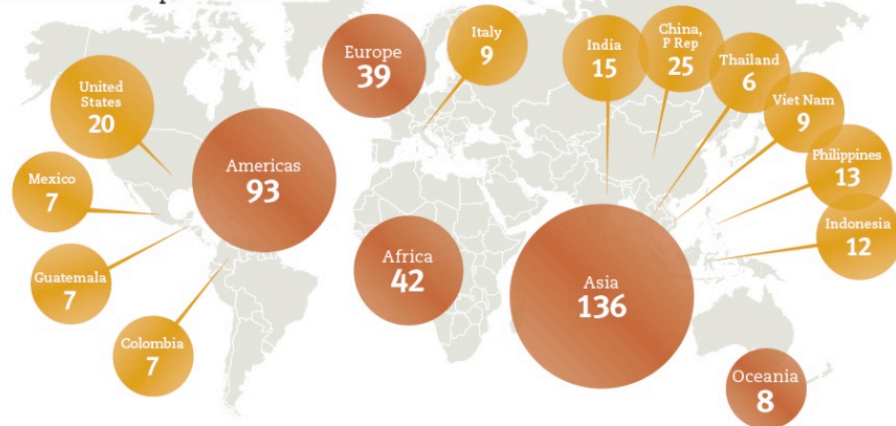


# OCCURRENCE OF NATURAL DISASTERS

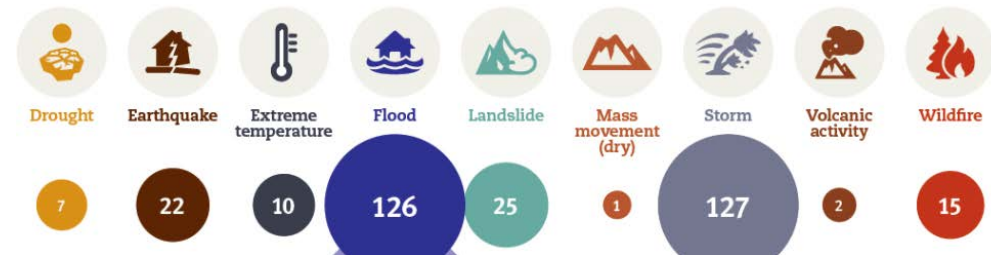
- US has been ranked **No.2** among the hardest hit countries by natural disasters

- No. of disaster occurrence in 2017**

Number of disasters by continent and top 10 countries



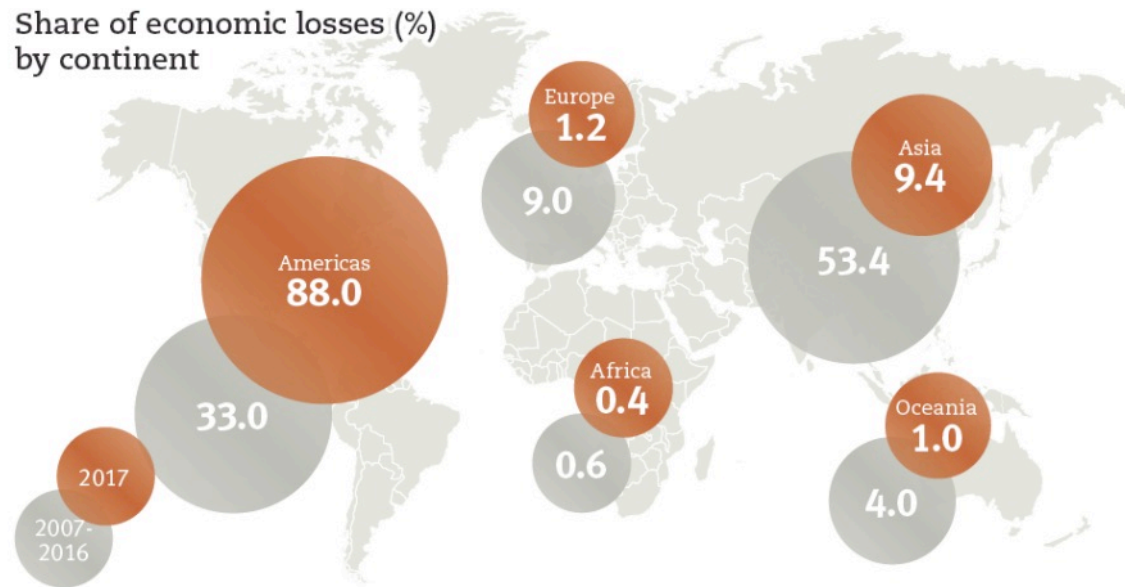
- Disaster types in 2017**








# ECONOMIC LOSS

- Americas had the most economic damage from natural disasters in 2017.

Share of economic losses (%)  
by continent



- Top 5 economic loss**

 USA	Hurricane Harvey	95 billion
 USA & Caribbean	Hurricane Irma	80.7 billion
 USA & Caribbean	Hurricane Maria	69.7 billion
 USA	Wildfire	13 billion
 China, Vietnam, Macao & Hong Kong	Typhoon Hato	7.1 billion

Economic loss by continent  
(total loss: **\$334 billions** in 2017)



# IN THE AFTERMATH OF DISASTERS

## Basic demands

- Food
- **Water**
- Medicine
- ...

## Water for:

- Drinking
- Food preparation
- Domestic hygiene
  
- At least **15 L/person · day**



# 3 HOUSEHOLD EWTs (FEMA)

- Boiling
- Chlorination
- Distillation

Food and  
Water in an  
Emergency

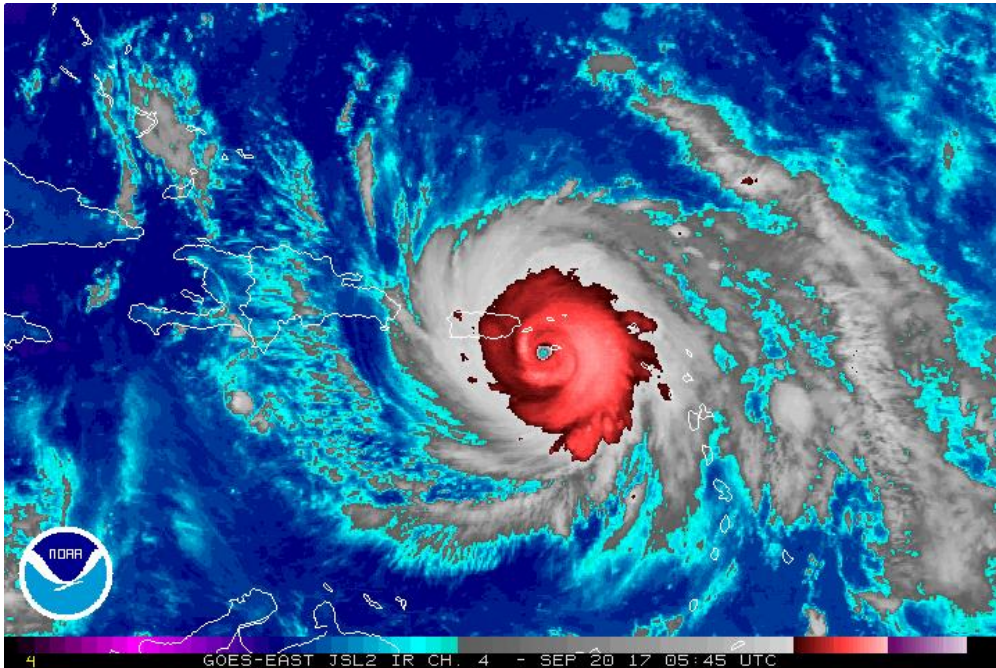


- Are they feasible and technically effective ?



# WATER CRISIS IN THE AFTERMATH OF HURRICANE MARIA IN PUERTO RICO

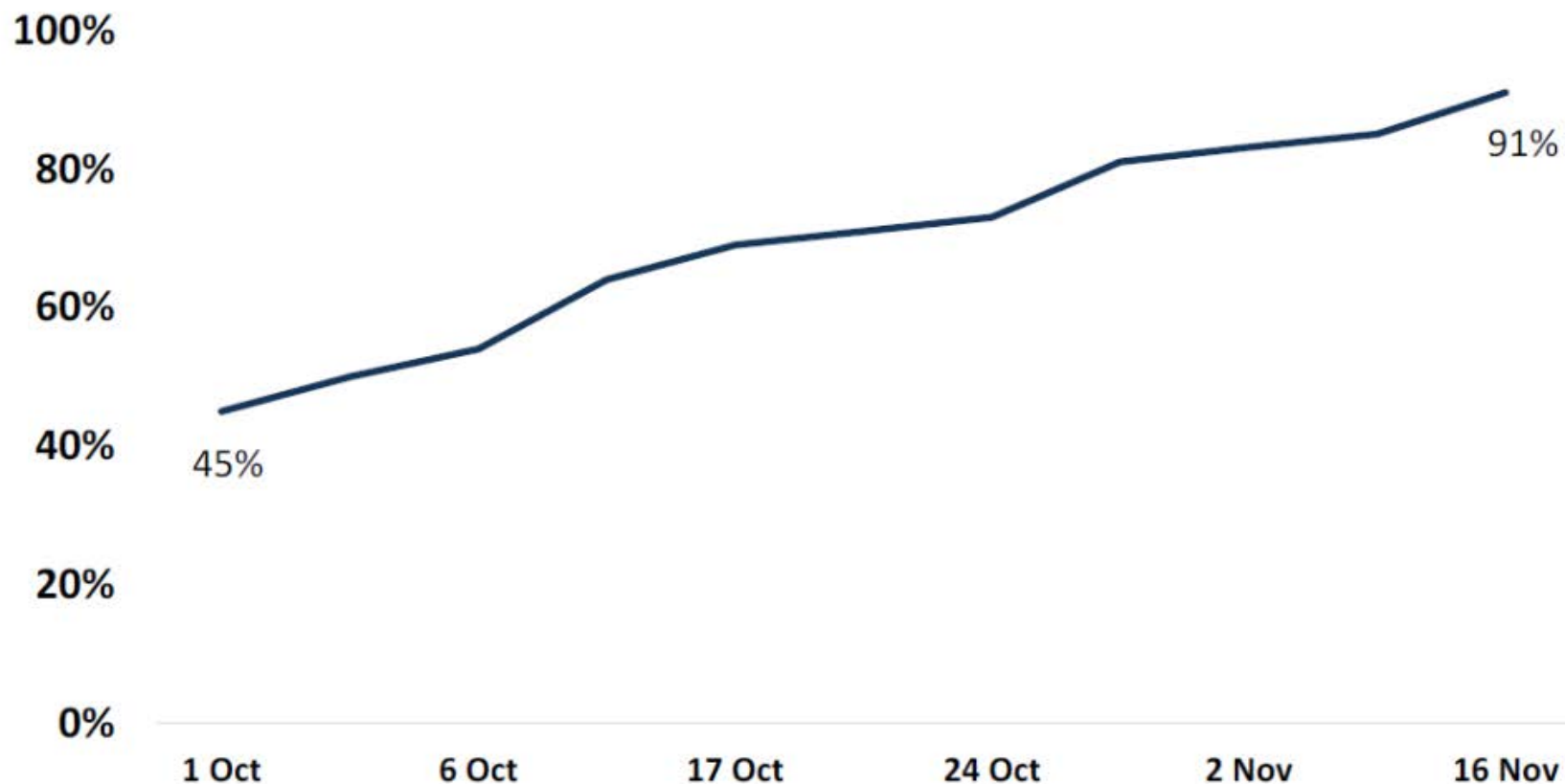
- Hurricane Maria hit Puerto Rico (09/20/17)
- Category 4
- 50% more residents (3.6 million) had no water immediately



# WATER ACCESS IN THE AFTERMATH OF HURRICANE MARIA IN PUERTO RICO

Figure 1

## Percent of Puerto Rico's Population with Access to Potable Water, October 1 – November 16, 2017



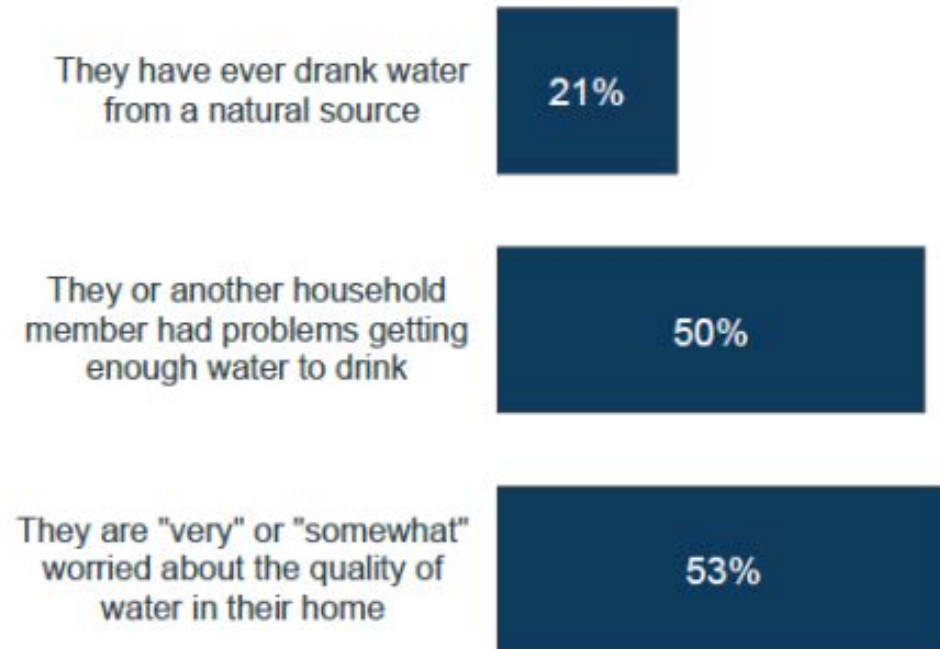
Data reported in FEMA Daily Briefing Reports on Hurricane Response and Puerto Rico Water Authority statistics as reported on <http://status.pr>.



Figure 5

## Half Say They Had Problems Getting Enough Water To Drink After The Storm, Some Drank From Natural Sources

AMONG PUERTO RICO RESIDENTS: Percent who say, since Hurricane Maria, they have experienced each of the following:



SOURCE: Washington Post/Kaiser Family Foundation Survey of Puerto Rico Residents (July 3-August 29, 2018)



# WATER IN PR... AFTER HURRICANE MARIA





# CHALLENGES FROM PR IN THE AFTERMATH OF HURRICANE MARIA

**Power supplies...**

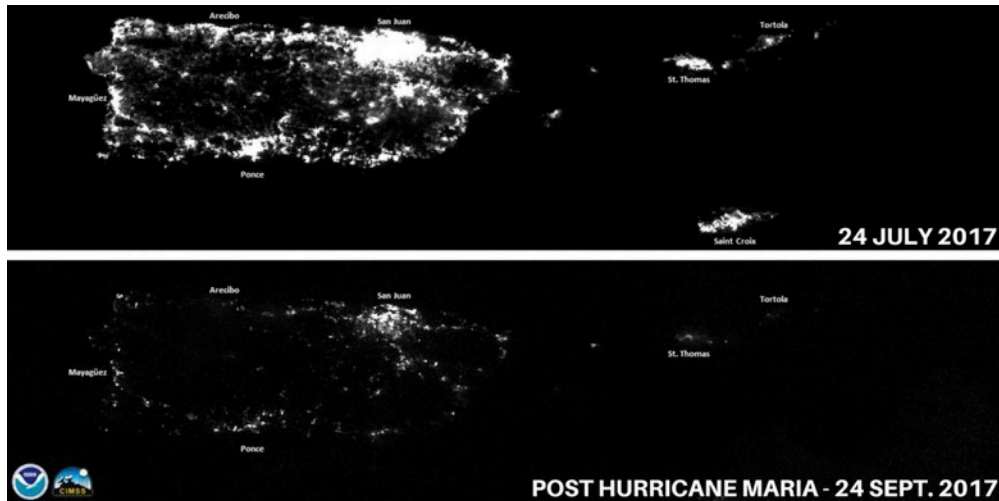


Photo from NOAA

**Road damage**



From Time.com

<http://time.com/5337866/fema-report-unprepared-hurricane-maria-puerto-rico/>



# CHALLENGES FROM PR IN THE AFTERMATH OF HURRICANE MARIA

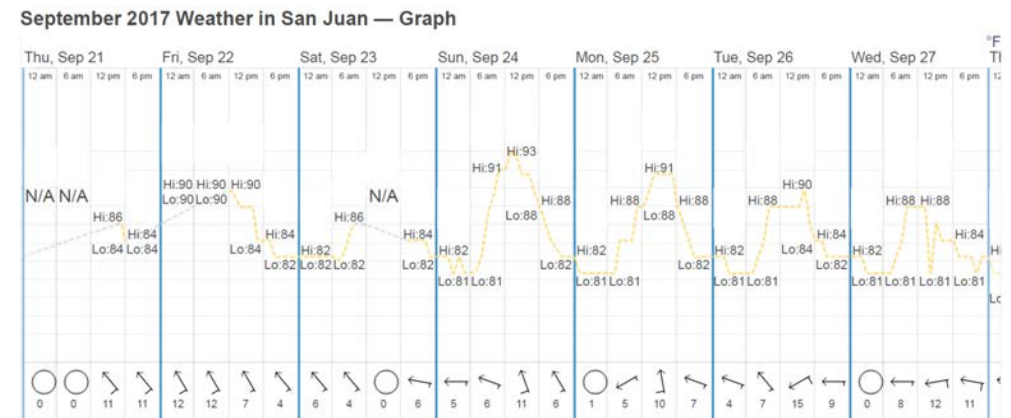
**Fuel shortage & curfew**



Photo from WNPR.org

<https://www.wnpr.org/post/disaster-more-dire-day-puerto-rico-after-hurricane-maria>

**High temp**



From timeanddate.com

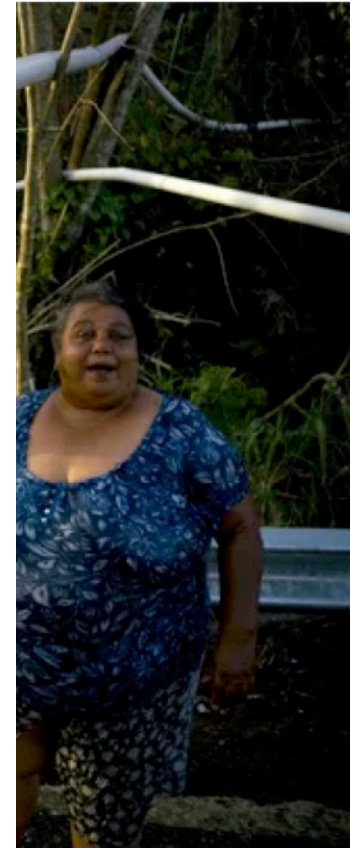


In storm-ravaged Puerto Rico, drinking water in short supply



# raise fears of health crisis six ria

Nov. 2, 2017 | Updated 5:08 p.m. ET Nov. 2, 2017



to Rico, on Oct. 14, 2017, nearly a month after Hurricane Maria made landfall. (Photo: Ramon



Puerto Rico collect water from a spring — more than two weeks after Hurricane Maria hit the island. | Photo by Images

By Dave Graham and Robin Respaut, Reuters

Like 0

September 27, 2017

**S**AN JUAN, Puerto Rico (Reuters) - A week after Hurricane Maria slammed into Puerto Rico, most of

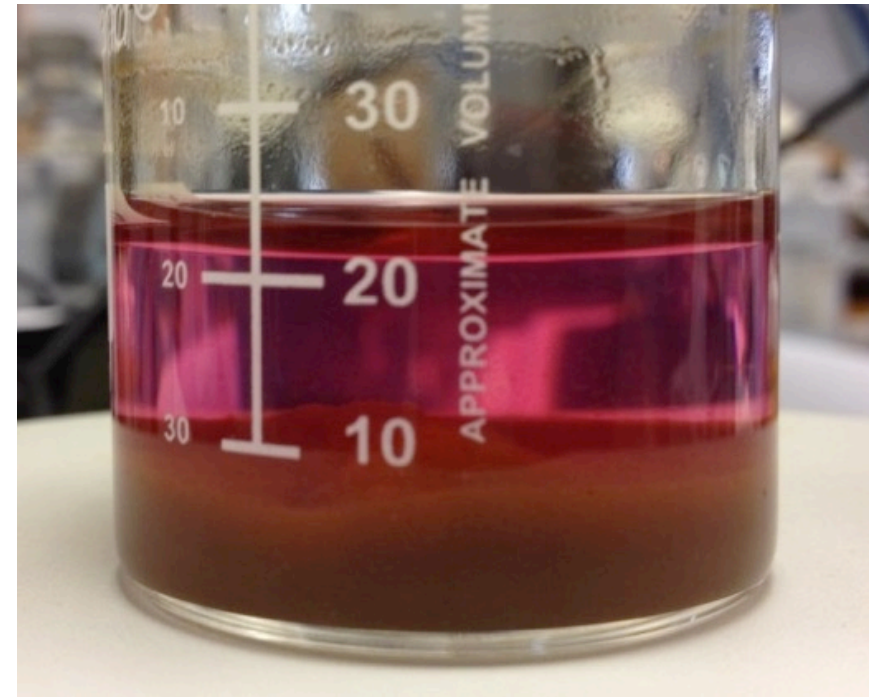
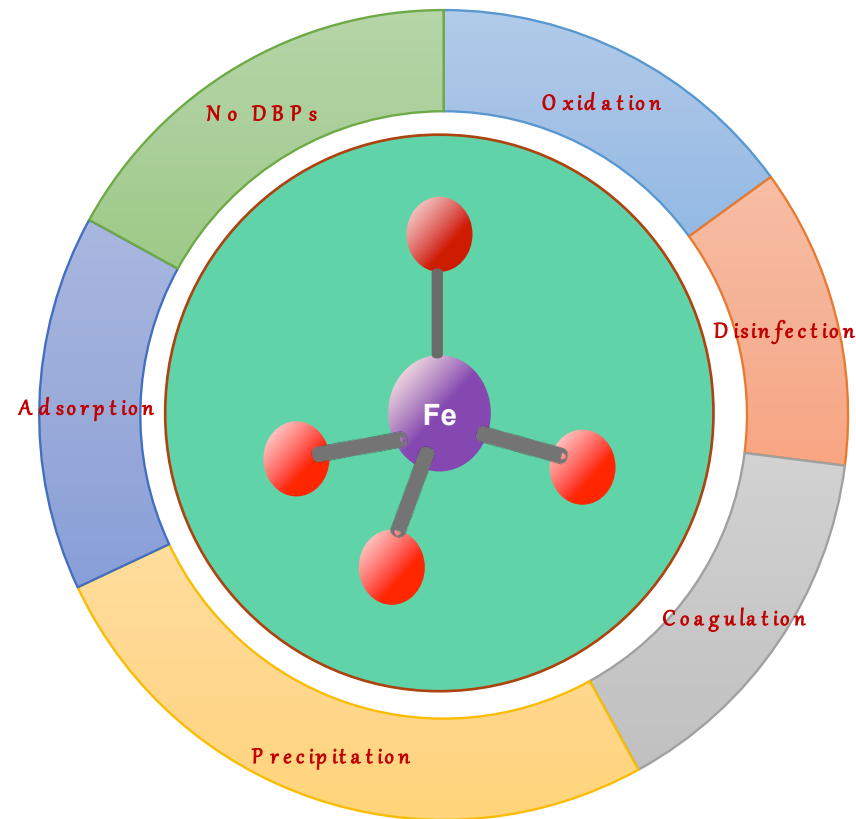


# CHALLENGES FOR EXISTING EWTs

- Multiple pollutants, rather than pathogens only, may be present;
- No or limited water quality monitoring and measurements are available;
- No or minimal energy (e.g. electricity, natural gas, and gasoline) is available;
- Easy operation, simple maintenance.

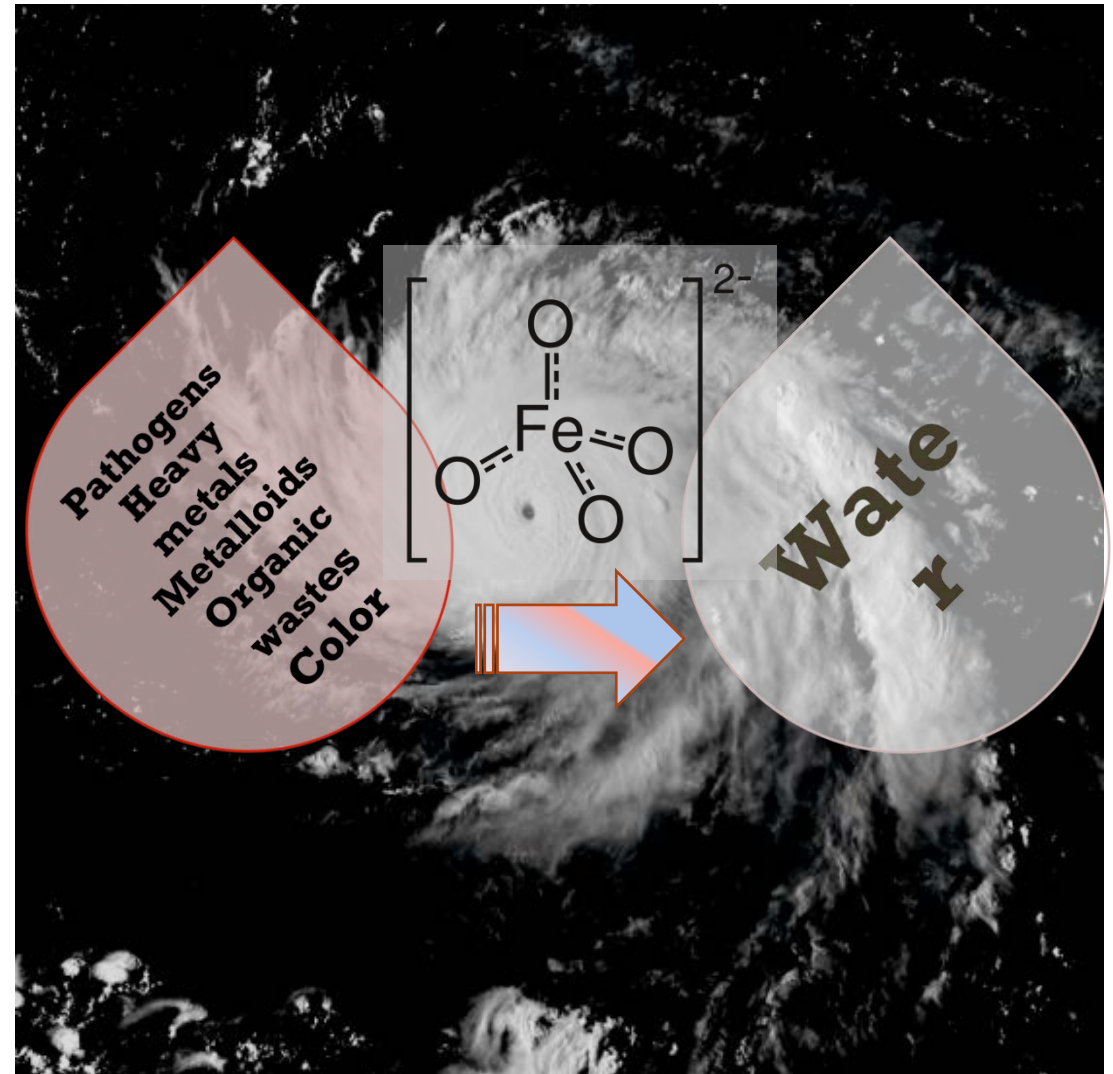


# Ferrate(VI) ( $\text{FeO}_4^{2-}$ ) FOR WATER TREATMENT



# OBJECTIVE

- A holistic approach was adopted to develop and design innovative EWTs with ferrate(VI).

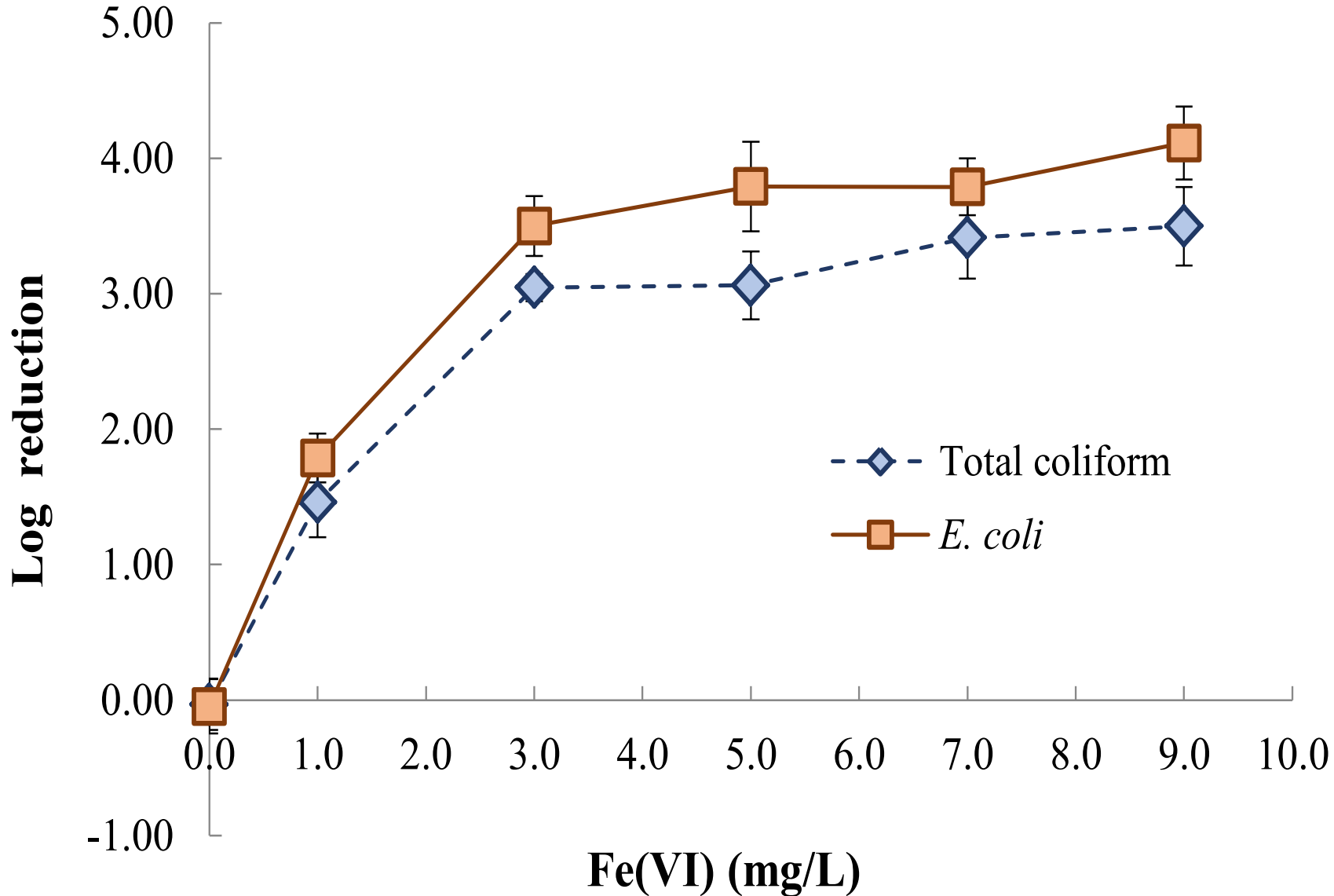


# LOG REDUCTIONS OF BACTERIAL INDICATORS

Total coliform:  $(1.99 \pm 0.14) \times 10^5$  MPN/100 mL

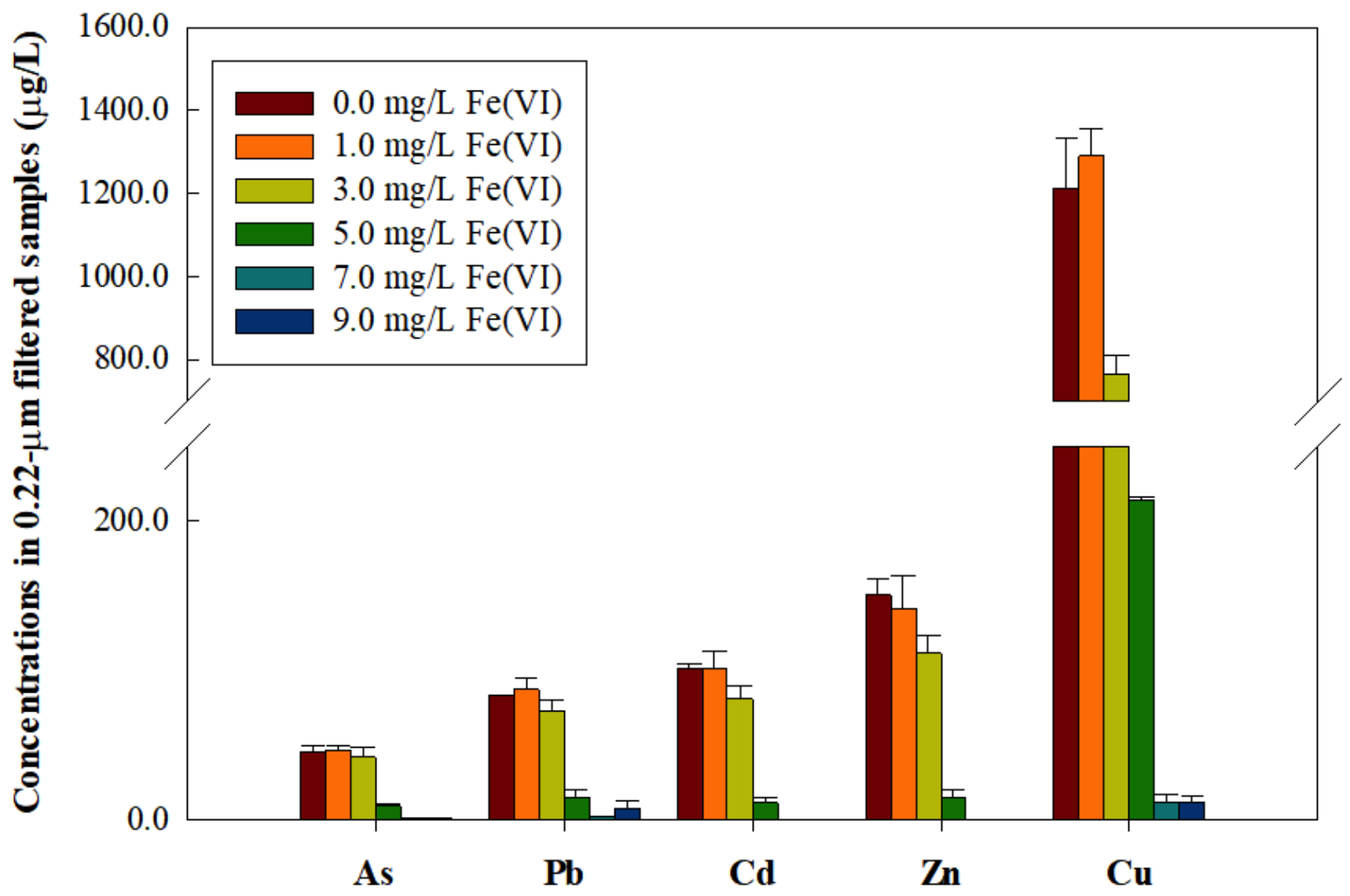
*E. coli*:  $(6.75 \pm 0.16) \times 10^4$  MPN/100 mL,

Cui *et al.* (2018)

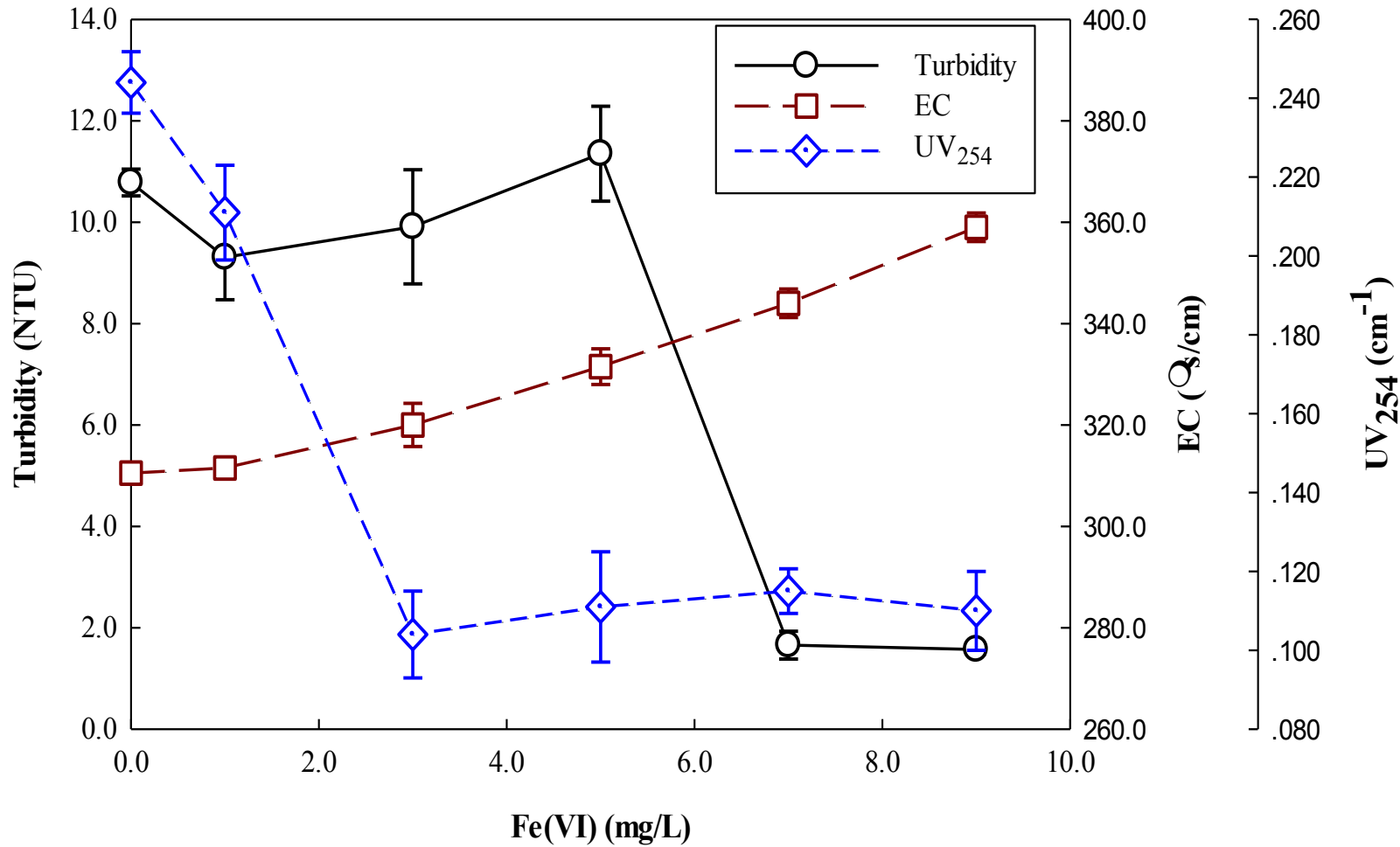


# RESIDUAL METALS & METALLOIDS

*Cui et al. (2018)*







# RESIDUAL TURBIDITY, EC, & UV<sub>254</sub> ABS.

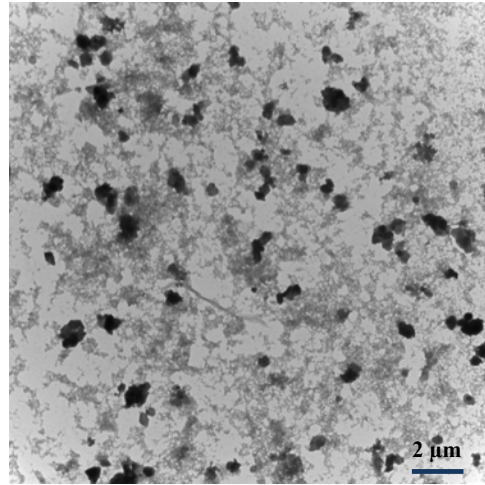
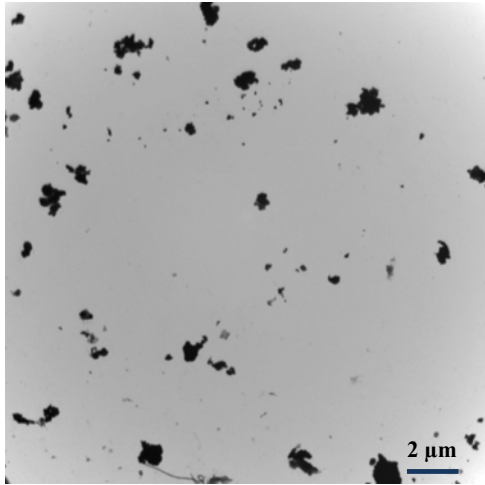
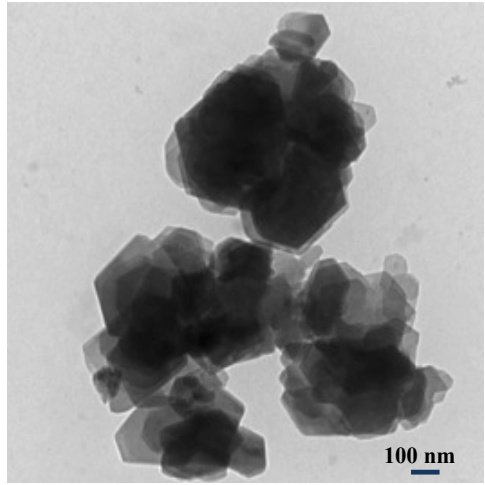
Initial turbidity: 11.88 NTU

Initial EC: 310  $\mu\text{s}/\text{cm}$

Initial UV<sub>254</sub> Abs. : 0.247  $\text{cm}^{-1}$

*Cui et al. (2018)*





**Kaolin particles in water**

**Kaolin Particles  
incorporated into  
Fe(VI) resultant  
particles**

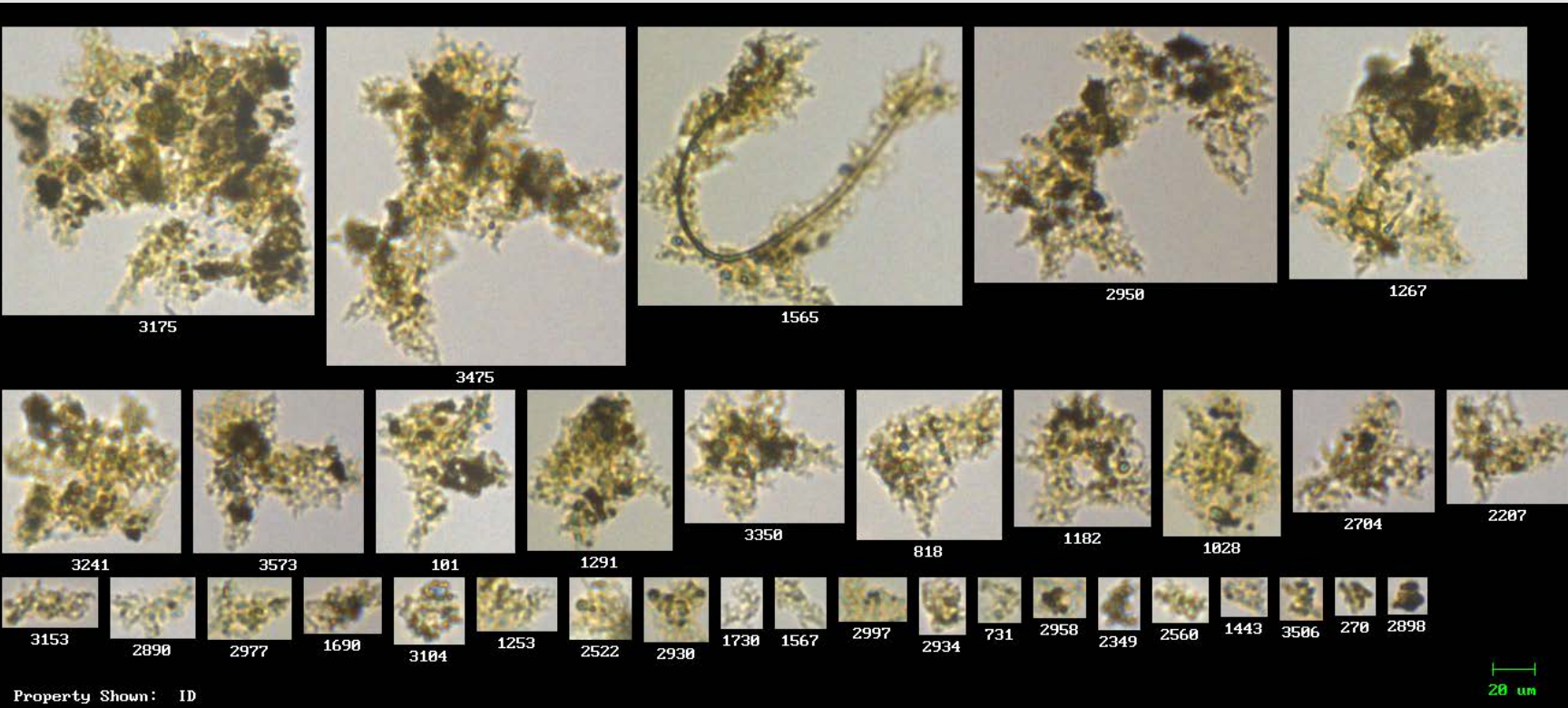
# PARTICLES & FE(VI) PARTICLES IN SIMULATED NATURAL WATER

*Lv et al. (2018)*



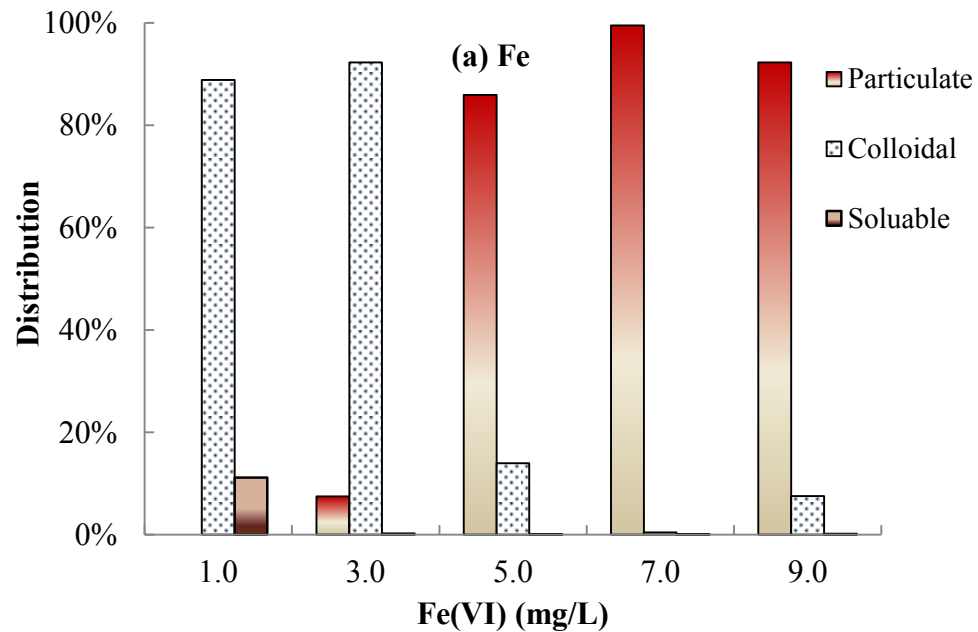
# FlowCAM IMAGES OF Fe(VI) PARTICLE CAPTURING ALGAL CELLS

Unpublished data

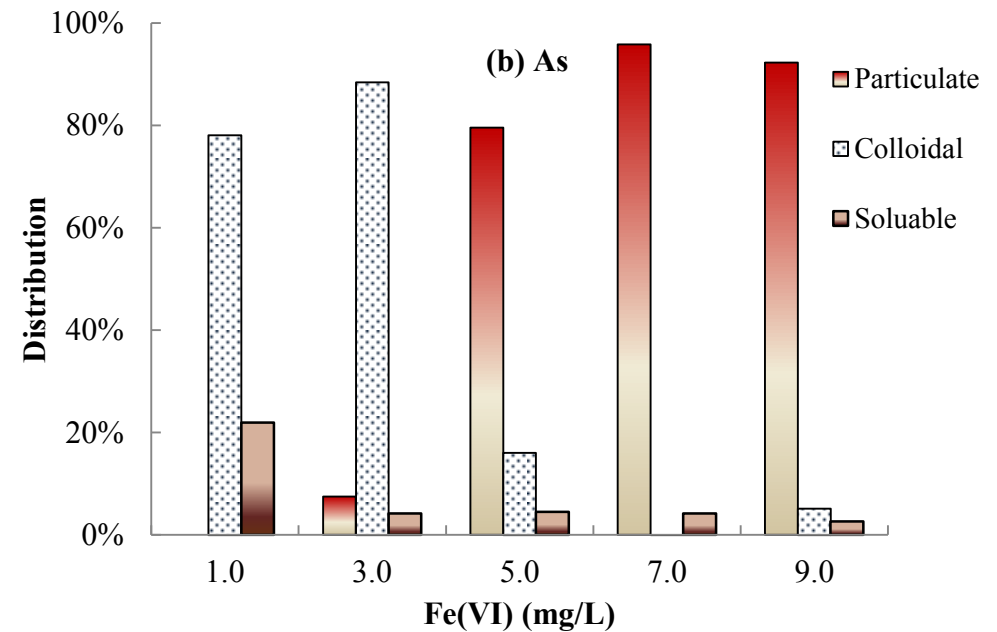


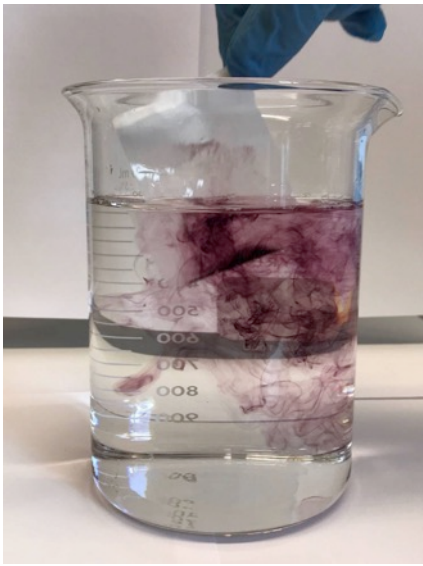
# DISTRIBUTIONS OF PARTICULATE, COLLOIDAL, & SOLUBLE ELEMENTS AFTER Fe(VI) TREATMENT

Fe



As





# DESIGN FOR HOUSEHOLD Fe(VI) EWT: PRE- PACKED TEABAG

Unpublished images



# COST

- \$0.14/day for a 4-person family;
- Compared with other commercial EWT products,

	<b>NaClO</b>	<b>NaDCC</b>	<b>Flocculant/ disinfectant</b>	<b>Ferrate(VI)</b>
Cost (\$x10 <sup>-2</sup> /10 L)	0.33	0.75	3.5	2.3



# CONCLUSIONS

- One-step treatment;
  - Effective and simultaneous removals of chemical and microbial contaminants;
  - No production of DBPs;
  - Affordable costs;
  - Simple operation;
  - Non-hazardous final products (iron sludge) (passing TCLP tests).
- 
- **Fe(VI) enables a new EWT design in the aftermath of natural disasters.**



# IMPLICATIONS & EFFORTS NEVER END...

- Straightforward and immediate benefits for disaster-affected populations;
- The resulted rapid disaster relief can save lives and minimize economic loss from disasters;
- Fe(VI) treatment can be readily applied can be readily applied at other scenarios such as industrial wastewater treatment (e.g. metal removal from flue-gas desulfurization (FGD) wastewater), small rural or island water supply systems, military bases, scientific expedition, and site remediation.





# OUR RECENT PUBLICATIONS ON Fe(VI) WATER TREATMENT & REUSE

- Cui, J., L. Zheng, Y. Deng (Front Cover Paper) (2018) "Emergency Water Treatment with Ferrate(VI) in Response to Natural Disasters," *Environmental Science: Water Research & Technology*, 4, 339-470.
- Deng, Y., C. Jung, Y. Liang, N. Goodey, T. Waite (2018) "Ferrate(VI) Decomposition in Water in the Presence of Natural Organic Matter (NOM)," *Chemical Engineering Journal*, 334, 2335-2342.
- Lv, D., H. Zhang, L. Zheng, Y. Deng (2018) "Coagulation of Colloidal Particles with Ferrate(VI)," *Environmental Science: Water Research & Technology*, 4, 701-710.
- Song, Y., Y. Deng, C. Jung (2016) "Mitigation and Degradation of Natural Organic Matter (NOM) during Ferrate(VI) Application for Drinking Water Treatment," *Chemosphere*, 146, 145-153.
- Li, N., Y. Deng, D. Sarkar (2017) Ferrate(VI) Reaction With Effluent Organic Matter (EfOM) in Secondary Effluent for Water Reuse, in Ferrites and Ferrates: Chemistry and Applications in Sustainable Energy and Environmental Remediation, by Virender Sharma (Editor), ACS Publications.
- Huang, X., Y. Deng, S. Liu, Y. Song, N. Li, J. Zhou (2016) "Formation of Bromate during Ferrate (VI) Oxidation of Bromide in Water," *Chemosphere*, 155, 528-533.
- Zheng, L., Y. Deng (2016) "Settleability and Surface Characteristics of Ferrate(VI)-Induced Particles in Advanced Wastewater Treatment," *Water Research*, 93, 172-178.
- Deng, Y., M. Wu, L. Zheng, H. Zhang, Acosta, H., Hsu, T. (2017) "Addressing Harmful Algal Blooms (HABs) Impacts with Ferrate(VI): Simultaneous Removal of Algal Cells and Toxins for Drinking Water Treatment," *Chemosphere*, 186, 757-761.



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- Junkui Cui (PhD candidate)
- Lei Zheng (PhD candidate)
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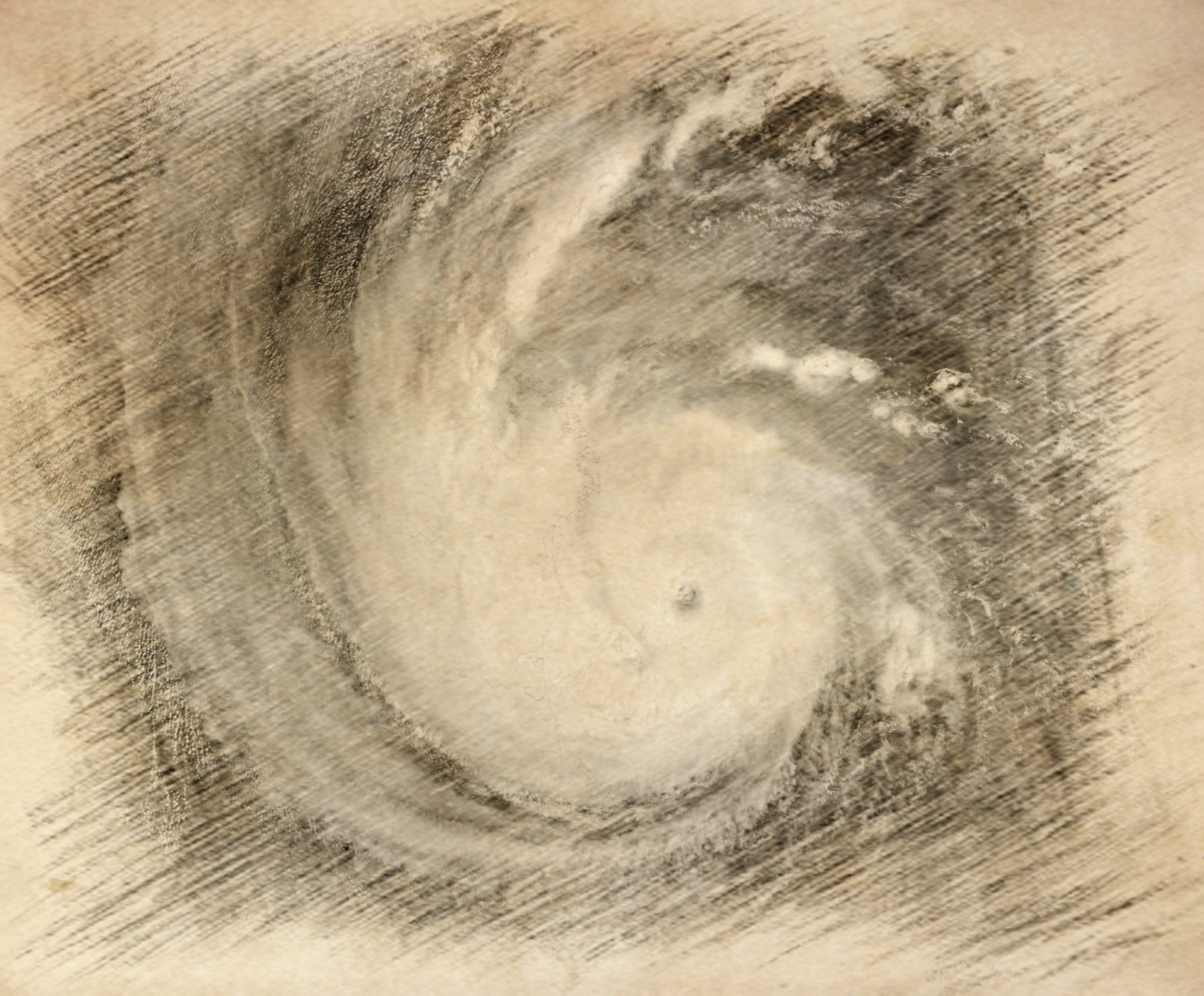


# ACKNOWLEDGEMENT



**MONTCLAIR STATE UNIVERSITY**  
**PSEG INSTITUTE FOR**  
**SUSTAINABILITY STUDIES**





**THANKS ...**



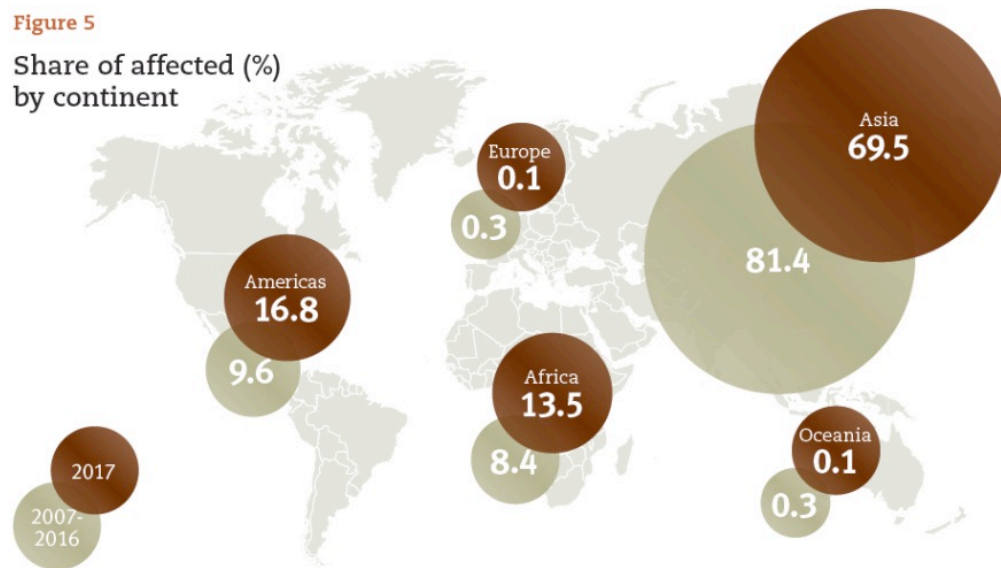
# NATURAL DISASTERS: HUMAN IMPACTS (2017 VS. 2007-2016)

- **Total affected (96 millions in 2017)**

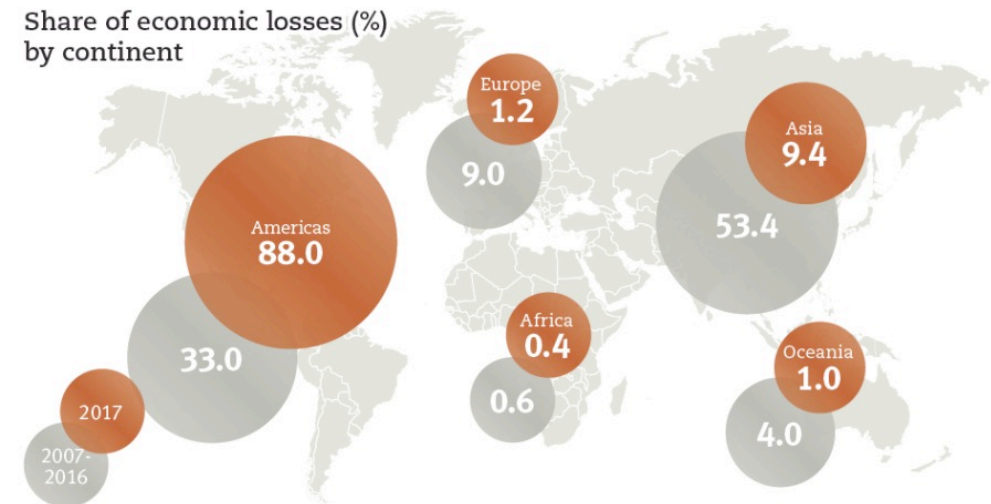
- **Total death (9,697 in 2017)**

Figure 5

Share of affected (%)  
by continent

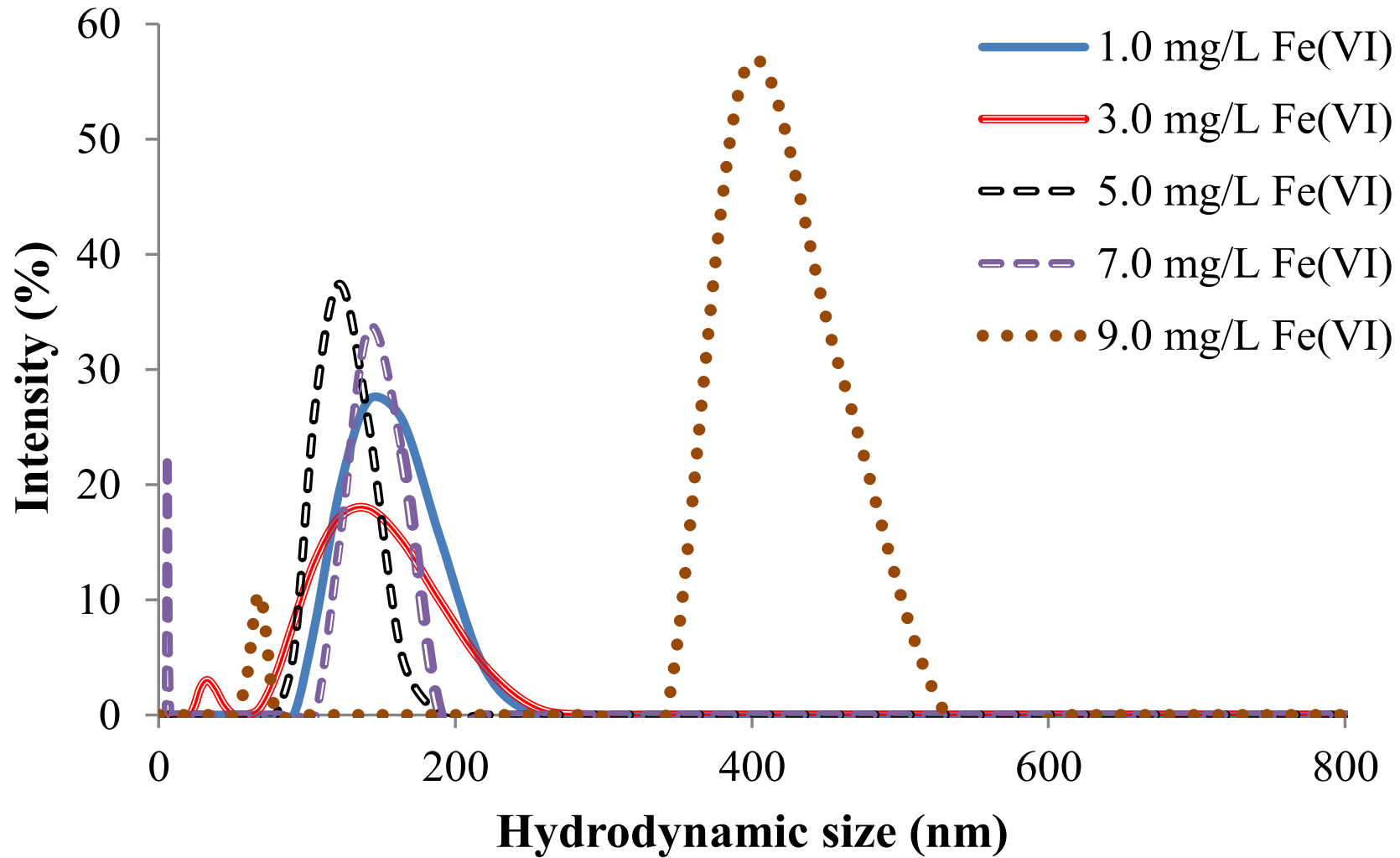


Share of economic losses (%)  
by continent



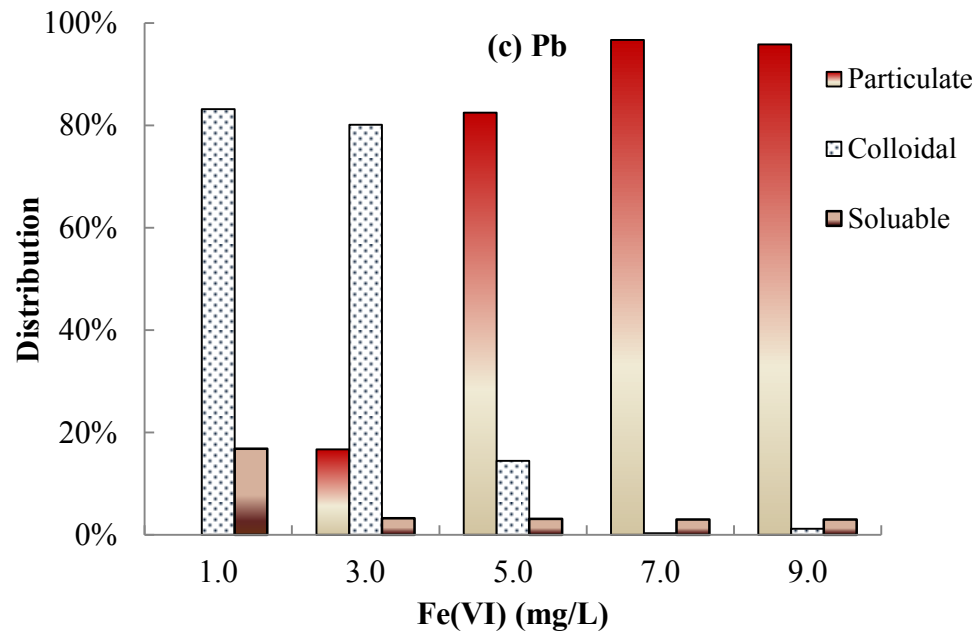
# DISTRIBUTION OF NON-SETTABLE FERRATE(VI) RESULTANT PARTICLES.

*Cui et al. (2018)*

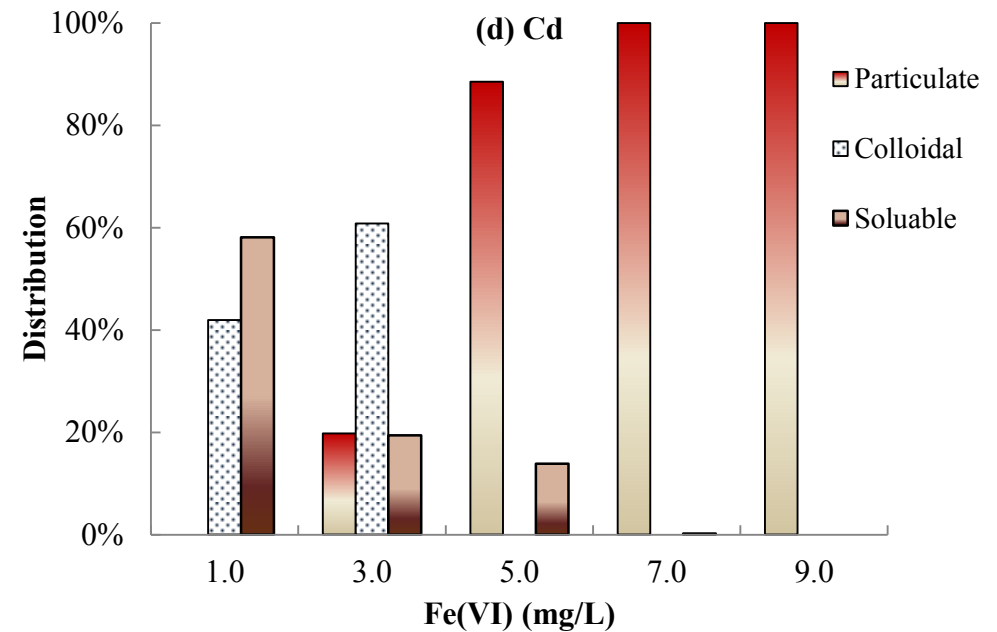


# DISTRIBUTIONS OF PARTICULATE, COLLOIDAL, & SOLUBLE ELEMENTS AFTER Fe(VI) TREATMENT (Cont.)

**Pb**

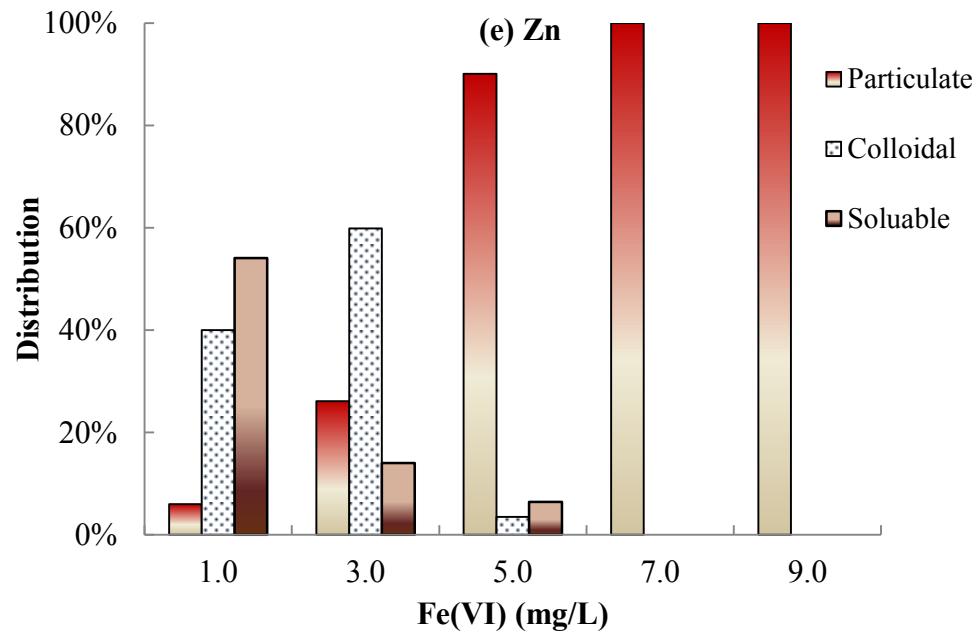


**Cd**



# DISTRIBUTIONS OF PARTICULATE, COLLOIDAL, & SOLUBLE ELEMENTS AFTER Fe(VI) TREATMENT (Cont.)

**Zn**



**Cu**

