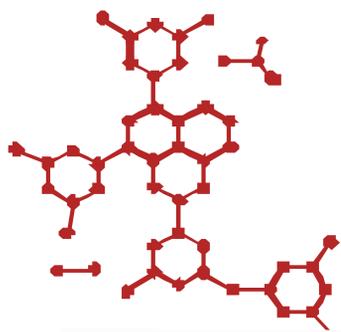


Occurrence of Pharmaceutical Compounds in Indian Matrices

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What are pharmaceuticals ?

Pharmaceuticals are compounds that are designed to induce various therapeutic responses in humans and animals.

Some classes of pharmaceuticals

- Antibiotics
- Anticancer
- Analgesics
- Beta blockers
- Cardiovascular
- Lipid regulator etc.

- Anti-inflammatories, analgesics, beta blockers, X-ray contrast are the most resistant to treatment.

Pharmaceuticals are designed chemically stable and so their abatement in wastewater treatment plants is difficult.

WWTPs are designed for the treatment of easy to moderate biodegradable organics.



Why occurrence of pharmaceuticals in environment is a concern ?

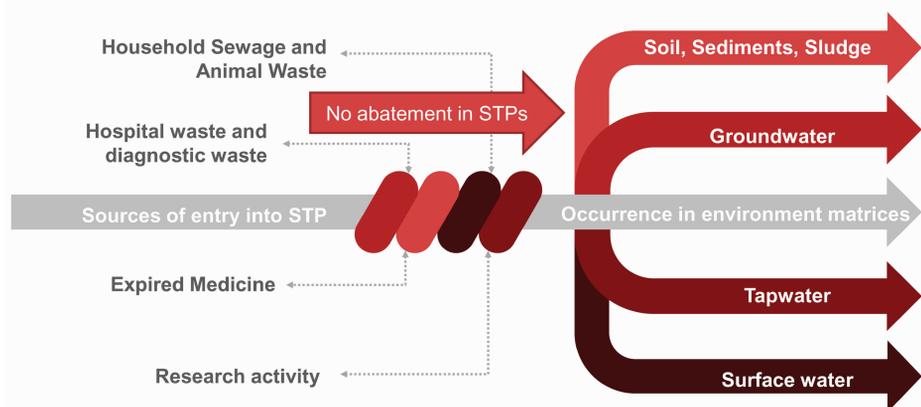
"A post-antibiotic era means in effect an end to modern medicine as we know it. Things as common as strep throat or a child's scratched knee could once again kill" -- Dr Margaret Chan
WHO, Director General



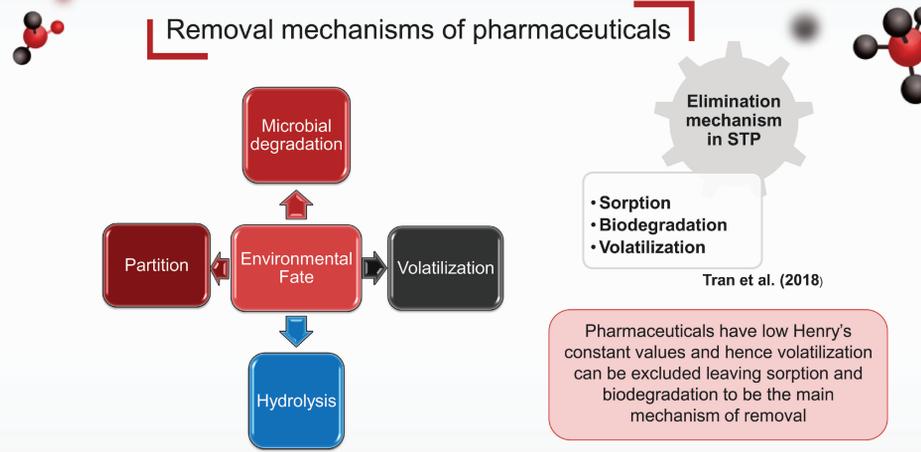
Disinfection of water containing pharmaceuticals can yield carcinogenic disinfection byproducts
-- Shen and Andrews (2011)

Diabetes Drug Makes Male Minnows More Female
Exposure to metformin (Type-2 diabetes drug), feminizes male minnows and impacts fertility at levels common in wastewater effluent.

Source and fate of pharmaceuticals



Removal mechanisms of pharmaceuticals



Studies highlighting high pharmaceutical concentration in Indian matrices

Case Study 1

Larsson et al. (2007)

- Effluent from a wastewater treatment plant (serving 90 bulk manufacturers of drugs) situated in Hyderabad was analyzed.
- The samples contained the highest concentration of pharmaceuticals than reported elsewhere in the world.

Compounds	Conc. (mg/L)
Ciprofloxacin	31
Losartan	2.5
Cetirizine	1.4

Case Study 2

Fick et al. (2009)

- Surface and ground water samples were analyzed for pharmaceuticals near the bulk drugs manufacturing area, Hyderabad.
- Pharmaceuticals in mg/L range were detected in lake water samples.

Compounds	Conc. (mg/L)
Ciprofloxacin	6.5
Cetirizine	1.2
Norfloxacin	0.52
Enoxacin	0.16

Maximum reported concentration of different pharmaceuticals present in Indian matrix along with Europe and North America. Values are in µg/L range and the matrix taken is WWTP influent.

Compound	India	North America	Europe	References
Azithromycin	300	2.5	1.13	(Larsson et al. 2007; Miede et al. 2009; Mohapatra et al. 2016; Senta et al. 2013)
Ciprofloxacin	31,000*	246	13.6	(Larsson et al. 2007; Tran et al. 2018)
Clarithromycin	27.7	8	0.60	(Lübbert et al. 2017; Miede et al. 2009; Senta et al. 2013; Tran et al. 2018)
Sulfamethoxazole	10.6	4.2	11.50	(Lübbert et al. 2017; Tran et al. 2018)
Atenolol	300	2.6	33	(Mohapatra et al. 2016; Tran et al. 2018)
Metoprolol	75	0.15	4.1	(Mohapatra et al. 2016; Tran et al. 2018)
Acetaminophen	150	500	482	(Mohapatra et al. 2016; Tran et al. 2018)
Carbamazepine	50	0.4	3.1	(Mohapatra et al. 2016; Tran et al. 2018)

* indicates concentration in treatment plant effluent.

Pharmaceutical compound (Concentration in µg/L)	River Matrix	Location	References
Azithromycin (0.99), Sulfamethoxazole (0.81), Carbamazepine (0.11), Diclofenac (0.412), Glibenclamide (0.80), Ibuprofen (1.8)	Ahar River	Udaipur City	Williams et al. (2019)
Caffeine (0.743), Ketoprofen (0.107)	Ganga River	Northern India	Sharma et al. (2019)
Aspirin (1.34), Ibuprofen (2.3), Paracetamol (1.56), Caffeine (2.64), Ranitidine (0.43), Carbamazepine (1.34), Codeine (0.26), Diazepam (0.3)	Yamuna River	Delhi City	Mutiyar and Mittal (2018)
Benzophenone (0.05), Lignocaine (0.022), Mefenamic acid (0.68)	Periyar River	Kerela	Khalid et al. (2018)
Triclosan (9.65)	Gomti River	Uttar Pradesh	Nag et al. (2018)
Primidone (0.068)	River water samples	Central India	Appa et al. (2018)
Caffeine (174), Benzophenone (16), Irgasan (16), Ciprofloxacin (7.5)	Lake	Nagpur City	Archana et al. (2017)

Concluding note

Concentration of few pharmaceuticals such as ciprofloxacin (31 mg/L) and fluconazole (236 mg/L) reported in wastewaters of Hyderabad city in India show the highest values compared to pharmaceuticals concentration reported elsewhere in the world.

Metoprolol (950 µg/L), enrofloxacin (900 µg/L), citalopram (840 µg/L), moxifloxacin (694 µg/L), norfloxacin (420 µg/L), azithromycin (300 µg/L), atenolol (300 µg/L), levofloxacin (200 µg/L) are amongst other pharmaceuticals that have been detected at high concentration.

Disparity exists in occurrence data with most of the studies concentrated in southern India.

India is amongst the top manufacturer and consumer of the pharmaceutical compounds and with pharmaceuticals occurring at alarmingly high concentration in environmental waters, much needed attention and emphasis is required to conduct nation-wide occurrence study program to fully assess the ecological risks possessed by the pharmaceuticals.

