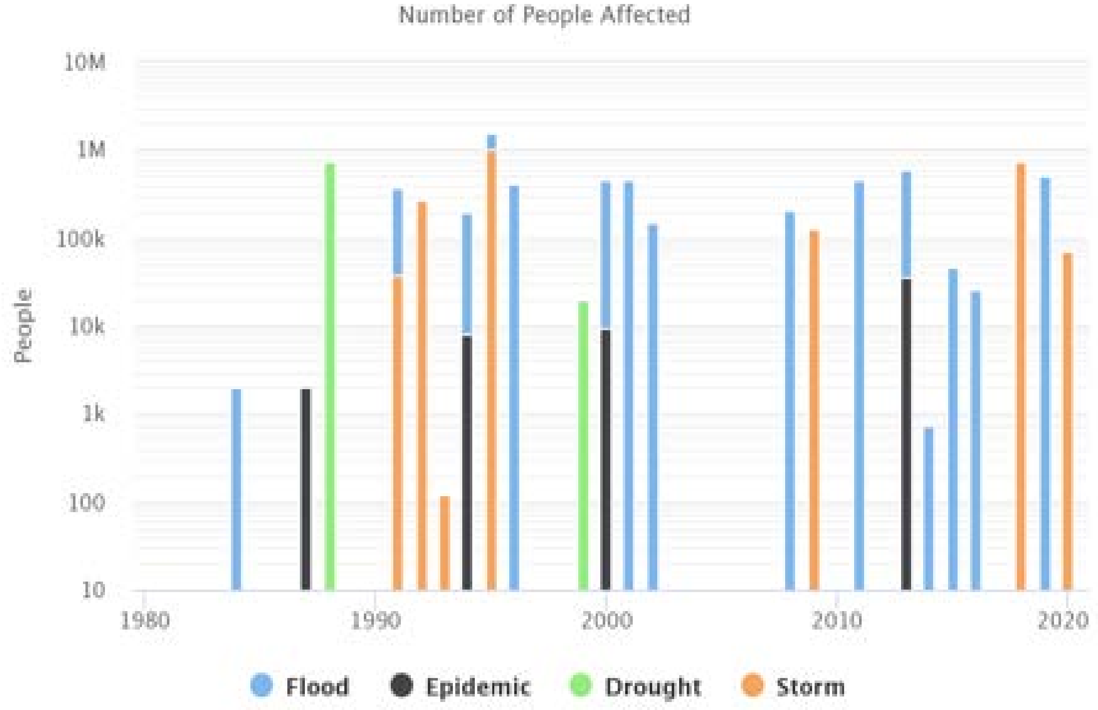
- **Location:** Middle of South-East Asia;
- **Area:** 236,800 Square kilometres; 80% of mountainous area;
- **Population:** 7.43 million (Census in 2021);
- **Border:** Vietnam, China, Myanmar, Thailand, and Cambodia;
- **Season:** rainy season and dry season;
- **Major income:** Agricultural and industrial (75% of GDP);
- **Major river:** Mekong river (flow 1,805 km^2)and its tributary (Encyclopaedia of the Nations 2012).

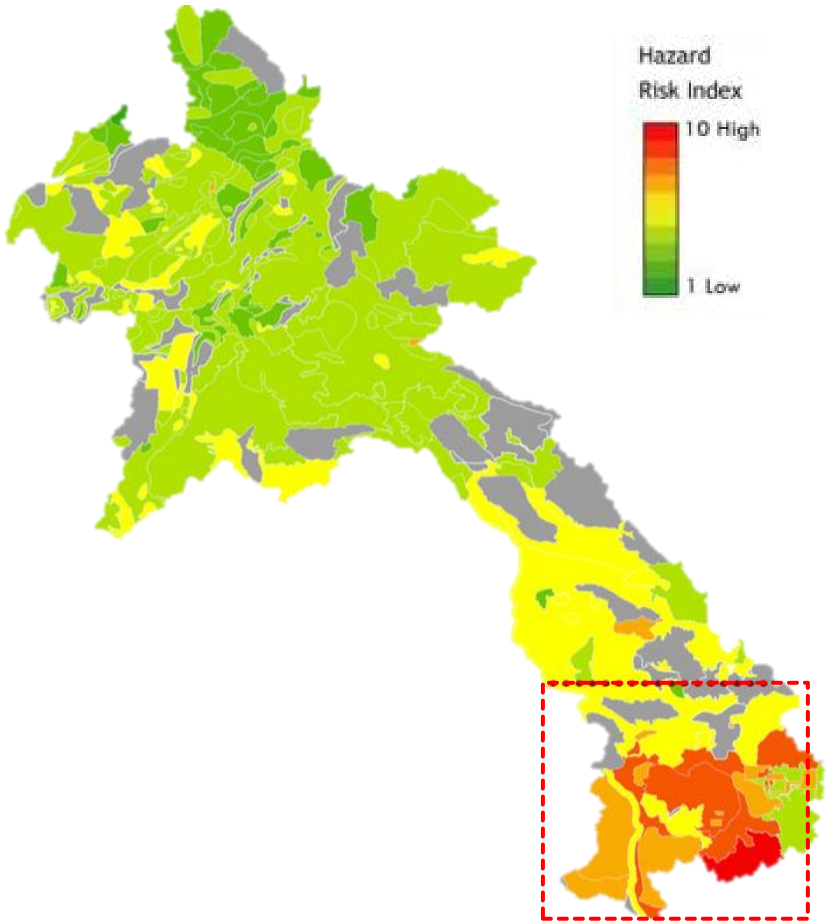
INTRODUCTION

Major Disaster and Climate Change in Lao s

Laos has encountered to many natural disaster, especially flooding and drought event, which mostly happened in the central and southern provinces. (Lao PDR National Assessment Report., 2012).

Key Natural Hazard Statistics for 1980 – 2020 (World Bank., 2021)





INTRODUCTION

The Impact of Climate Change

BBC NEWS

Laos dam collapse: Many feared dead as floods hit villages

24 July 2018

Dam collapse due to heavy rain in Southern Laos, 2018.

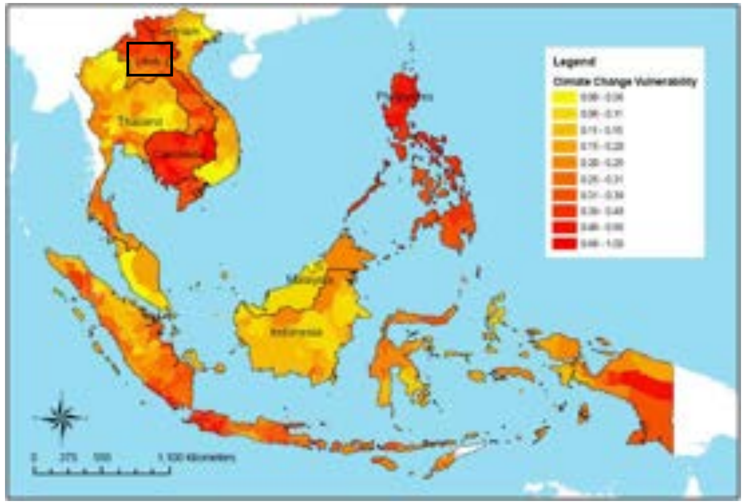
Sources:https://www.bbc.com/news/world-asia-44935495

INTRODUCTION

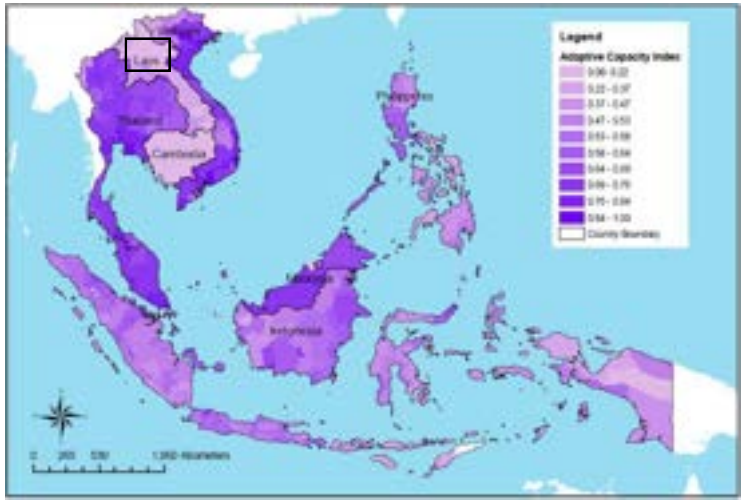
The Impact of Climate Change

Why does Laos so vulnerable?

- Laos has a low capacity to adapt to climate c hange because of its **poor socio - economic dev elopment.**
- Highly **depends on natural resources.**
- The northern and north-western parts of Laos are vulnerable to drought.
- Along the Mekong River, in the central and southern provinces are vulnerable to flood.



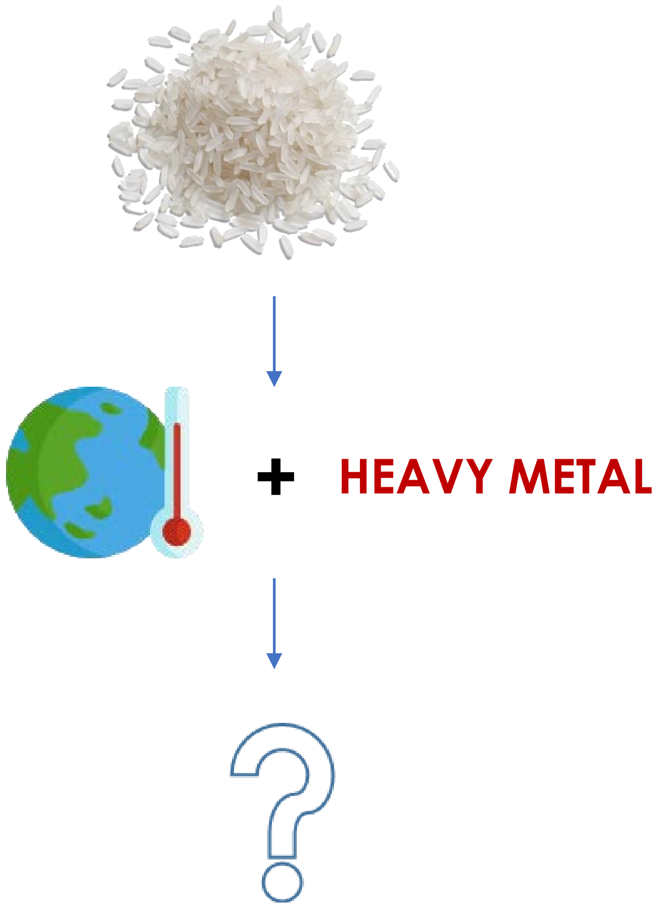
Vulnerability ↑



Adaptation ↓

The Effect of Climate Change to Agriculture in Laos

- The great majority of Laos's farmers are engaged in **rice agriculture.**
- Laos' per capita rice consumption is among the highest in the world at around **206 kg/year** (World Bank., 2020)
- By 2024, the **production of rice yield will decrease around 5–20%** due to the influence of climate change.
- However, **rice production threatened by coupled stresses of climate change and heavy metal** is still unknown.



INTRODUCTION

Why Mekong River with Floodplain Area ?

- Heavy metal enrichment from **non-point sources due to natural geochemical processes.**
- The flow through anthropogenic activities from the Upper area might **transport large amounts of industrial pollutants, into lower catchment** (Krüger, F et al., 2005).
- Floodplain soils constitute **long-term sinks and source** when heavy metal are remobilized during flooding events (Hürkamp et al. 2009).
- Dam construction and gold mining dredging in southern Laos was **ruining water quality and the people** who live in downstream on the Mekong River tributary (Radio Free Asia: RFA), 2013).

OBJECTIVES

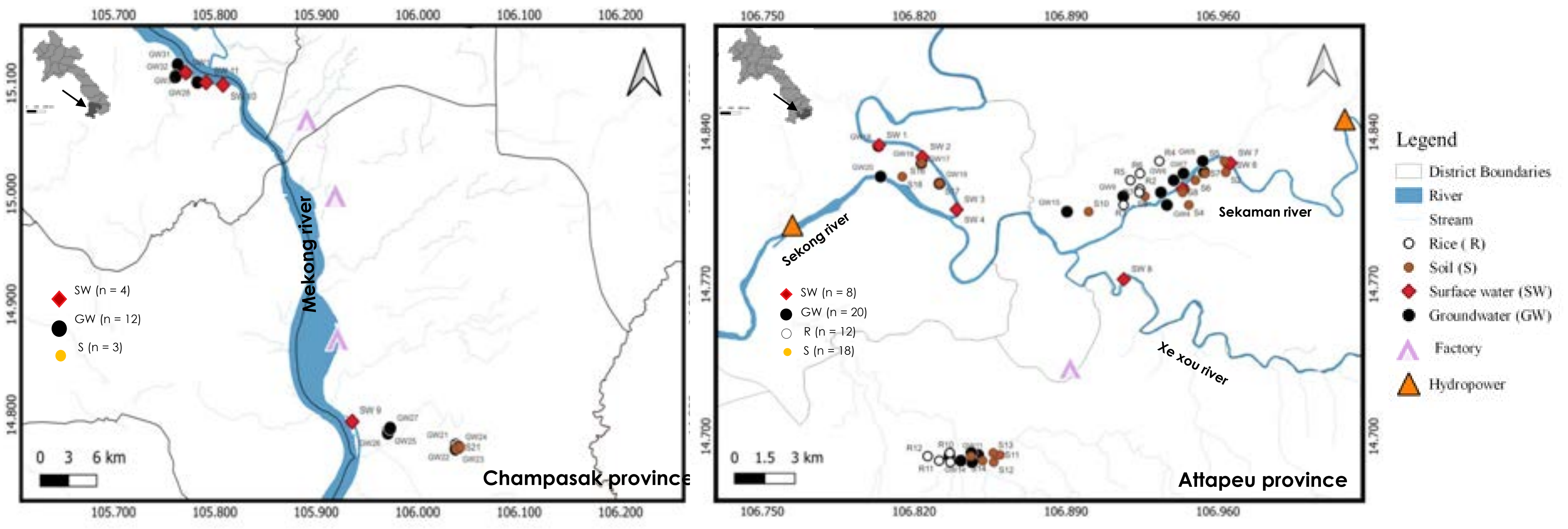
Preliminary survey on Heavy Metal Concentration in Rice Grain and Groundwater From Floodplain Area

STUDY AREAS

Floodplain area along with Mekong river and Bolavan Plateau with inactive volcanic areas

14° 52′ 58.8″ N, 105° 51′ 57.6″ E

14° 48′ 0″ N, 106° 49′ 58.8″ E



STUDY AREAS






RESULTS and DISCUSSION

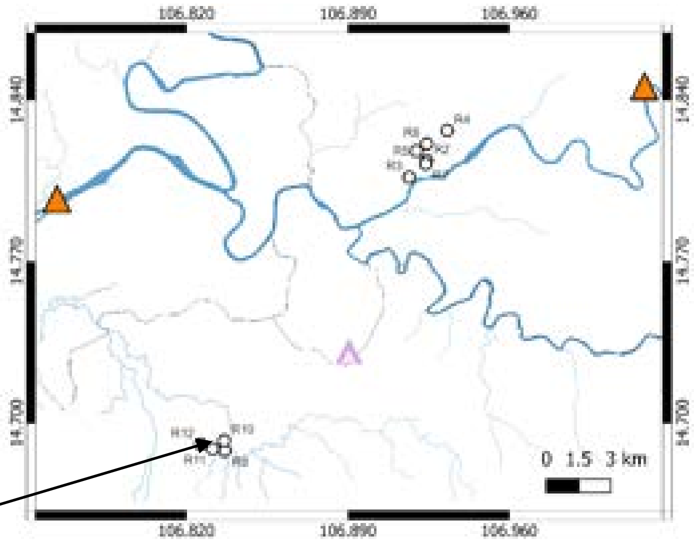
- **Heavy metal concentration in Rice grain (n = 12)**

Sample ID	Heavy metal concentration (mg/kg)						
	Mn	Fe	Cu	Zn	As	Cd	Pb
R1	14.90	13.22	2.50	16.75	0.29	0.02	ND
R2	13.22	14.02	9.48	25.03	0.24	0.01	0.07
R3	13.50	11.23	12.03	20.82	0.26	0.01	0.07
R4	13.69	16.17	2.34	18.11	0.21	0.02	0.02
R5	11.21	13.06	3.20	20.55	0.22	0.01	0.07
R6	22.95	11.46	3.68	21.07	0.25	0.00	ND
R7	18.43	35.35	30.87	23.09	0.27	0.02	**0.23**
R8	14.78	13.94	3.14	25.36	0.23	0.03	ND
R9	14.55	11.07	5.00	25.83	0.24	ND	ND
R10	16.75	11.58	2.33	27.08	**0.31**	ND	ND
R11	12.96	13.77	5.91	19.70	**0.31**	ND	ND
R12	18.65	8.32	2.45	28.88	**0.59**	0.02	**0.22**
Mean ± SD	15.47 ± 3.23	14.43 ± 6.88	6.91 ± 8.15	22.69±3.77	0.28 ± 0.10	0.02 ± 0.01	1.22 ± 0.70
Range	11.21 – 22.95	8.32 – 35.35	2.33 – 30.87	16.75 – 28.88	0.21 – 0.59	0.00 – 0.03	0.41 – 2.88
***CODEX**	-	-	-	-	**0.30**	**0.40**	**0.2**

* CODEX: Codex Alimentarius – General standard for Contamination and Toxics in Food and Feed (2012)

% Recovery _SRM 1568a Rice flour: Mn95%, Fe 93.82%, Cu 120.74%, Zn 86.05%, As 109.92%, Cd 123.92%.

ND : Not Detected



- The most relevant contaminant in flooded rice paddies is **As** (Muehe, E.M. et al., 2019).
- The As concentration of rice sample from the low catchment area of Attapeu province where the sugar cane industries are located has exceed the maximum limit of 0.3 mg/kg.

RESULTS and DISCUSSION

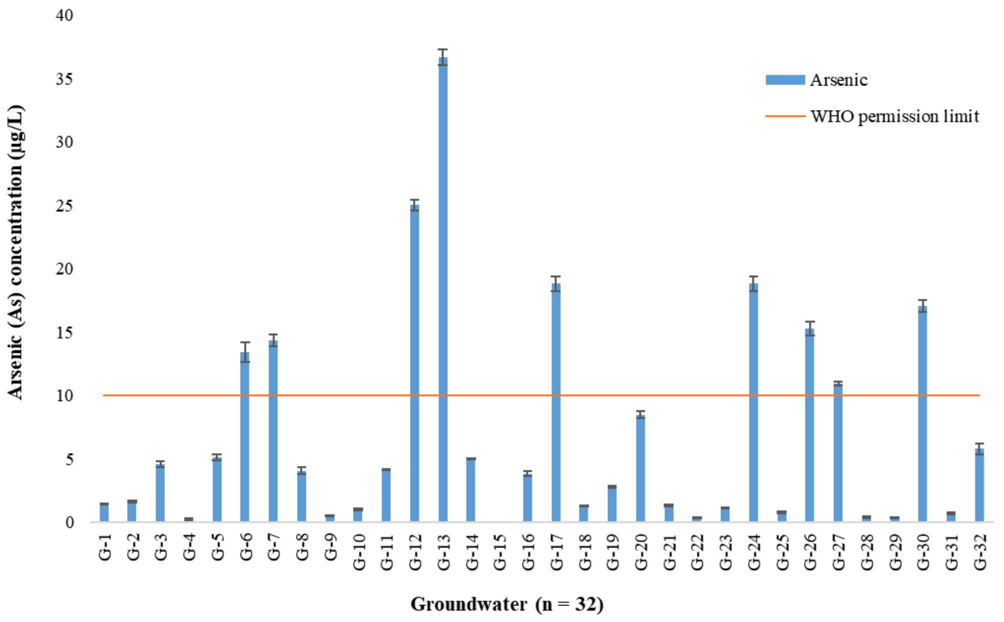
- **Water Quality**

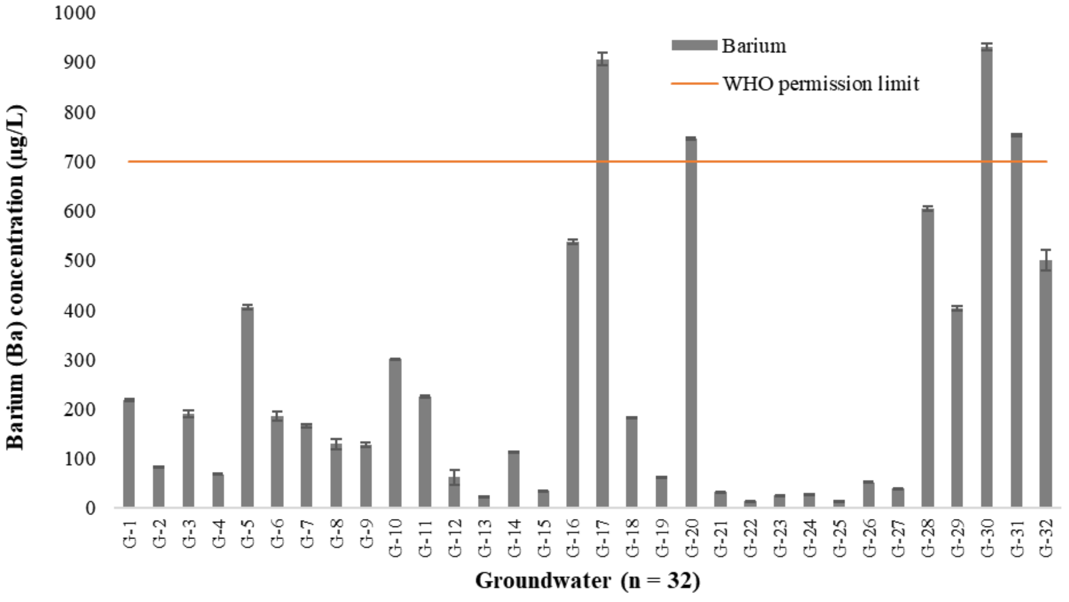
Parameter	Unit	Groundwater (n = 32)		Surface water (n = 12)		WHO*
		Mean	Range	Mean	Range	
Dept (m)	m	27	10 - 60	-	-	-
Temp	°C	28.9	27.1 - 30.2	27.9	26.9 - 29.1	
pH	-	6.5	5.5 - 7.2	6.9	6.2 - 7.2	6.5 - 8.5
EC	uS/cm	490.1	**39.7 - 1419**	71.2	50.9 - 132.7	1400
DO	mg/L	3.5	1.7 - 8.6	6.8	5.4 - 7.3	6.0
TDS	mg/L	312.2	25.4 - 547.8	45.6	32.6 - 132.7	1000
Salinity	ppt	0.2	0.00 - 0.7	ND	ND	-
Sodium (Na^+)	mg/L	26.3	4.9 - 122	2.9	1.6- 7.4	200
Ammonium (NH_4^+)	mg/L	0.1	0.0 - 0.6	ND	ND	-
Potassium (K^+)	mg/L	1.4	0.0 - 4.86	1.1	0.7 - 2.0	55
Calcium (Ca^{2+})	mg/L	51.8	2.8 - 153.1	10.1	4.9 - 30.0	500
Magnesium (Mg^{2+})	mg/L	14.4	0.6 - 32.1	2.8	1.5 - 7.0	50
Fluoride (F^-)	mg/L	0.13	0.01 - 0.3	0.05	0.0 - 0.1	1.5
Nitrite (NO_2^-)	mg/L	ND	ND	ND	ND	-
Chloride (Cl^-)	mg/L	15.4	1.25 - 100.5	3.5	1.4 - 11.9	250
Bromide (Br^-)	mg/L	0.9	0.7 - 1.5	ND	ND	-
Nitrate (NO_3^-)	mg/L	5.1	0.0 - 20.6	49.5	1.0 - 542.2	50
Phosphate (PO_4^{3-})	mg/L	2.1	2.0 - 2.2	MND	ND	12
Sulphate (SO_4^{2-})	mg/L	44.5	**0.9 - 508.2**	3.2	1.5 - 8.3	400

* WHO (2011) : Guidelines for Drinking-water Quality

RESULTS and DISCUSSION

- **Arsenic and Barium concentration in Groundwater (n = 32)**





- The groundwater has shown on **high concentration of As and Ba**, which exceed WHO (2011) permission limit of 10 ug/L, and 700 ug/L respectively.
- The source of a portion of the As and Ba ??? (Chanpiwat et al., 2014)

세계초일류
이공계대학

THANK YOU

GIST

Gwangju Institute of Science and Technology

Collaborative Research for Early-Career Scientists (CRECS)
Small Grants Programme

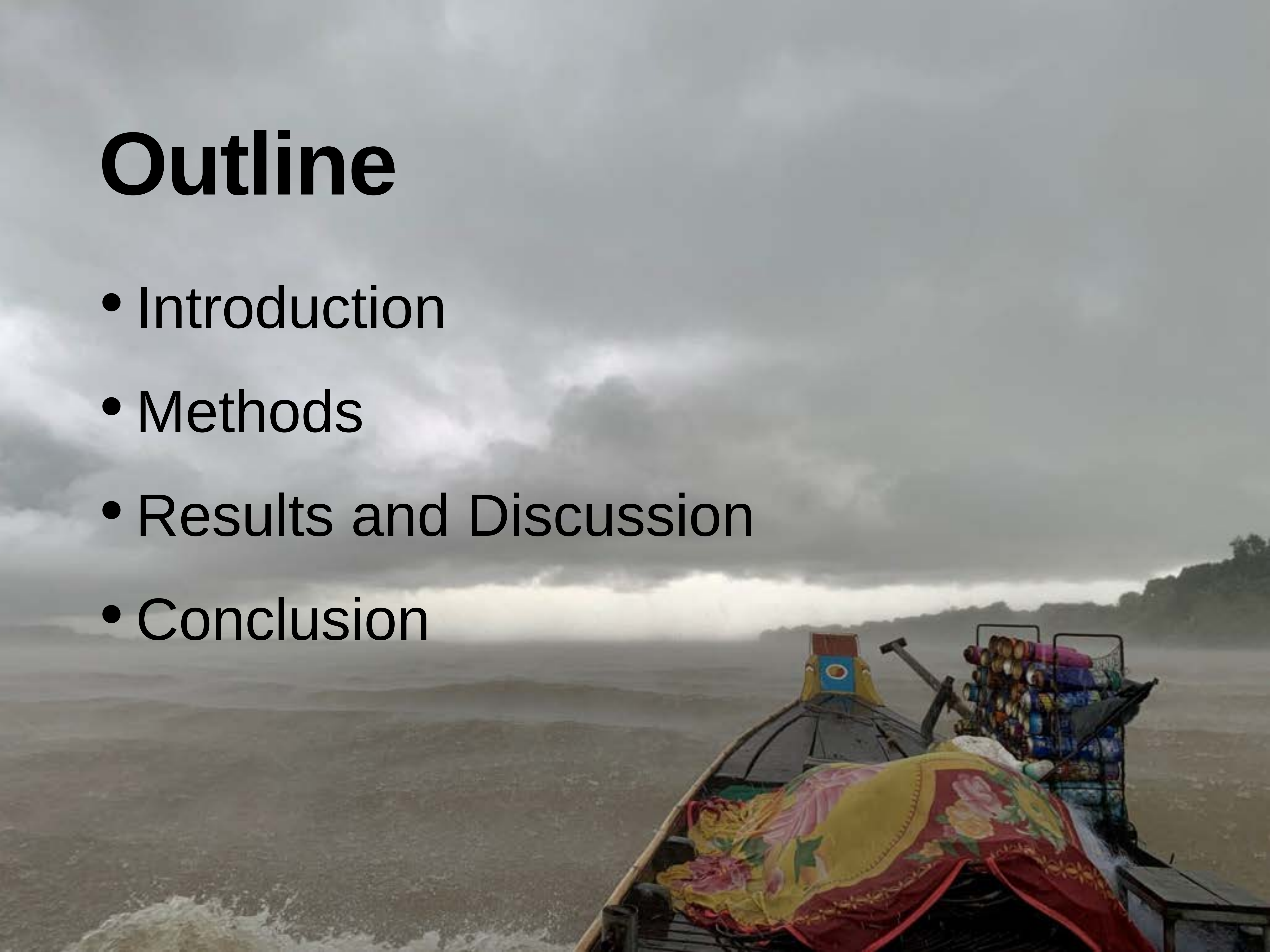
Arsenic mass balance and its mobility in Mekong sub-region groundwater

Dr. Seah Kah Yee (Cary)
Post-doc Researcher
IERI, GIST

2022 Annual Workshop on Capacity Building of the Dept. of Env. Eng. Seesion 4 : Water 2022.12.21 (Wednesday)

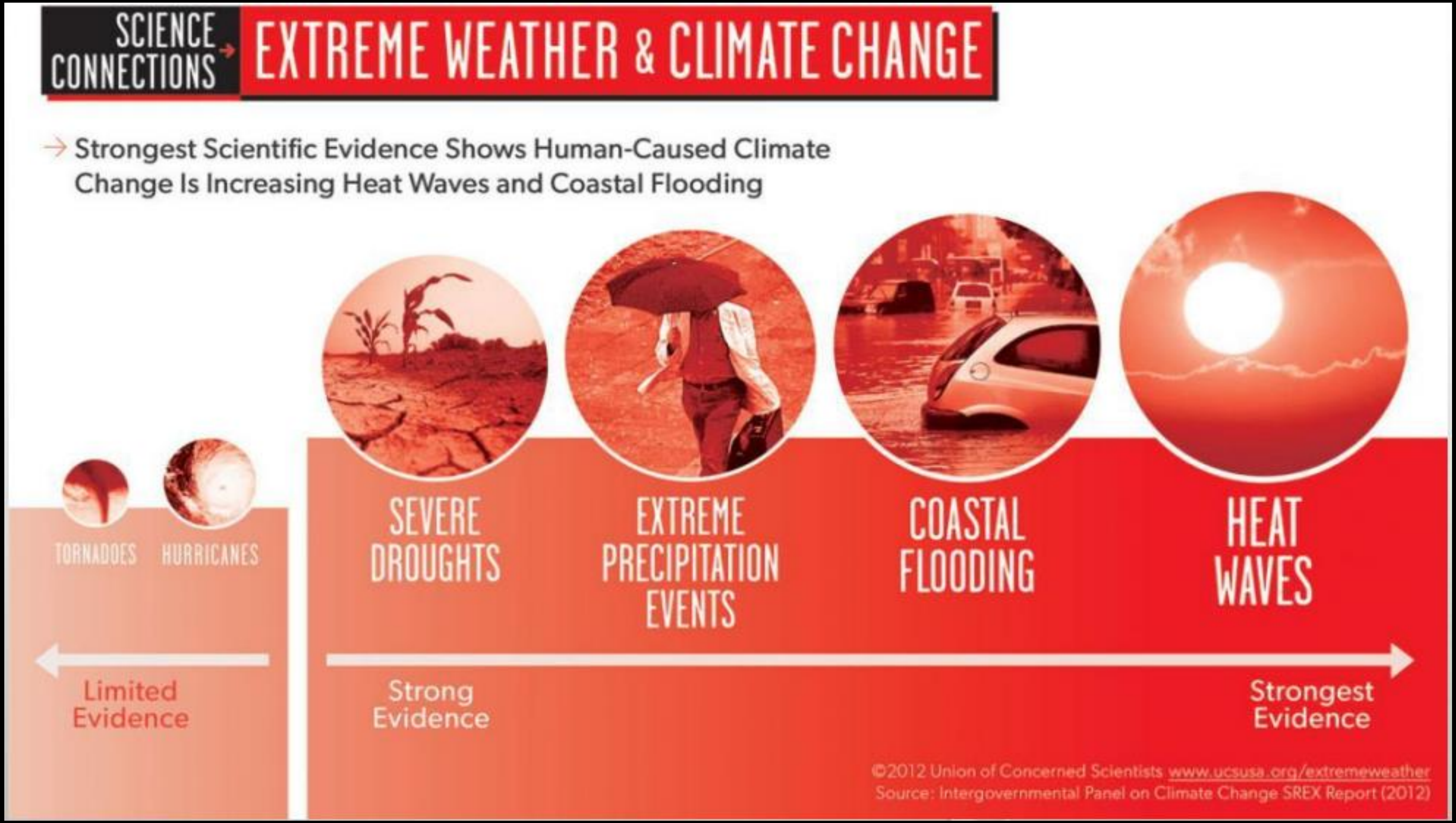
Outline

- Introduction
- Methods
- Results and Discussion
- Conclusion

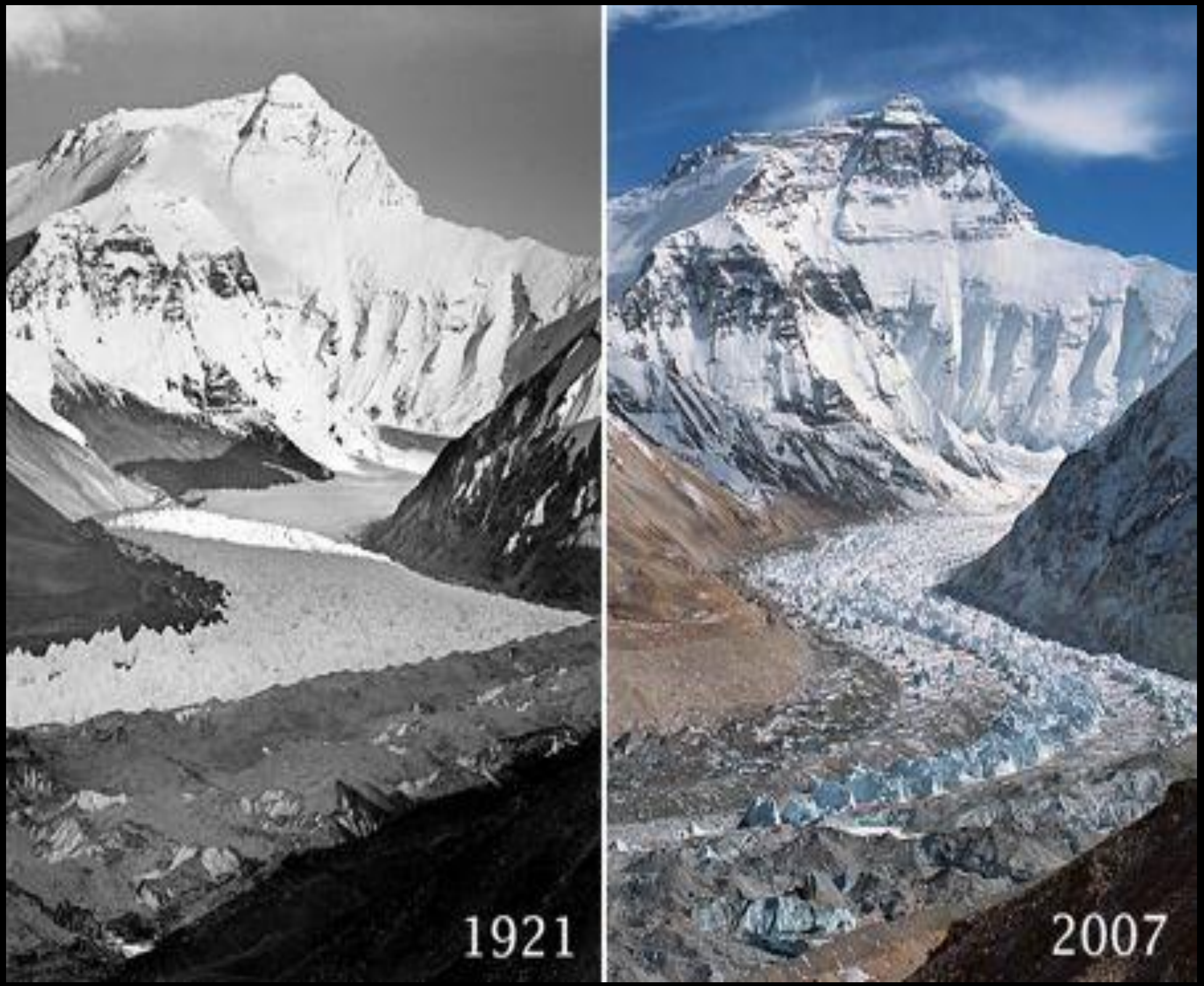


Introduction

Climate change



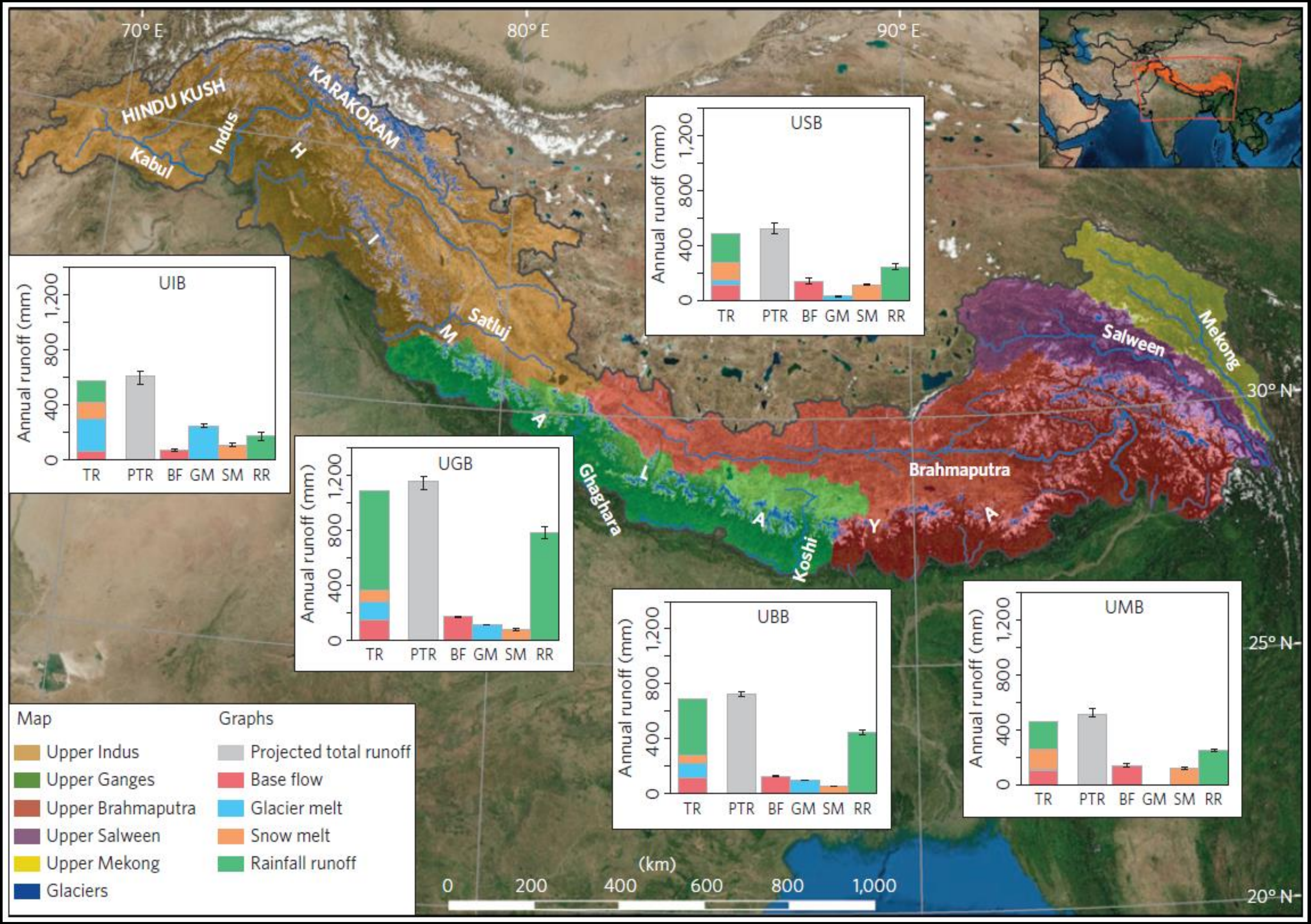
Introduction



The 2007 IPCC report says: “Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate.”

Himalayan Mountains are home to the highest peak in Mount Everest at 29,029 feet, but also to the third largest deposit of ice and snow in the world, after Antarctica and the Arctic.

Rivers originating in the **high mountains of Asia** are among the most meltwater-dependent river systems on Earth



The upstream basins of Indus, Ganges, Brahmaputra, Salween and Mekong. Bar plots show the average annual runoff generation (TR) for the reference period (1998–2007, REF; first column). The second column shows the mean projected annual total runoff (PTR) for the future (2041–2050 RCP4.5) when the model is forced with an ensemble of 4 GCMs. In the subsequent columns, PTR is split into four contributors (BF: baseflow, GM: glacier melt, SM: snow melt, RR: rainfall runoff). Error bars indicate the spread in model outputs for the model forced by the ensemble of 4 GCMs.

DOI:10.1038/nclimate2237

Why MEKONG?

Topography Mekong River

Area 790,000 km^2
Length 4,020 km
Population 250,000,000
Trans-boundary nature
China (21%),
Myanmar (3%),
Thailand (23%),
Laos (25%),
Cambodia (20%),
Vietnam (8%)

Arsenic contamination in Southeast Asia is featured by contaminated sediments naturally eroded from Himalayan.
As is released in groundwater following reductive release from solid phases under anaerobic conditions.

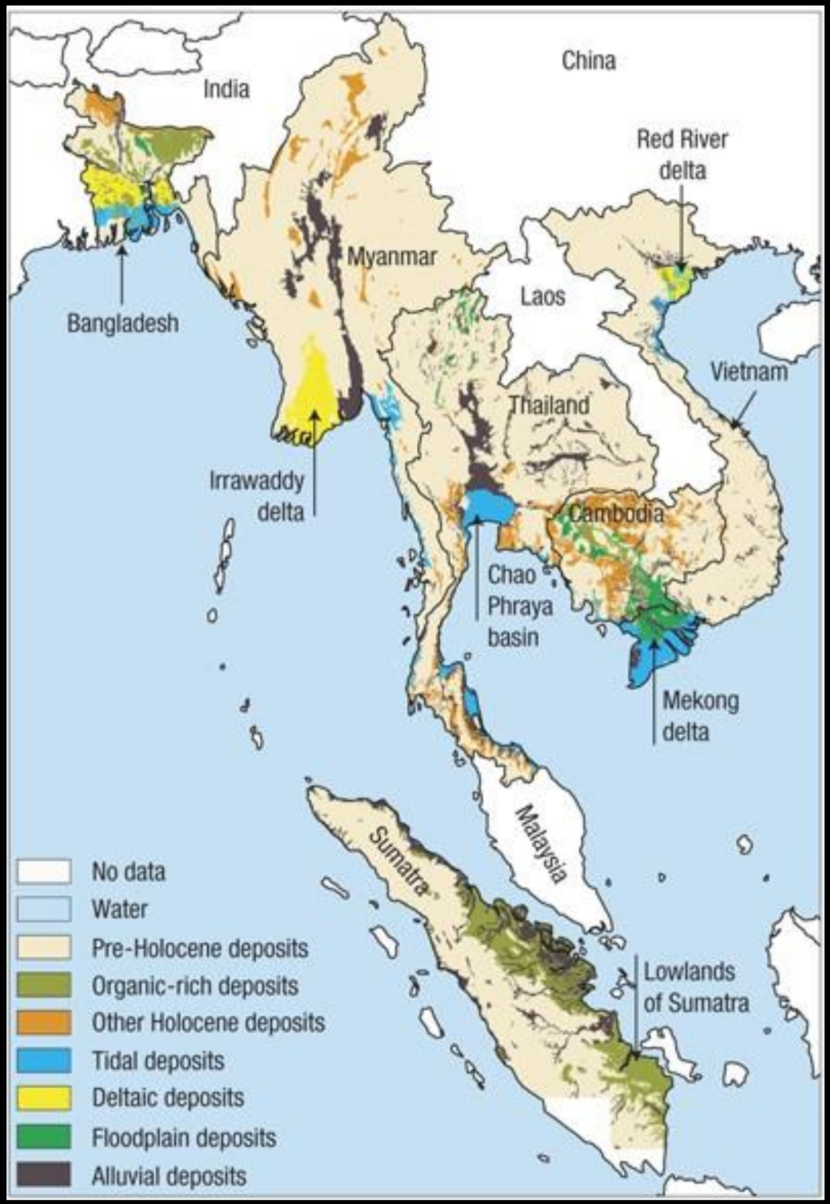
On the minimally disturbed Mekong delta of Cambodia, arsenic is released from near-surface, river-derived sediments and transported through the underlying aquifer back to the river. (centennial timescale; 100yr)

Arsenic in Cambodia

(mid-1990s) UNICEF drilled tube wells so that people would have drinking water that was purer than the microbe-infested water they skimmed from ponds in the village.

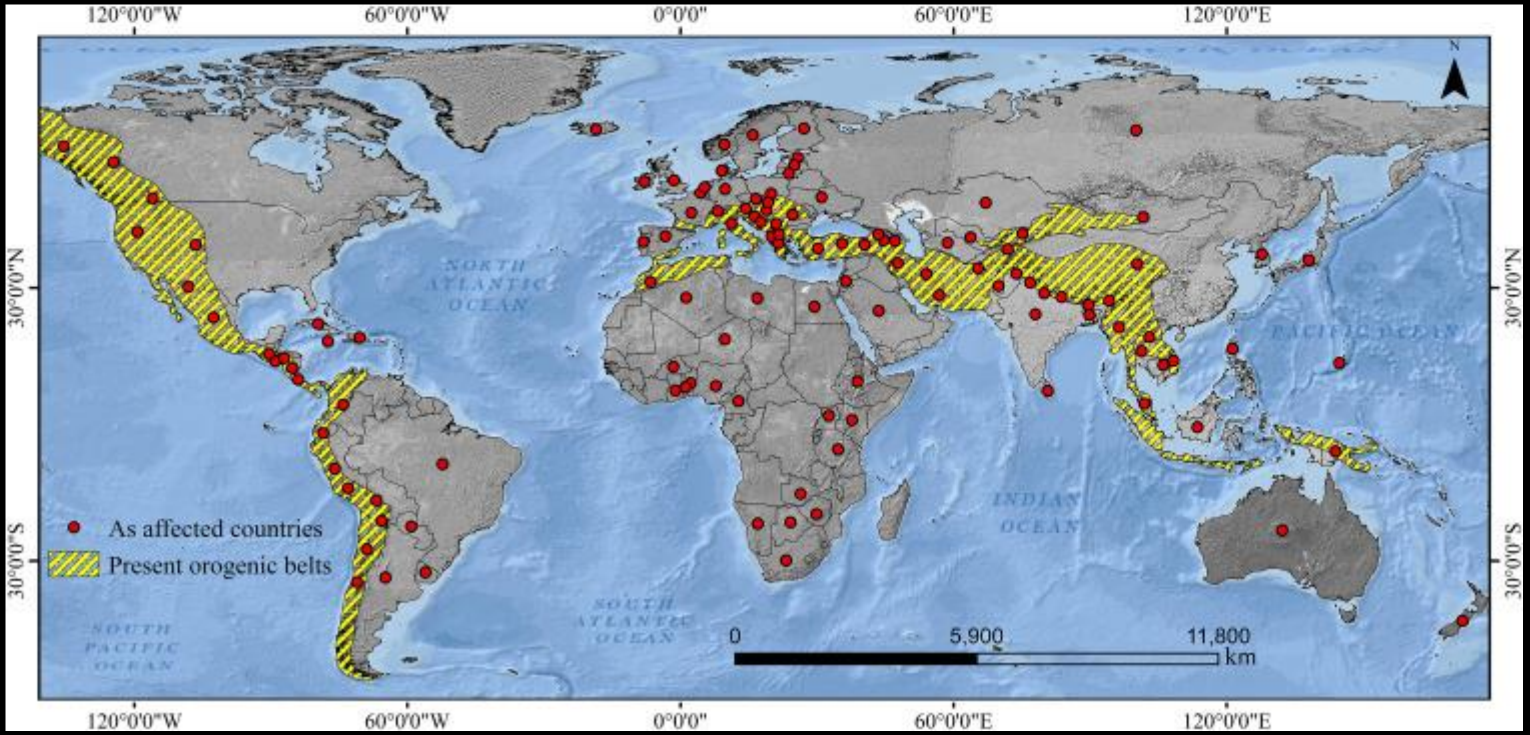
A 2009 study by the UN children's fund, Unicef, estimated that 35 percent of wells in Kandal province have toxic levels of arsenic.

Arsenic in Laos



https://doi.org/10.1038/ngeo254

Arsenic in groundwater was predicted from surface parameters in Southeast Asia

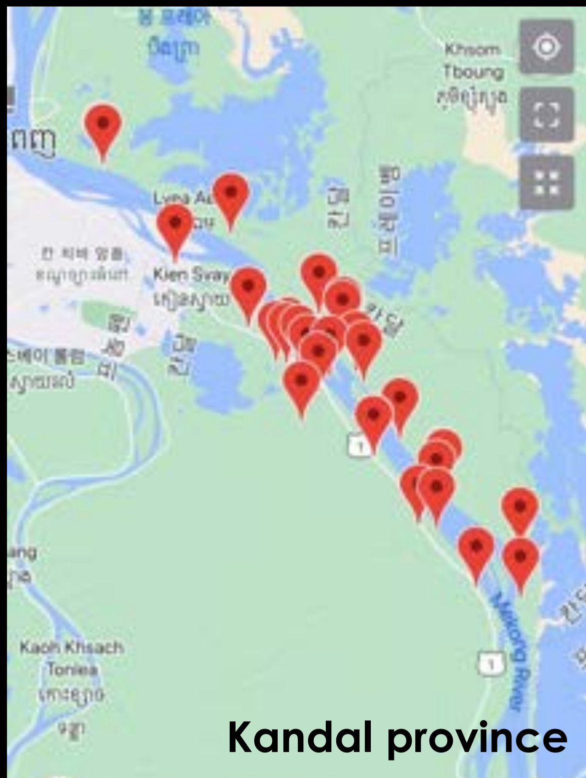


https://doi.org/10.1016/j.gsf.2020.08.015

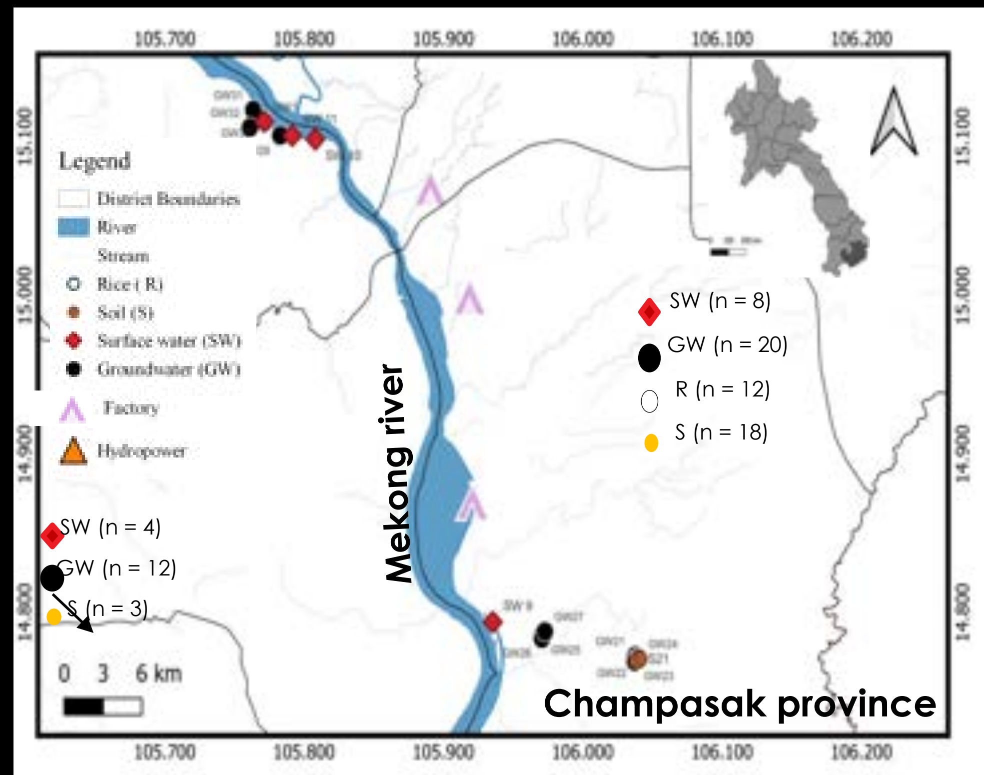
Arsenic contaminated regions superimposed on the tectonic map of the world. See that arsenic affected regions are mostly confined in the sedimentary basins _close to the modern mountain belts and deltaic areas.

To determine how the climate change phenomenon affect the arsenic geochemistry in Mekong river and its surrounding groundwater

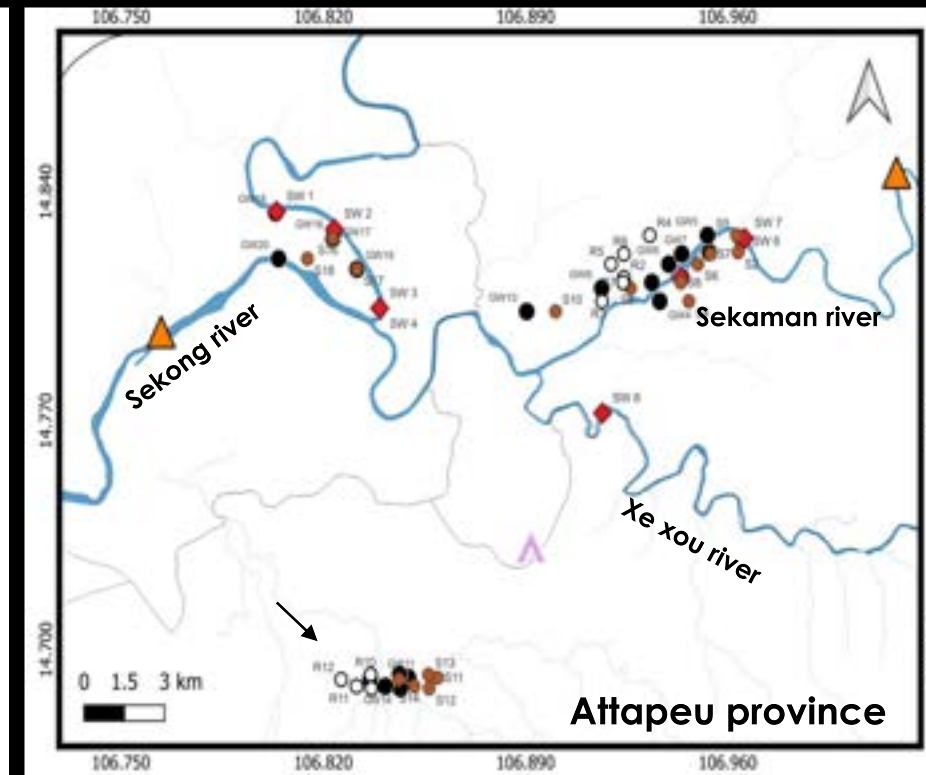
STUDY AREAS



May 2022



August 2022



August 2022

Tube well: 26,
Dug well: 1,
Rainwater: 3
Surface water: 7

Tube well: 12,
Surface water: 4

Tube well: 5,
Surface water: 4

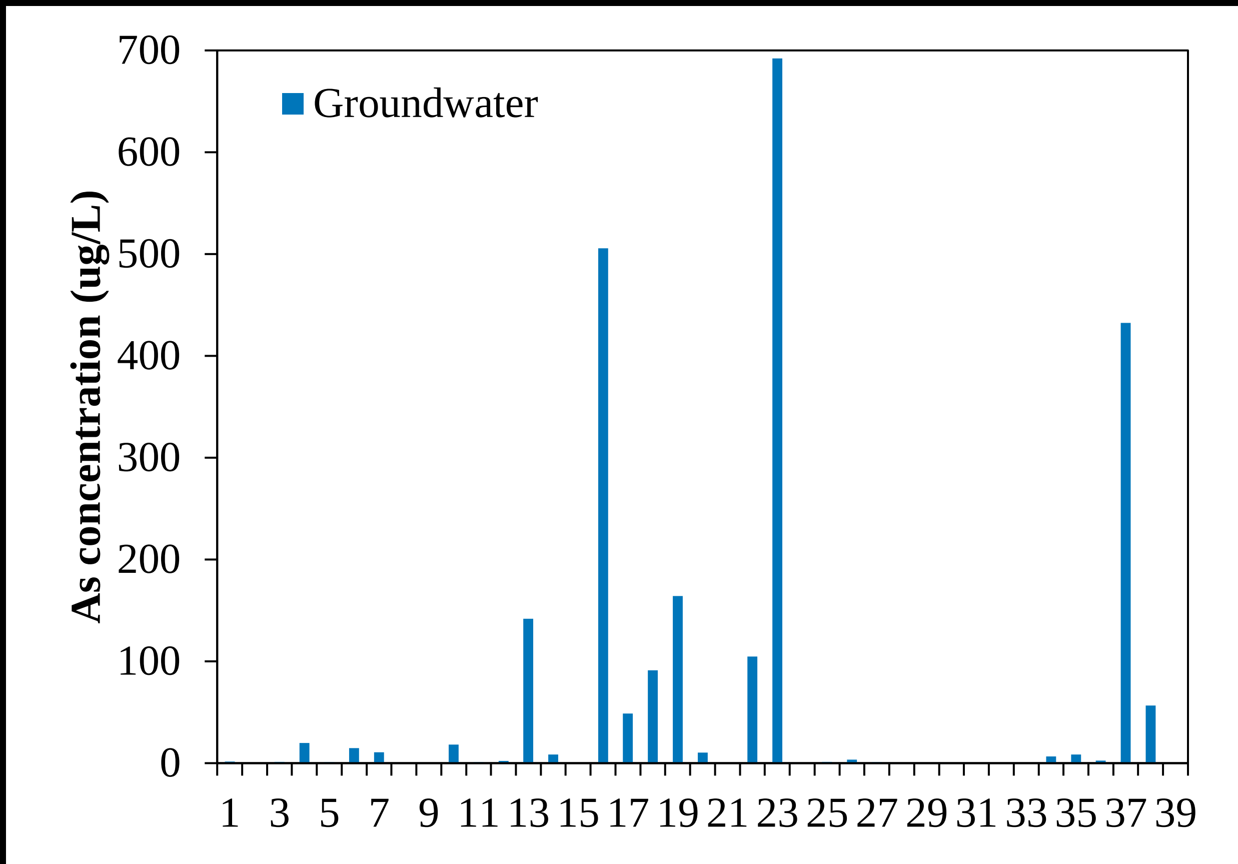
Cambodia sites

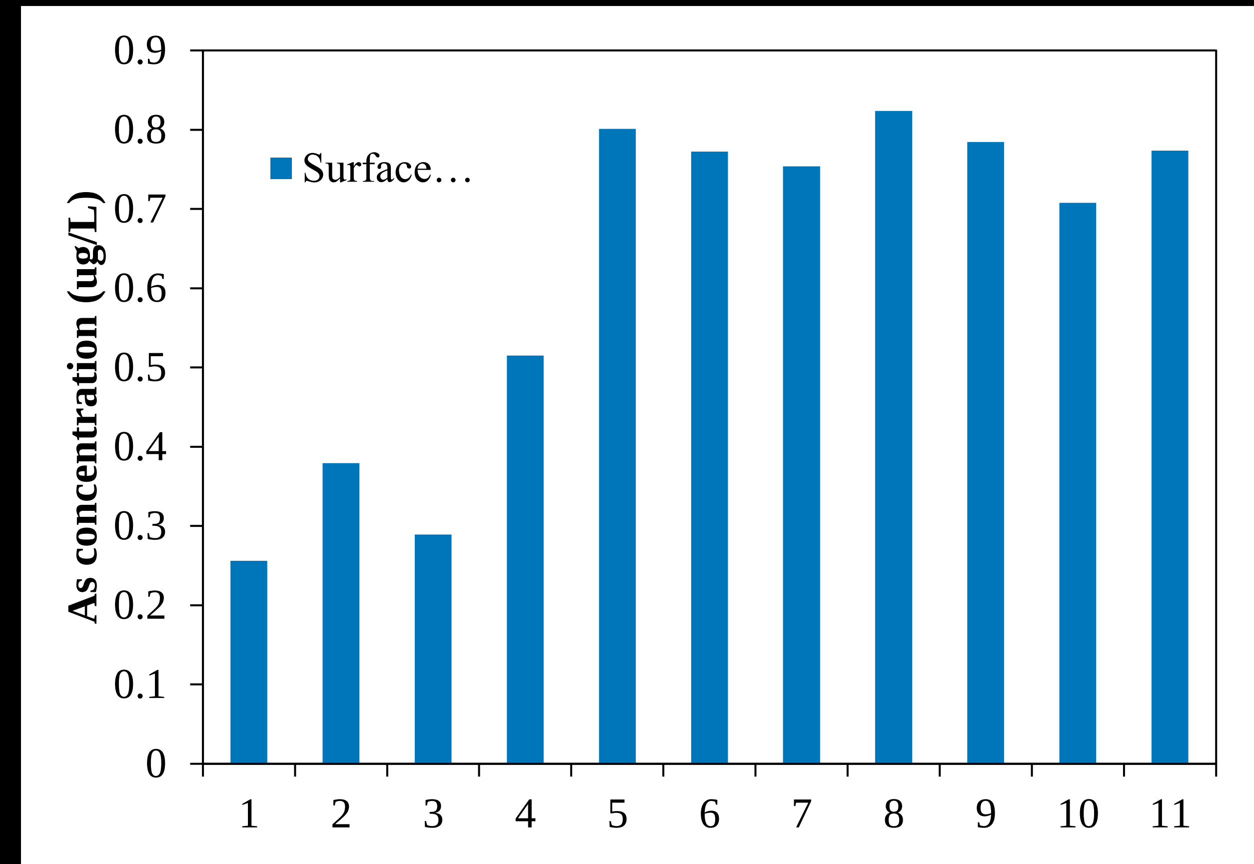
Laos sites

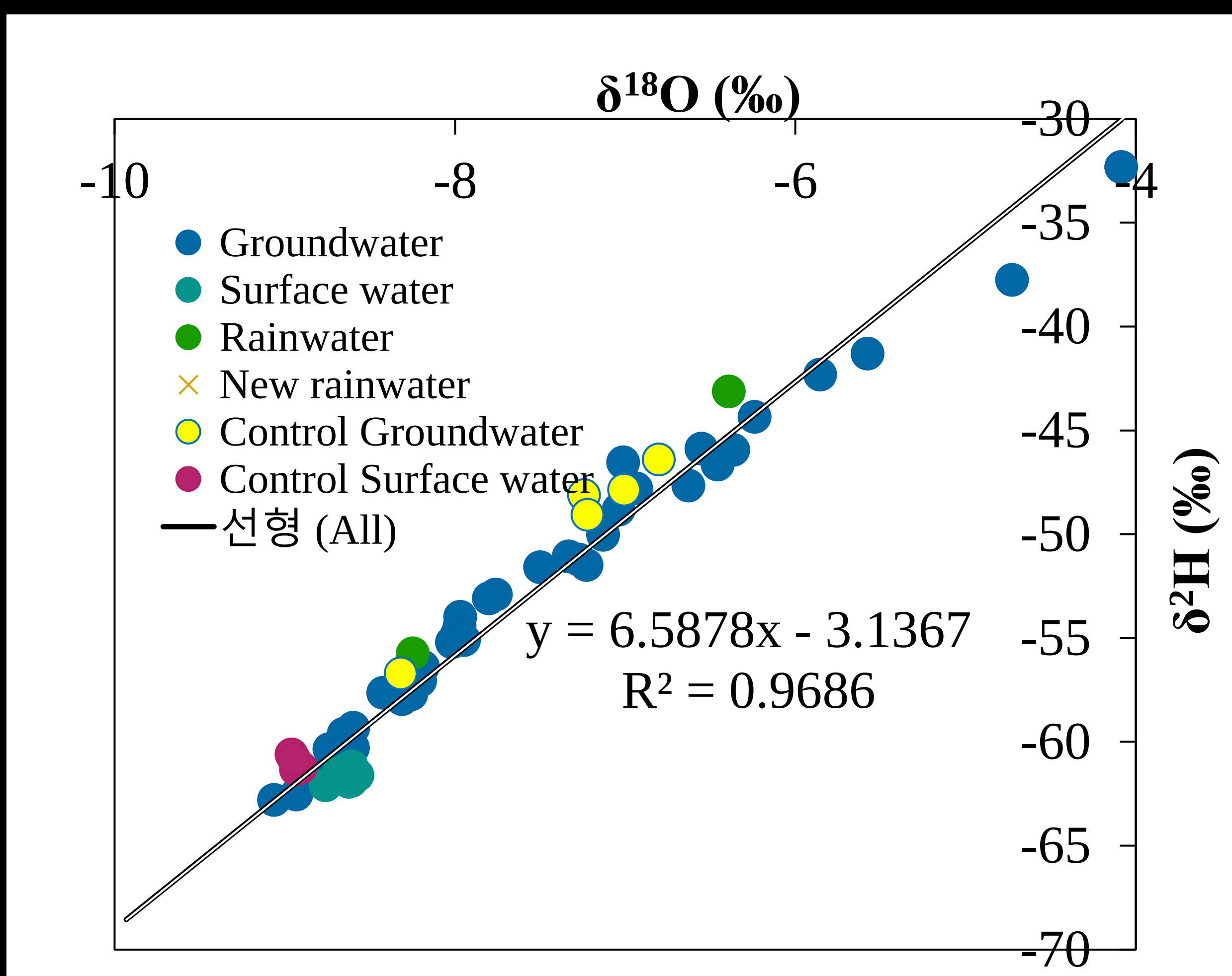
Control sites

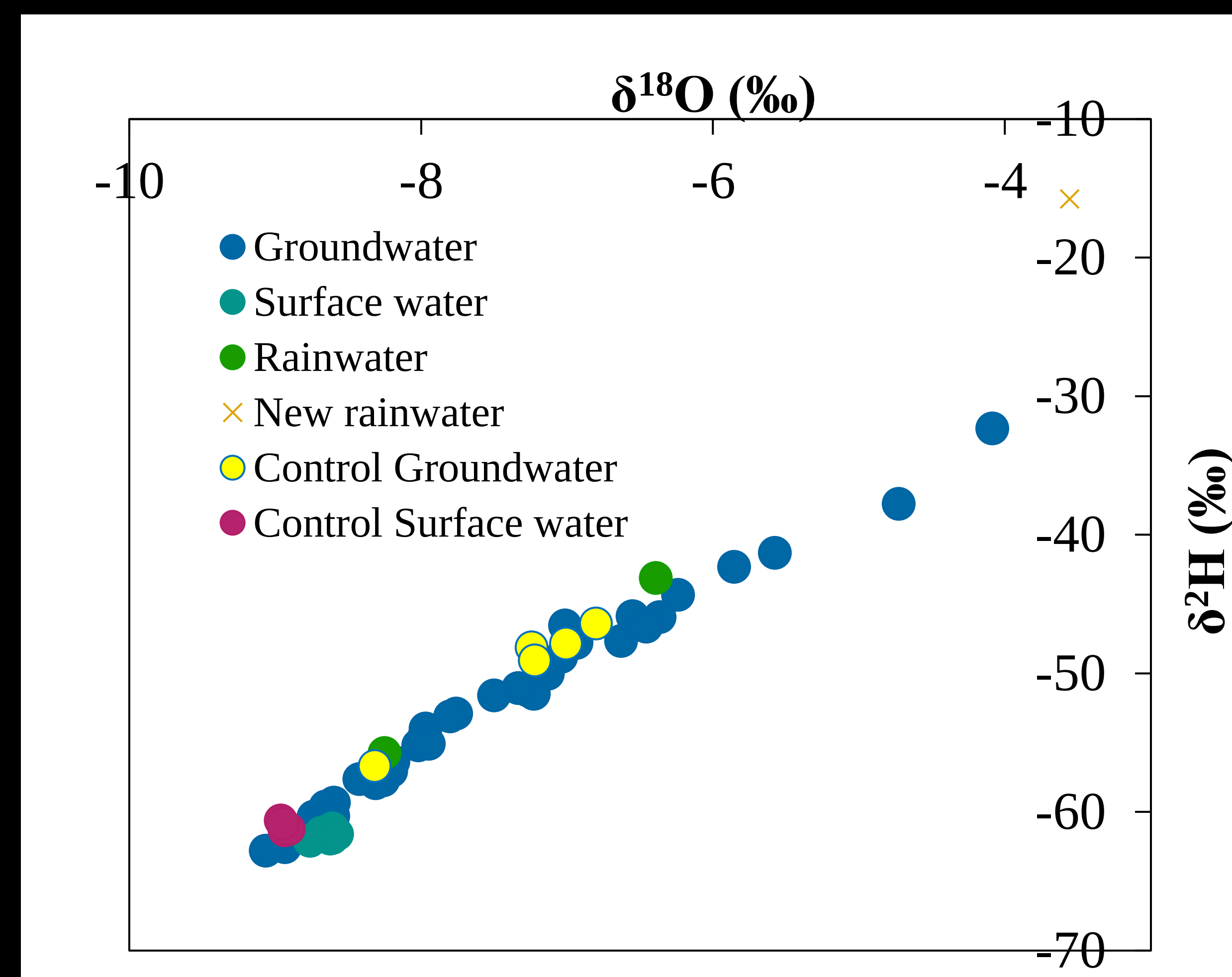
Preliminary results

	Water quality				
		Groundwater (n=39)		Surface water (n=11)	
Parameter	Unit	Mean	Range	Mean	Range
Depth	m	43	13 - 75	15	10 - 18
Temp	ºC	31.1	26.8 – 35.8	31.6	26.9 – 37.7
pH		7.0	5.7 – 7.8	7.5	6.5 – 8.0
EC	uS/cm	653.7	116.3 – 1787.0	140.7	57.7 – 212.5
DO	mg/L	4.1	1.9 – 5.6	6.2	5.4 – 7.1
TDS	mg/L	347.3	74.4 – 901.3	75.7	36.9 – 106.0
Salinity	ppt	0.2	0 – 0.5	0	0
Na^{+}	mg/L	30.8	6.0 – 88.5	7.6	2.1 – 9.6
NH_4^{-}	mg/L	4.0	0 – 28.1	2.7	0.3 – 3.3
K^{+}	mg/L	2.2	0.1 – 4.9	2.7	0.7 – 3.8
Ca^{2+}	mg/L	35.8	6.0 – 101.3	14.5	6.3 – 16.9
Mg^{2+}	mg/L	45.5	2.9 – 116.9	16.5	2.2 – 30.9
F^{-}	mg/L	1.1	0.1 – 2.0	0.8	0 – 1.2
Cl^{-}	mg/L	18.9	4.0 -100.5	15.4	1.5 – 22.1
NO_3^{-}	mg/L	4.6	0.9 – 10.5	7.9	1.0 – 24.8
SO_4^{2-}	mg/L	20.5	1.2 – 82.7	15.6	1.5 – 21.9


Groundwater
As concentration (ug/L)


Surface…
As concentration (ug/L)


δ18O (‰)
δ2H (‰)
Groundwater
Surface water
Rainwater
New rainwater
Control Groundwater
Control Surface water
선형 (All)
y = 6.5878x - 3.1367
R² = 0.9686


δ18O (‰)
δ2H (‰)
Groundwater
Surface water
Rainwater
New rainwater
Control Groundwater
Control Surface water

Sediment sampling

Summary

1. Groundwater shows high As concentration compared to surface water thus the As could have release from the sediment underlying which need to be determine in our future study.

2. The isotope data revealed that the correlation between the surface and groundwater of Mekong river.

3. Sediment and pore water samples data will be analysed.

Special thanks to Prof KW Kim and Prof Kongkea’s research team

Associated curriculum in GIST

Qualifying exam

Announcement for Qualifying Examination

1) Environmental Transport Phenomena
2) Environmental Chemistry
3) Environmental Microbiology
4) Your major subject

Associated curriculum in GIST

https://env1eng.gist.ac.kr/env1eng/sub01_01_04_02.do

Kim Gyeong-yeol

- Qualification : Ph.D
- Year of graduation : 2014

Q 1. Name of institution currently enrolled and assigned task

Assistant Professor of Environmental & Sustainable Engineering at University at Albany and State University of New York (SUNY). Conducting research to realize carbon neutrality in the future and solve the problem of clean water and energy depletion on Earth through environmental engineering. Also, striving to cultivate talented people who fit the new trend of environmental engineering.

Q 2. Relevance of what you studied in the School of Earth Sciences and Environmental Engineering and your current work

At the time of my admission (and now), the School of Earth Sciences and Environmental Engineering at GIST was conducting research in a variety of new environmental engineering fields that were incomparable to other universities. This environment has helped me think about my research area from different perspectives through interactions with other laboratories and is still helping me get a sense of new areas. The department's research-related infrastructure (facilities, equipment, devices, etc.) and accessibility have been at the highest level, and the experience I had has been a great help in carrying out various research tasks even after graduation.

Q 3. What you would like to tell students attending the School of Earth Sciences and Environmental Engineering

Although it's inconvenient, we can survive without a smartphone. However, without clean water and the Earth, we cannot survive. It is said that people do not value what they have until it is gone. If you do not realize the importance of the environment now, it will be too late to regret it at a later date. Although environmental engineering is not flashy, I want you to remember that it is currently the most precious science to mankind and to take pride in it to fulfill your dreams as a member of the School of Earth Science and Environmental Engineering at GIST.

Thank you for your attention!