Problems and research needs on Emerging Pollutants in urban waters of Sri Lanka

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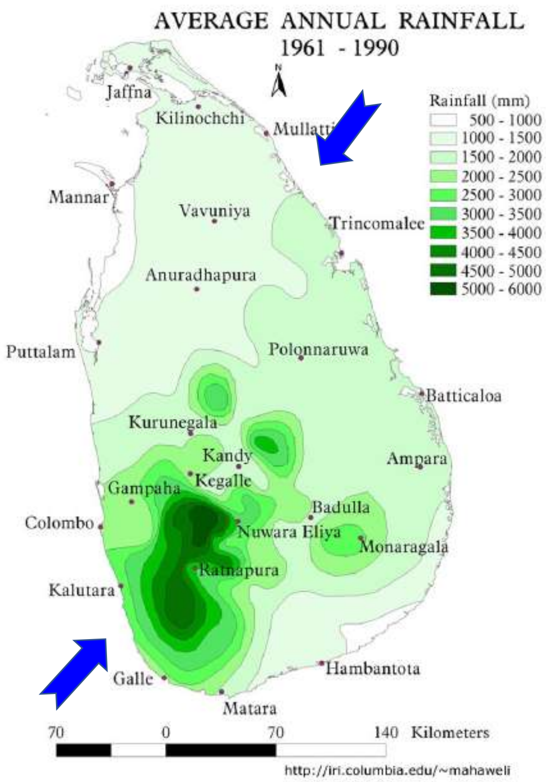
Climate in Sri Lanka

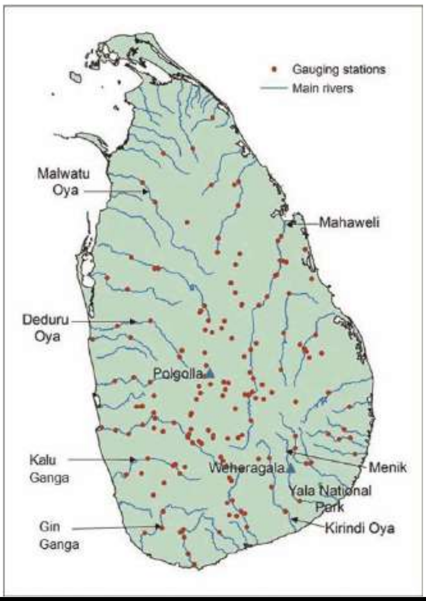
The island receives rain mainly through two monsoons.

The rainfall intensity varies markedly across the island (*Annual average rainfall: 2,000 mm*)



Water in Sri Lanka

- Water Resources
  - *No. of river basins: 103*
  - *Major reservoirs and dams: 80*
  - *Small tanks: 14,204*
  - *Small anicuts: 12,942*
- Land extent: 65,610 km^2
- Total volume of water: 131.22 bil. m^3
- Discharge to sea: **66.18 bil. m^3** (>50%)



Water Availablity:
2437 m^3 / per year / per capita

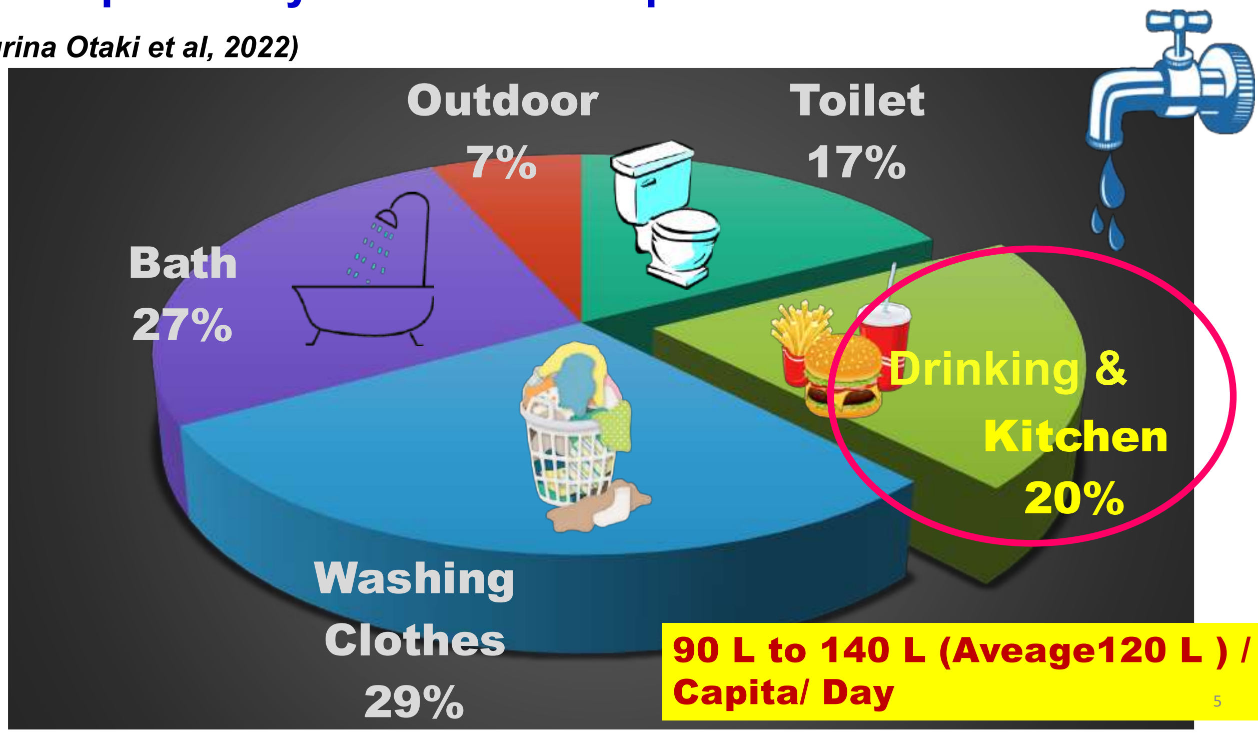
Only 45% of the population have access to piped water

Water problems in Sri Lanka :

- **Drinking water**
  - Quality
  - Guaranteed supply
  - Adequate pressure
  - Service restricted to urban areas only
- **Irrigation water**
  - Wastage
  - Irrigation efficiency
  - Water productivity
- **Water pollution**
  - Non-enforceable laws
  - Education and sense of responsibility
  - Lack of proper waste disposal mechanisms and facilities
- **Water governance**
  - Political
  - Institutional

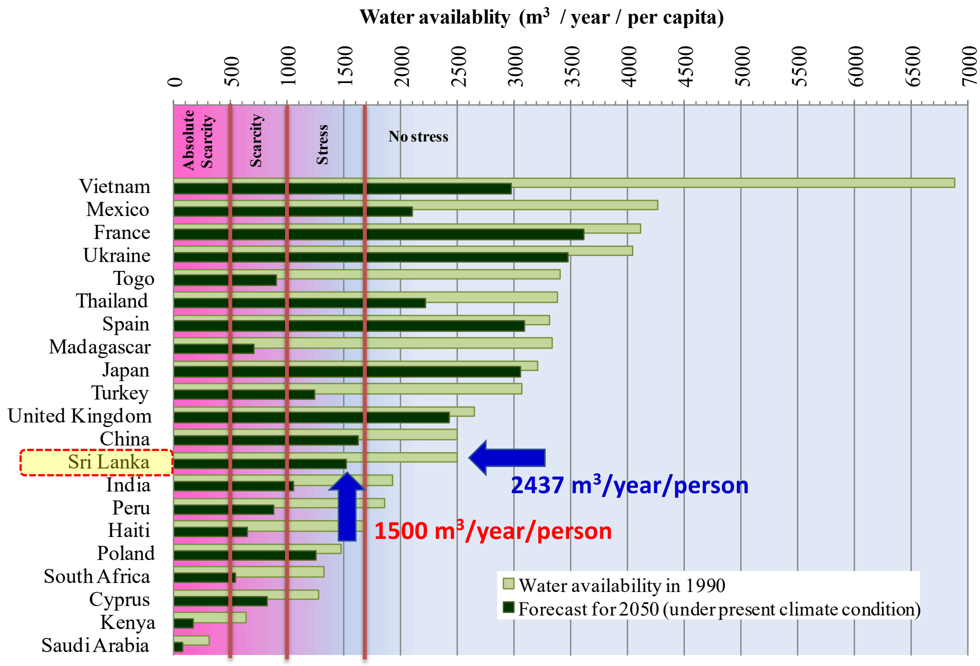
Per-capita Daily water consumption in Sri Lanka

(Yurina Otaki et al, 2022)



90 L to 140 L (Aveage120 L) / Capita/ Day

Forecast for water availability (m³/year/per capita) in 2050 for the present climatic conditions



(Modified by Chaminda, 2010, after report of the IPCC (1995) cited in K. D. Frederick and d. C. Major, 1997)

Climate change and increased water demand through population growth / rapid urbanization have significantly impacted on freshwater resources

Impact on freshwater resources

SUSTAINABLE DEVELOPMENT GOALS

Reused water or alternative waters are increasingly recognised as a potential 'new' source of clean water for potable and non-potable uses, resulting in social, environmental and economic benefits…..

SUSTAINABLE DEVELOPMENT GOALS

Emerging pollutants can be understood in a broad sense as any synthetic or naturally-occurring chemical or any microorganism that is not commonly monitored or regulated in the environment with potentially known or suspected adverse ecological and human health effects.

Target 6.1: *Achieve universal and equitable access to* ***safe and affordable drinking water for all***

Target 6.3: *Improve water quality by* ***reducing pollution***

(Source: UNESCO Project on "Emerging Pollutants in Wastewater Reuse in Developing Countries")

Emerging pollutants are addressed under the following 2030 Agenda's of SD goals and targets:

Target 1.4

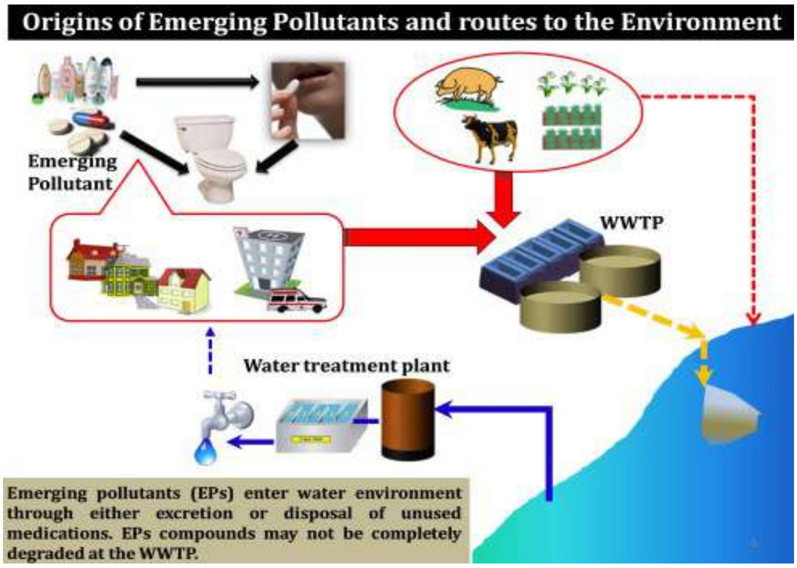
Target 3.3

Target 3.9

Target 12.4

Target 15.1

Contaminants of Emerging Concern :



Source:
Tushara Chaminda, et al., 2018

Derived from 3 broad categories:

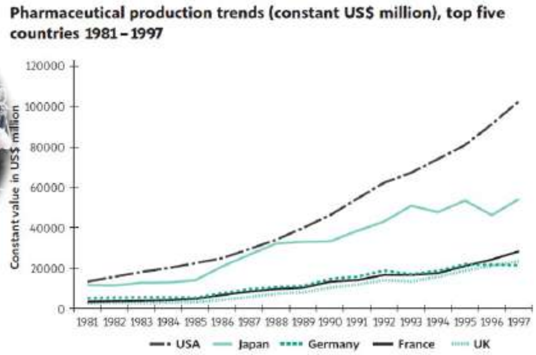
- ***Pharmaceuticals (PhACs)***
- ***Personal Care Products (PCPs)***
- ***Endocrine Disrupting Compounds (EDCs)***

Chemicals that had not previously been detected (or lesser concentrations) are discovered in the water supply are known as "contaminants of emerging concern" or simply "emerging contaminants." Emerging contaminants are important because the risk they pose to human health and the environment is not yet fully understood

Pharmaceuticals and Personal Care Products (PPCPs)

Pharmaceuticals

Products used by individuals for personal health or agribusiness to enhance growth or health of livestock. The global consumption of drugs used by humans >100,000 metric tons per year



(Source: WHO, 2004)

Personal care products

Products used by individuals for personal care or cosmetic reasons (Fragrances , Cosmetics , Sun-screen products , Shampoo, Insect repellents, etc)

PPCPs . . .

❖Persistence:

The physicochemical properties of PPCPs, means that many are not easily removed by conventional water treatment process

❖ Bioaccumulation

Although PPCPs are available in aquatic environment at relatively low concentrations, many of them and their metabolites are biologically active and can impact non-target aquatic organisms, especially fish.

❖ Toxicity

The major concern about the toxic implications of pharmaceuticals is that they were designed specifically to maximise their biological activity at low doses and to target certain metabolic, enzymatic, or cell-signalling mechanisms.

Antibiotic Resistance Bacteria

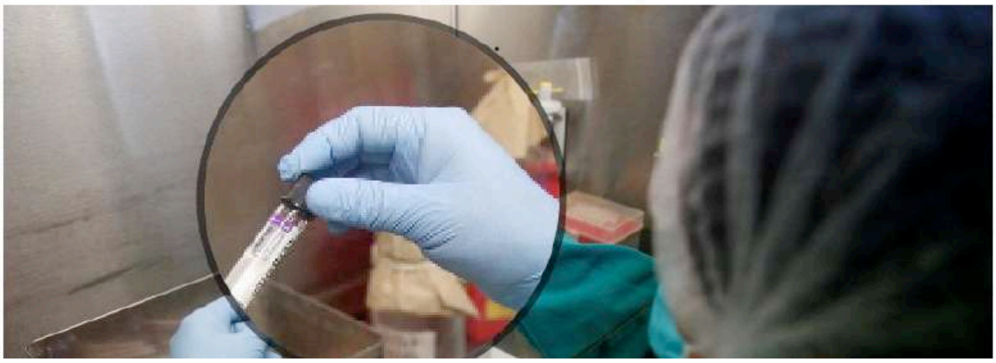
HEALTHCARE & PHARMA   MARCH 23, 2017 / 5:24 AM / UPDATED 4 YEARS AGO

Rise of superbug tuberculosis hampers global control efforts

By Kate Kelland

REUTERS®

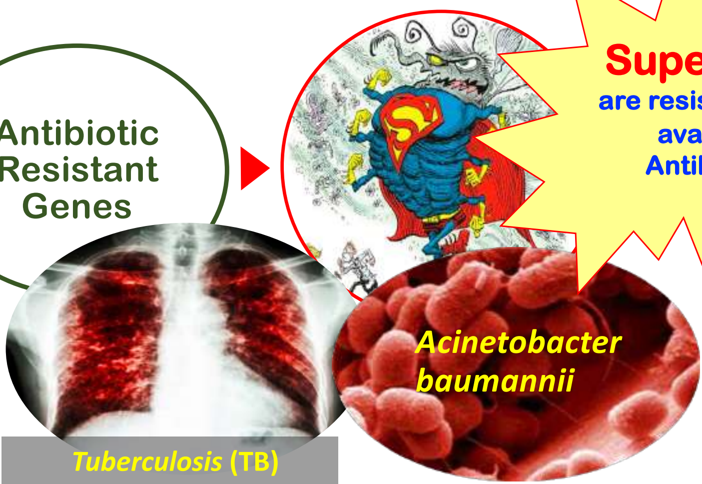
London (Reuters) - Rising rates of superbug tuberculosis (TB) are threatening to derail decades of progress against the contagious disease, experts said on Thursday, and new drugs powerful enough to treat them are few and far between.



PPCPs → Antibiotics

Most significant fact is the possible Antibiotic Resistance. Antibiotic resistance occurs When the antibiotic becomes no longer capable of controlling or preventing bacterial growth

Bacteria exposed to antibiotics → Antibiotic Resistant Genes →



Superbugs are resistant to all available Antibiotics

PPCPs as an emerging contaminants in urban waters, Sri Lanka

Colloborative Research with *Ochanomizu University* and *Hitotsubashi University*

- ✓ **Ground water** : **19 samples (Galle)**
- ✓ **Surface water** : **6 samples (Galle)**
- ✓ **STP (Influent)** : **2 sample**
- ✓ **STP (effluent)** : **2 sample**

STP influent

STP effluent

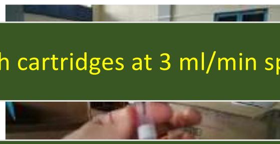
Surface water

Ground Water

Occurrence of PPCPs in Urban Waters of Sri Lanka

Methodology ….

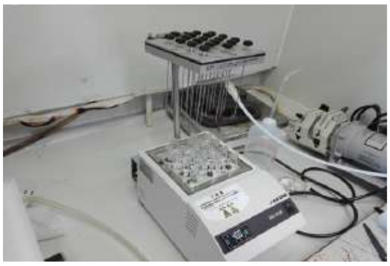
1. Spiked 0.2ml Surrogate standards and keep it 1 hour.
2. Conditioned cartridges using 4ml of MeOH and 4ml Mili Q.
3. Samples were passed through cartridges at 3 ml/min speed.
4. Cartridges were washed using 4 ml Mili Q after filtration.
5. Kept 30 minute for fully dryness. Sealed until further studies.



Colloborative Research with *Ochanomizu University and Hitotsubashi University*

Methodology ....

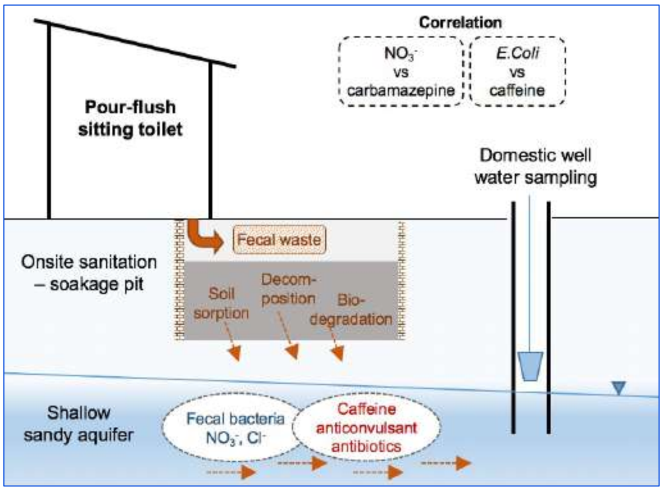
6. Eluted the cartridges with 6 ml of MeOH.
7. The Elute was evaporated using Nitrogen evaporator. (40 °C).
8. Internal standard vortex mixing was spiked.
9. Conditioned the LC/MS spectrometer.
10. The final analysis was done by using LC/MS spectrometer.

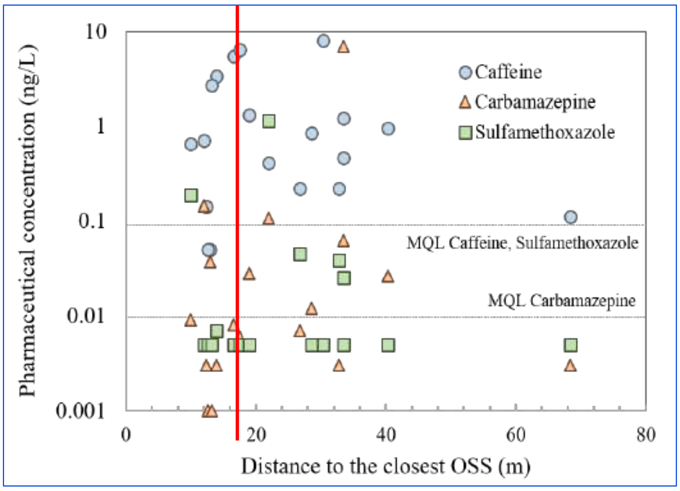


High Performance Liquid Chromatography - Mass Spectrometry

Maximum value (ng/L) of analyzed pharmaceuticals in 19 domestic wells in comparison to previous studies (Quyen et al, 2021)

	This study (Sri Lanka)	DF	(Schaider *et al.*, 2014) (Cape Cod USA)	(Phillips *et al.*, 2015) (New York, USA)
Caffeine	7.9	89%	< 10 (MRL)	n.d
Carbamazepine	6.9	42%	72	79
Sulfamethoxazole	1.1	10%	113	n.d
Acetaminophen	n.d	n.a	n.a	n.d
Atenolol	n.d	n.a	0.8	n.d
Cotinine	n.d	n.a	1_c	24
Sufapyridine	n.d	n.a	n.a	n.a
OSS type	Soakage pits		Conventional septic systems	Cesspools
Research setting	19 shallow drinking wells laterite aquifer,		20 shallow wells, sand gravel aquifer	2 temporary wells, 1 monitoring well, surficial sandy aquifer
# analytes detected	3/7		9/45	14/103





- Presence of PPCPs in well (Ground) waters indicated the vulnerability of the drinking groundwater source to fecal contaminants from the outdated sanitation system. A setback distance >18 m is unlikely to protect groundwater from OSSs contamination.
- We observed that *E.Coli* and total coliform had a significant positive correlation with **Caffeine** concentration in groundwater.
- Occurrence of the persistent pollutants, such as Carbamazepine and Sulfamethoxazole indicated the extent of pollutant transport from OSSs.

Concentration ranges and means (g/L) for wastewater compounds in urban STP influent and hospital effluent and three previous studies (Quyen et al, 2021).

Target Compounds	IQL [a] µg/L	STP Influent – This Study – Range	STP Influent – This Study – Mean	STP Influent – Previous Studies – Influent	Hospital Wastewater – This Study – Effluent – Range	Hospital Wastewater – This Study – Effluent – Mean	Hospital Wastewater – Previous Studies – Influent (Mean/Median Value)	Hospital Wastewater – Previous Studies – Effluent (Mean/Median Value)
ACT	0.15	29.7–44.3	39.0	116.0 [a] 77.7 [b]	70.2–123.6	92.8	813.5 [a]	0.04 [a]
CAF	0.15	16.2–68.7	49.1	35.2 [b]	12.5–23.7	16.6	28.2 [c]	0.35 [c]
CBZ	0.003	0.07–0.24	0.13	0.53 [a] 0.37 [b]	0.44–0.60	0.50	0.3 [a] 0.08 [c]	0.63 [a] 0.015 [c]
COT	0.1	1.9–2.2	1.9	n.a.	1.36–2.35	1.86	n.a.	n.a.
SFM	0.1	0.1–0.2	0.17	0.5 [a] 0.01–0.1 [d]	2.20–2.96	2.58	3.9 [a] 1.4 [c] 0.1–1 [d]	0.81 [a] 0.21 [c] 0.001–0.01 [d]
SFP	0.1	0.38–0.47	0.44	0.072–1 [d]	2.05–2.32	2.18	0.01–0.1 [d]	bql [d]
ATE	0.15	0.19–0.48	0.30	2.4 [a]	0.54–1.11	0.79	3.2 [a]	0.019 [a]
ACS	0.15	8.2–10.6	9.0	11.5 [b]	0.98–2.0	1.43	n.a.	n.a.

[a] Urban WWTP in France with a flow rate of 5355 m^3 day^{-1}; hospital with 450 beds, n = 27 [22]; [b] WWTP in Singapore, n = 16 [23]; [c] Ioannina Hospital in Greece, 800 beds, flow rate 550 m^3 day^{-1}, n = 32 [24]; [d] 24 h composite sample of two urban WWTPs in Netherland; hospital with an on-site pharmafilter process including a membrane bioreactor, ozonation, granulated activated carbon, and UV treatment [25]. n.a.: not available; bql: below quantification limit; * CM: concentration magnitude; ACT: acetaminophen; CAF: caffeine; CBZ: carbamazepine; COT: cotinine; SFM: sulfamethoxazole; SFP: sulfapyridine; ATE: atenolol; ACS: acesulfame.

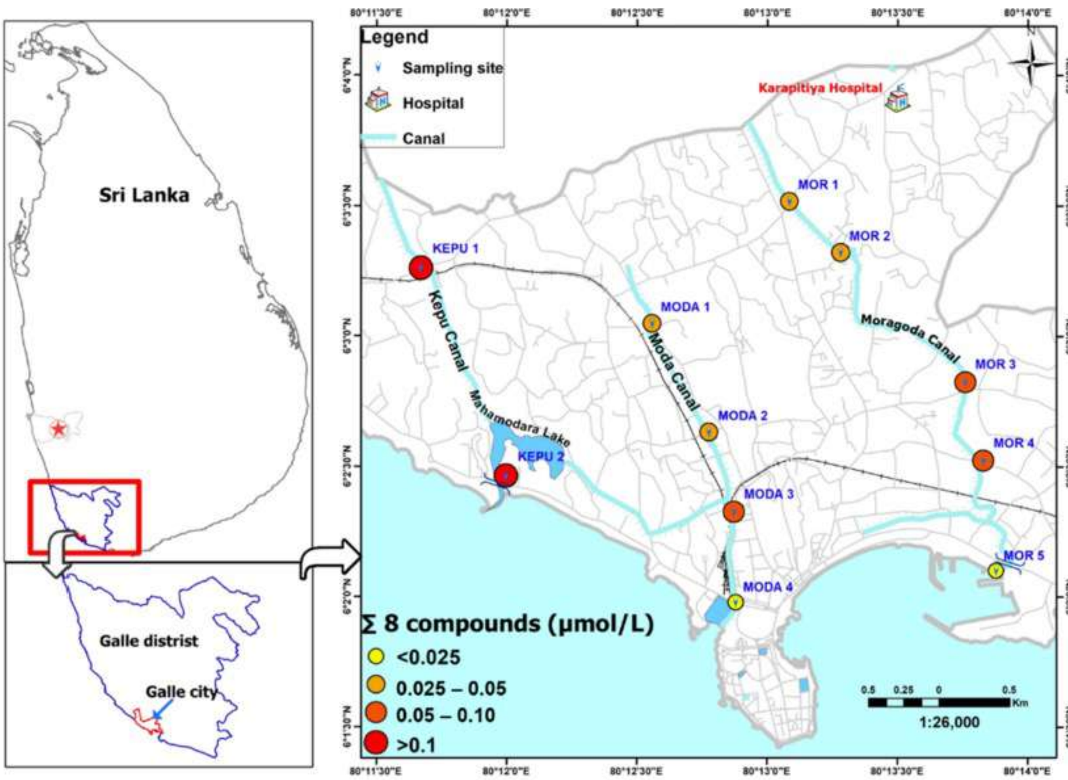
Marker	Category	Persistency	Excretion Rate (%)	Potential Pathway	Hospital Discharge CM **	Urban Sewage CM
ACS	Artificial sweetener	Y	>99 [32]	B, G	<10	60
ACT	Antipyretic	N	<5 [33]	B	625	260
ATE	Beta-blocker	Y	50 [34]	B	<10	<10
CAF	Stimulant	N	<5 [35]	G	111	327
CBZ	Neuroactive drugs	Y	<1 [36]	B	167	43
COT	Tobacco metabolite	Y	13 * [37]	B	21	21
SFM	Antibiotic	Y	<20 [38]	B	29	<10
SFP	Antibiotic	Y	<2 [39]	B	24	<10

CAF indicates the magnitude of graywater loading at each sampling site.

ACT indicates the impact of untreated human excretion over short distances.

ACS indicates the general impact of domestic wastewater (both black and gray) on surface water.

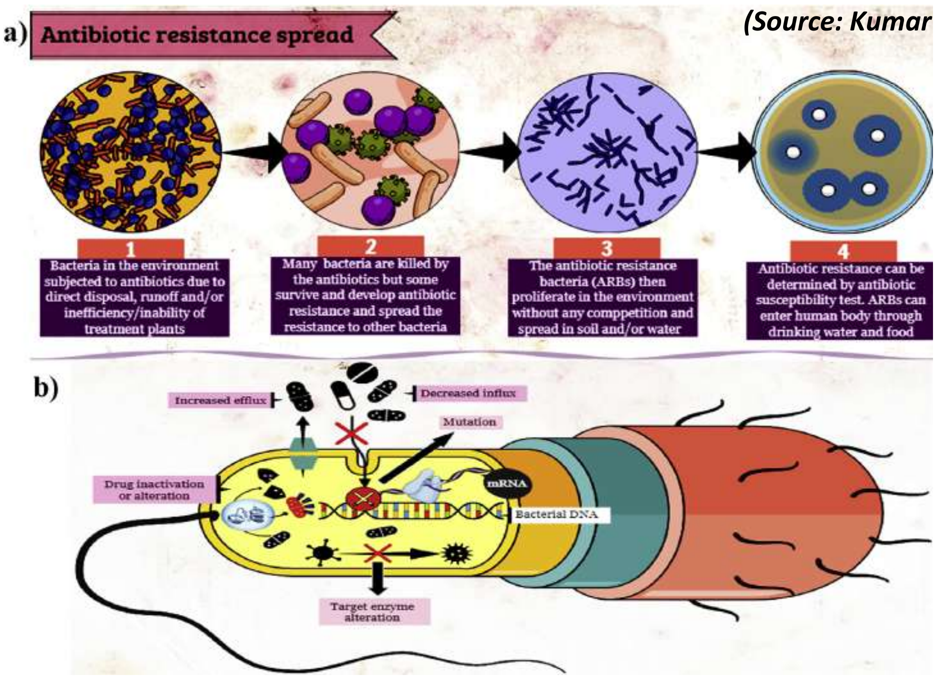
CBZ indicates the presence of hospital residues over long distances.



- Despite their high concentrations in raw wastewater, up to 99% of CAF (124 µg/L) and ACT (24 µg/L) was removed by the STP
- Consideration of the magnitude, persistency, and metabolism rates of eight target sewage markers in urban wastewater (including black water, greywater, and hospital wastewater) suggests that CAF is useful for understanding the magnitude of greywater discharge.
- Presence of labile ACT is evidence of the mixing of raw black water in surface water.
- Treated hospital wastewater included trace amounts of active pharmaceutical ingredients that could contribute to surface water pollutants. The use of persistent indicators, such as CBZ, to identify hospital wastewater discharges into the drainage network proved useful.

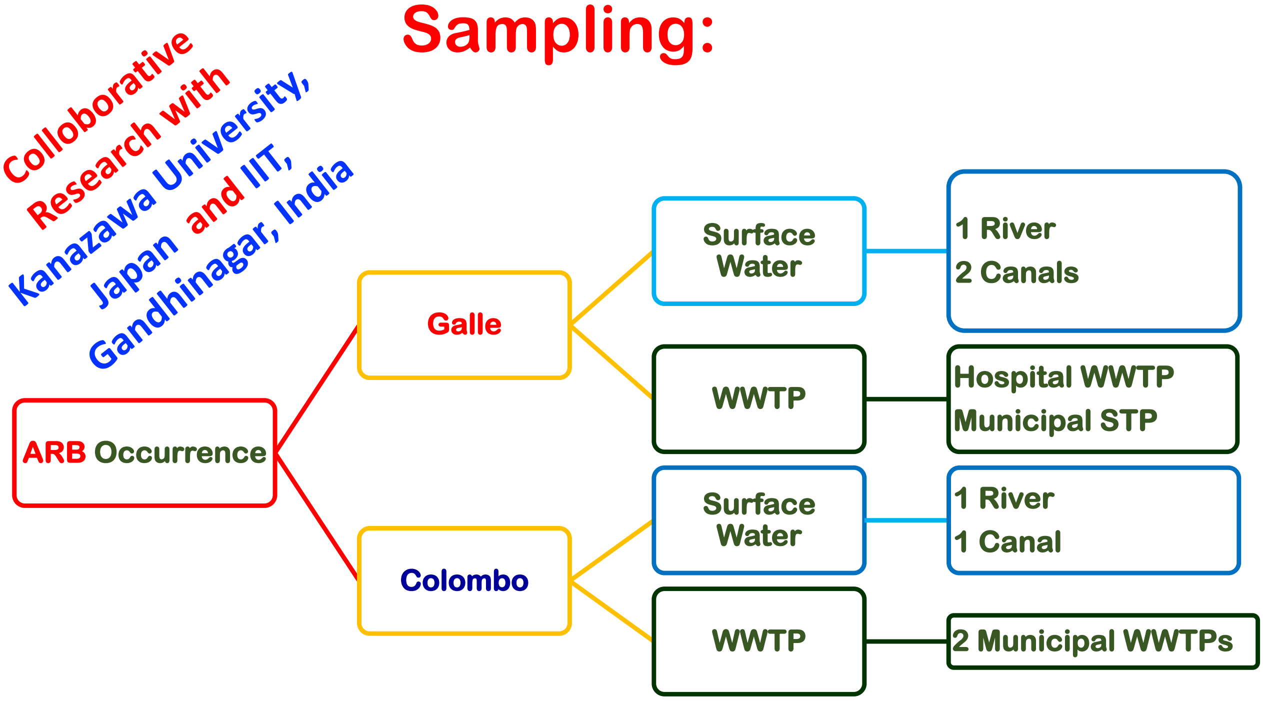
Schematic flow diagram representing antibiotic-resistance dissemination in the environment and within the bacteria

(Source: Kumar et al, 2020)



Antibiotic Resistance Bacteria (ARB)

Sampling:



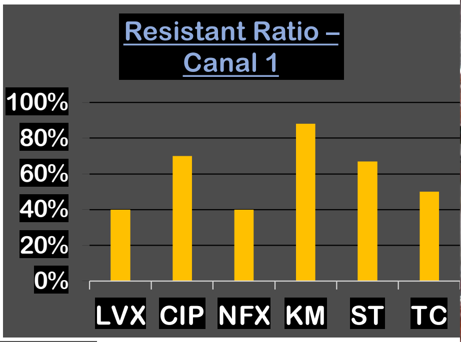
Experimental procedure

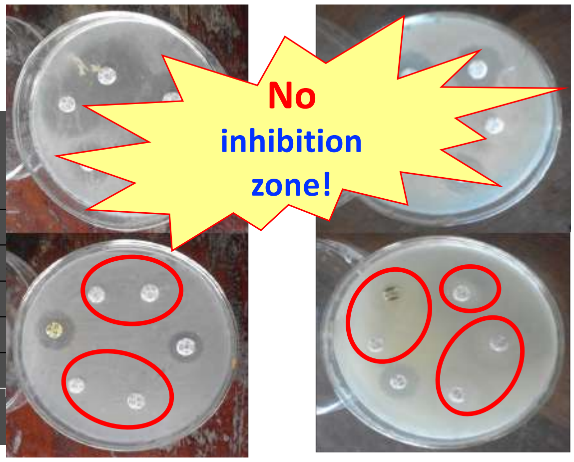
Based on Standard Operating Procedures Antibiotic-resistance test for *E.coli* in water samples (*R. Honda, et al, 2016*).

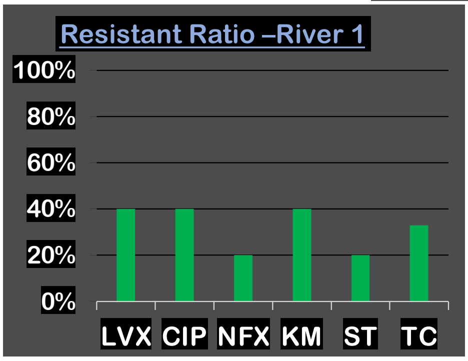
$$\text{Resistant ratio} = \frac{\text{no. of resistant colonies}}{\text{no. of isolated colonies}}$$

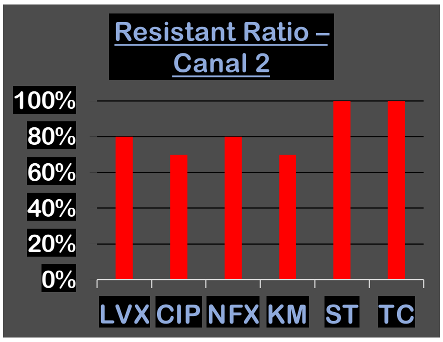
KB Disc	Diameter of inhibition circle (mm)		
	Resistant	Intermediate	Sensitive
Kanamycin Monosulphate (KM)	=<13	14-17	>=18
Tetracycline (TC)	=<11	12-14	>=15
Norfloxacin (NFX)	=<12	13-16	>=17
Ciprofloxacin (CIP)	=<15	16-20	>=21
Levofloxacin (LVX)	=<13	14-16	>=17
Sulfamethoxazole (ST)	=<10	11-15	>=16

Surface water – Galle, Sri Lanka

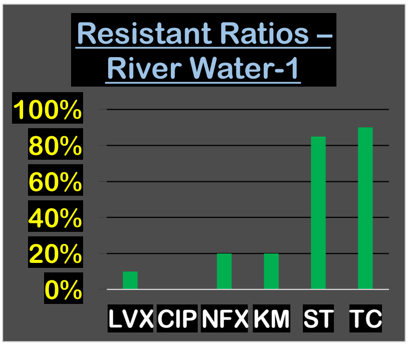


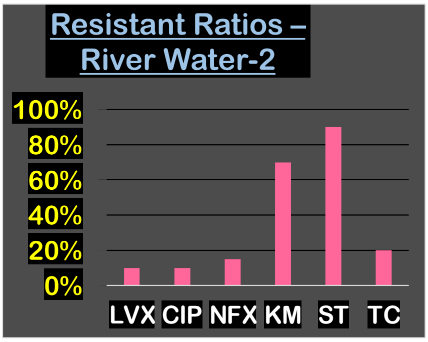


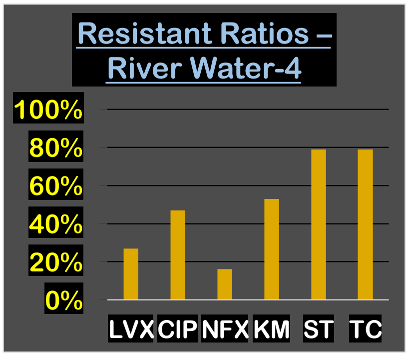




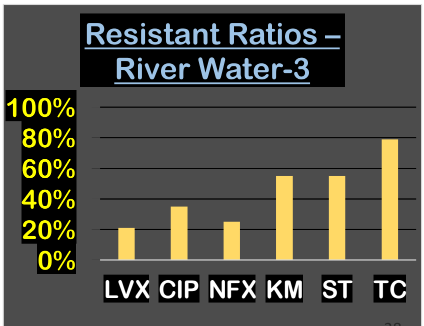
Surface water – Colombo, Sri Lanka



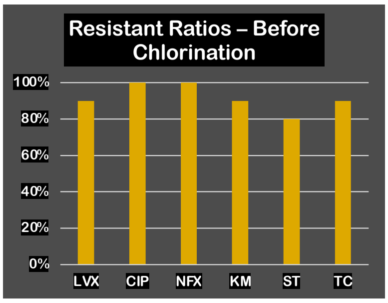


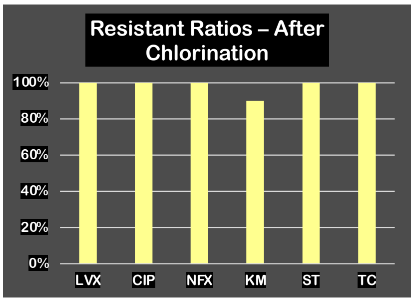


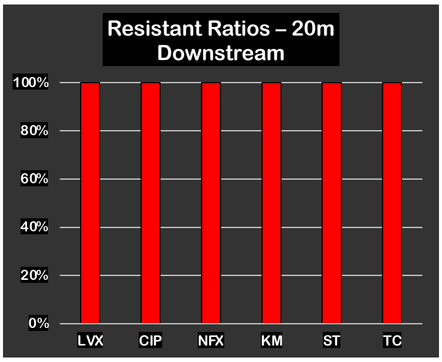
- LVX, CIP and NFX resistant ratio increased when moving downstream
- ST and TC having higher resistant ratio

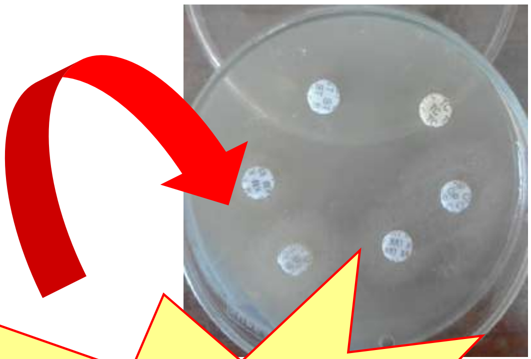


Wastewater – Galle, Sri Lanka





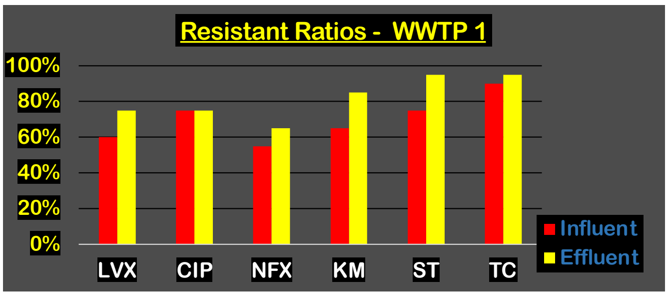


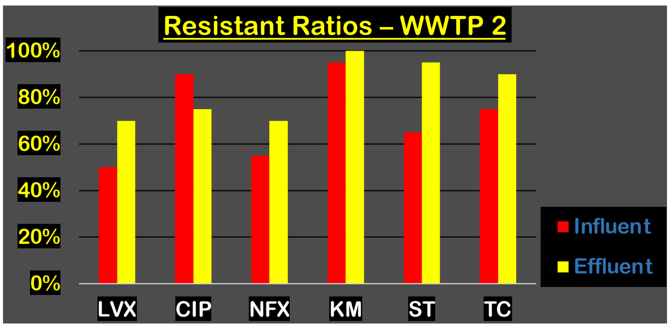


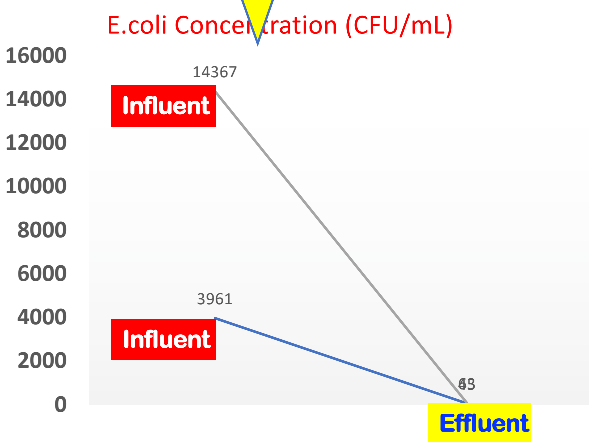
NO inhibition zone for all antibiotics

Wastewater – Colombo, Sri Lanka

E.Coli has reduced but Not the resistance







Conclusions :

- 43 PPCPs were detected in Urban Waters (Surface, WW, Groundwater)
- A setback distance >18 m is unlikely to protect groundwater from OSSs contamination.
- We observed that *E.Coli* and total coliform had a significant positive correlation with Caffeine concentration in groundwater.
- Despite their high concentrations in raw wastewater, up to 99% of CAF (124 µg/L) and ACT (24 µg/L) was removed by the STP
- Presence of labile ACT is evidence of the mixing of raw black water in surface water

- All sampling points subjected to Antibiotic Resistance Test had colonies resistance to more than one antibiotic category.
- Municipal canals having higher resistive bacteria than major rivers
- WWTP effluents contain higher resistant colonies than influents.
- It was observed that 100% resistance for all the 6 AB in a canal where 20m downstream to the discharge point of Hospital WWTP

- E. coli prevalence was reduced during treatment, but the remaining bacteria can adapt in the presence of antibiotics and lead to a further increase in resistance.
- E. coli strains of all the locations exhibited multidrug resistance implying some health concern in the near future
- The hospital WWTP had more resistance than the municipal WWTPs due to a higher concentration of antibiotics and less dilution.
- We found higher resistance to old generation antibiotics like tetracycline (TC), and sulfamethoxazole (ST)

Future directions :

- Treatments need to be developed and implemented to control antibiotic concentrations in wastewater and surface water.
- Continuous monitoring of the river and tributaries for emerging pollution loads (PPCPS, etc), as on-going assessments are required for management.
- Provide proper waste collection systems (including used medicines).
- Develop strict rules and policies for industrial, hospital and municipal wastewater discharge backed with robust local community effecting monitoring and implementation.

Colloborative Research with Japan and India

2019

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Treatment enhances the prevalence of antibiotic-resistant bacteria and antibiotic resistance genes in the wastewater of Sri Lanka, and India

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Prevalence of antibiotic resistance in the tropical rivers of Sri Lanka and India

Manish Kumar[a,*], Sulfikar[b], Tushara Chaminda[c], Arbind K. Patel[a], Himaya Sewwandi[c], Payal Mazumder[d], Madhvi Joshi[e], Ryo Honda[f]

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Seasonality impels the antibiotic resistance in Kelani River of the emerging economy of Sri Lanka

Manish Kumar[1], G. G. Tushara Chaminda[2] and Ryo Honda[3]

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Environmental Chemistry

Pharmaceutical Contaminants in Shallow Groundwater and Their Implication for Poor Sanitation Facilities in Low-Income Countries

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water 2021 MDPI

Article

Sewage Markers as Determinants to Differentiate Origins of Emerging Organic Pollutants in an Urban Sri Lankan Water Drainage Network

Do Thi Thuy Quyen [1,2,*], Otaki Masahiro [3], Yurina Otaki [4] and Tushara Chaminda [5]

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EDITORIAL

Occurrence and Spread of Emerging Organic Pollutants and Antibiotic Resistance in Urban Waters of Sri Lanka

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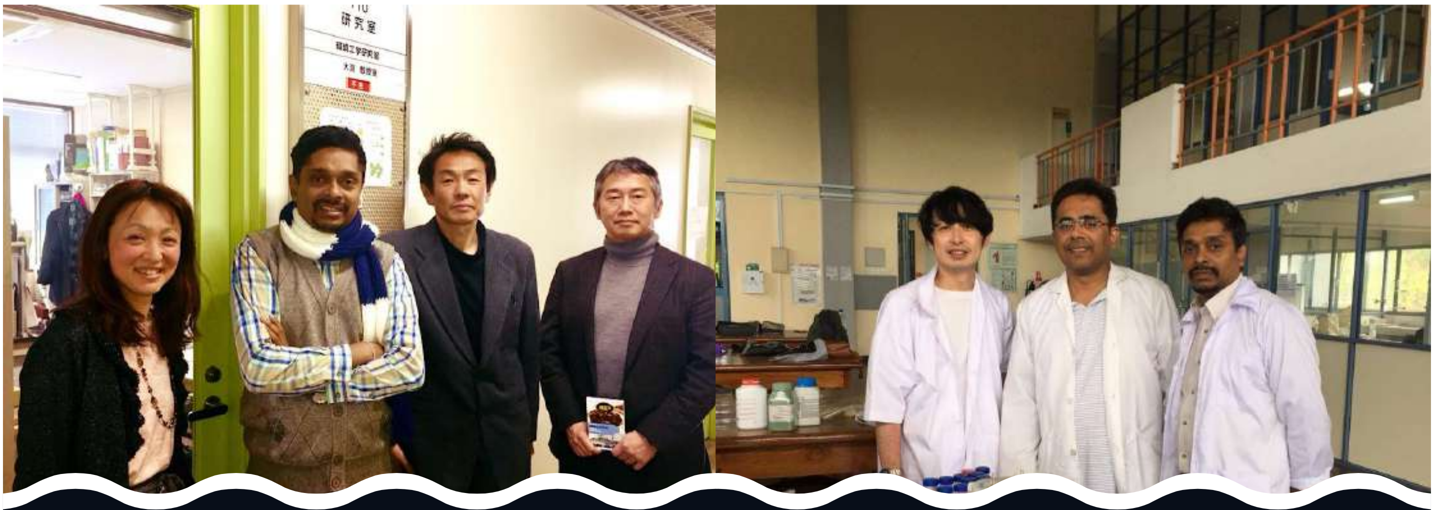
Abstract: Emerging pollutants such as Pharmaceuticals and Personal Care Products (PPCPs) in water resources are now considered a global water quality issue. Concerns associated with the presence of PPCPs in the environment include abnormal physiological processes and reproductive impairment, increased cancer incidence, the development of antibiotic-resistant bacteria, and the potential for increased toxicity of chemical mixtures. However, the number of studies on PPCPs in the aquatic environment and their use in wastewater tracking in developing countries, such as Sri Lanka, remains limited. Consequently, during the last five years, we have conducted various research to establish the comparative occurrence of PPCPs and antibiotics in urban waters in Sri Lanka. Our studies detected around 20 PPCPs in urban waters in Sri Lanka. Acetaminophen was



Research Collaborators:

37

Future Water Management in Sri Lanka - National Level :

Natural Pollution

(Mn, Fe, F, Hardness, etc.)

Safety of Water

Manmade Pollution

(Agrochemicals, Industrial discharges, Heavy metals, Organic pollutants, PPCPs, and Other Micropollutants, etc)

Water sharing

Resources

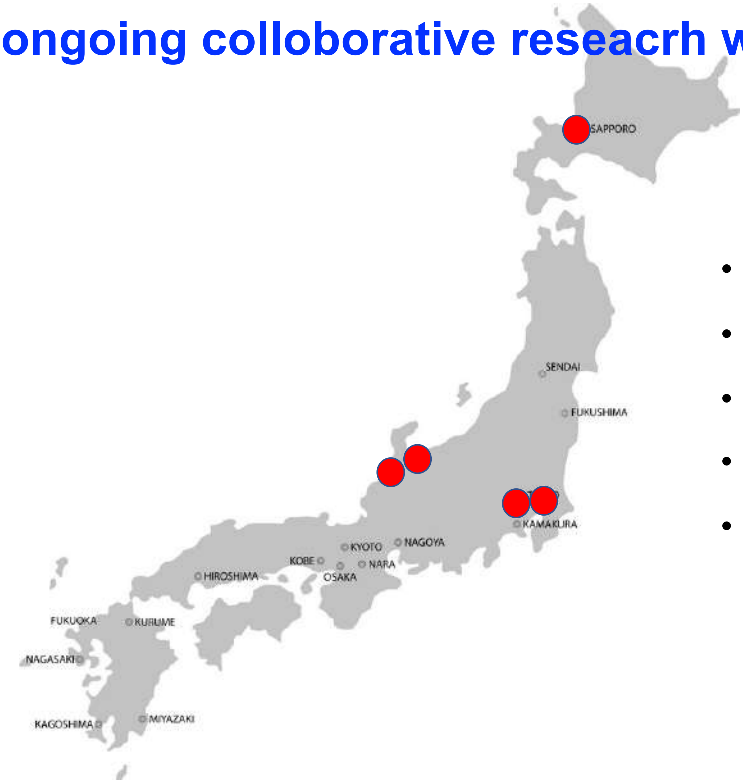
Security of Water

Climate Change

Lack of policies

38

My ongoing colloborative reseacrh with Japan



- ***Ochanomizu University***
- ***Hitotsubashi University***
- ***Kanazawa University***
- ***Toyama Prefectural University***
- ***Hokkaido University***

Our Publications related to obove researches :

- Sewage Markers as Determinants to Differentiate Origins of Emerging Organic Pollutants in an Urban Sri Lankan Water Drainage Network
  https://www.mdpi.com/2073-4441/13/20/2898

- Pharmaceutical Contaminants in Shallow Groundwater and Their Implication for Poor Sanitation Facilities in Low-Income Countries
  https://doi.org/10.1002/etc.5110

- Occurrence and Spread of Emerging Organic Pollutants and Antibiotic Resistance in Urban Waters of Sri Lanka
  http://doi.org/10.4038/jur.v9i1.7989

- Treatment enhances the prevalence of antibiotic-resistant bacteria and antibiotic resistance genes in the wastewater of Sri Lanka, and India
  https://doi.org/10.1016/j.envres.2020.109179

- Hygiene risk of waterborne pathogenic viruses in rural communities using onsite sanitation systems and shallow dug wells
  https://doi.org/10.1016/j.scitotenv.2020.141775

- A Review on Antibiotic Resistance Gene (ARG) Occurrence and Detection in WWTP in Ishikawa, Japan and Colombo, Sri Lanka
  https://link.springer.com/chapter/10.1007/978-981-32-9771-5_1

- Vulnerability of urban waters to emerging contaminants in India and Sri Lanka: Resilience framework and strategy
  https://www.apn-gcr.org/bulletin/article/vulnerability-of-urban-waters-to-emerging-contaminants-in-india-and-sri-lanka-resilience-framework-and-strategy/

AYUBOWAN

May all living-beings live long

ありがとう
ございました

Thank
You！