CVL100:Environmental Science(2-0-0)

Dr. Arun Kumar

Water Treatment-Mass Balance and Big-Picture
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Recap

Meta-Analysis of Mass Balances Examining Chemical Fate during Wastewater Treatment

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Mass balances are an instructive means for investigating the fate of chemicals during wastewater treatment. In addition

composition of biosolids is important because us sewage sludge as fertilizer in agriculture, f

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Occurrence of pharmaceuticals in a municipal wastewater treatment plant: Mass balance and removal processes

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ABSTRACT

Occurrence and removal efficiencies of fifteen pharmaceuticals were investigated in a conventional municipal wastewater treatment plant in Michigan. Concentrations of these pharmaceuticals were determined in both wastewater and sludge phases by a high-performance liquid chromatograph coupled to a

The mass flow calculation can be written as:

$(m_{lost}=m_{biodegradation}+m_{sorbed})$

$$m_{inf} = m_{eff} + m_{bio} + m_{sor} \tag{3}$$

where m_{inf} (kg d^{-1}) and m_{eff} (kg d^{-1}) are mass input and output of the treatment system. m_{bio} (kg d^{-1}) and m_{sor} (kg d^{-1}) refer to the mass of pharmaceutical lost due to biodegradation and sorption,

Table 2
Mass flux of the investigated pharmaceuticals at different treatment units.

Pharmaceuticals	Mass flux ($g\,d^{-1}$)									Mass in effluent (%) (C=100*(B/A))	Mass in dewatered sludge, R_{sor} (%) (E=100*(D/A))	Mass lost in WWTP, R_{bio} (%) (F=100-(C+E))
	Raw influent (A)	Pretreatment effluent	Primary effluent	Aeration effluent	Secondary effluent	Final effluent (B)	Primary sludge	Waste sludge	Dewatered sludge (D)	(C)	(E)	(F)
CTC	8.1 ± 8.2	7.7 ± 1.8	5.5 ± 1.1	2.4 ± 0.9	NA	NA	0.2	NA	NA	NA	NA	100
DMC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DOC	34 ± 25	22 ± 16	20 ± 16	26 ± 25	15 ± 18	17 ± 17	2.3 ± 1.5	1.3 ± 1.3	1.0 ± 0.5	50	3.0	47
OTC	1.3 ± 0.8	0.9 ± 0.6	1.2 ± 0.3	0.9 ± 0.2	0.6 ± 0.4	0.8 ± 0.2	0.1 ± 0.01	0.1 ± 0.03	0.03 ± 0.02	61	2.2	37
TC	14 ± 42	5.7 ± 2.0	7.0 ± 2.4	7.0 ± 3.9	NA	NA	NA	3.1 ± 1.7	1.0 ± 0.5	NA	7.1	93
SDZ	1.7 ± 0.5	1.6 ± 0.4	1.6 ± 0.3	2.0 ± 0.3	1.3 ± 0.1	1.2 ± 0.6	0.2 ± 0.04	0.2 ± 0.2	0.1 ± 0.03	73	5.2	22
SMR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SMZ	1.2 ± 0.1	NA	NA	NA	NA	NA	NA	0.03 ± 0	0.01 ± 0	NA	0.5	99
SMX	71 ± 26	58 ± 24	59 ± 23	75 ± 32	22 ± 3.9	8.1 ± 6.9	0.1 ± 0.1	0.3 ± 0.2	0.1 ± 0.03	11	<0.1	>89
ERY	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TYL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LCM	2.6 ± 3.6	6.1 ± 7.6	3.4 ± 5.1	2.6 ± 3.5	2.6 ± 2.0	1.6 ± 0.5	0.04 ± 0.05	0.2 ± 0.04	0.03 ± 0.02	60	1.0	39
CBZ	5.0 ± 1.2	5.4 ± 1.2	6.0 ± 1.8	7.7 ± 2.7	7.1 ± 2.2	7.0 ± 2.5	0.1 ± 0.1	0.1 ± 0.05	0.03 ± 0.02	141	0.6	-41
AMP	2800 ± 1493	2644 ± 1099	2561 ± 1238	145 ± 134	3.2 ± 1.6	4.5 ± 3.9	0.3 ± 0.1	0.5 ± 0.3	0.2 ± 0.1	<0.2	<0.01	>99
CAF	1871 ± 550	1737 ± 538	2436 ± 794	138 ± 205	3.3 ± 2.1	3.4 ± 2.7	0.3 ± 0.1	0.4 ± 0.6	0.1 ± 0.05	<0.2	<0.01	>99

NA, not currently available. Mass flux was calculated according to Eqs. (1) and (2). R_{bio} and R_{sor} were calculated using Eqs. (4) and (5), respectively.

tetracycline (TC), demeclocycline (DMC), chlortetracycline (CTC), oxytetracycline (OTC), doxycycline (DOC), meclocycline (MCC), sulfadiazine (SDZ), sulfamerazine (SMR), sulfamethazine (SMZ), SMX, tylosin (TYL), acetaminophen (AMP), erythyromycin (ERY), lincomycin(LCM), carbamazepine (CBZ) and Caffeine (CAF).

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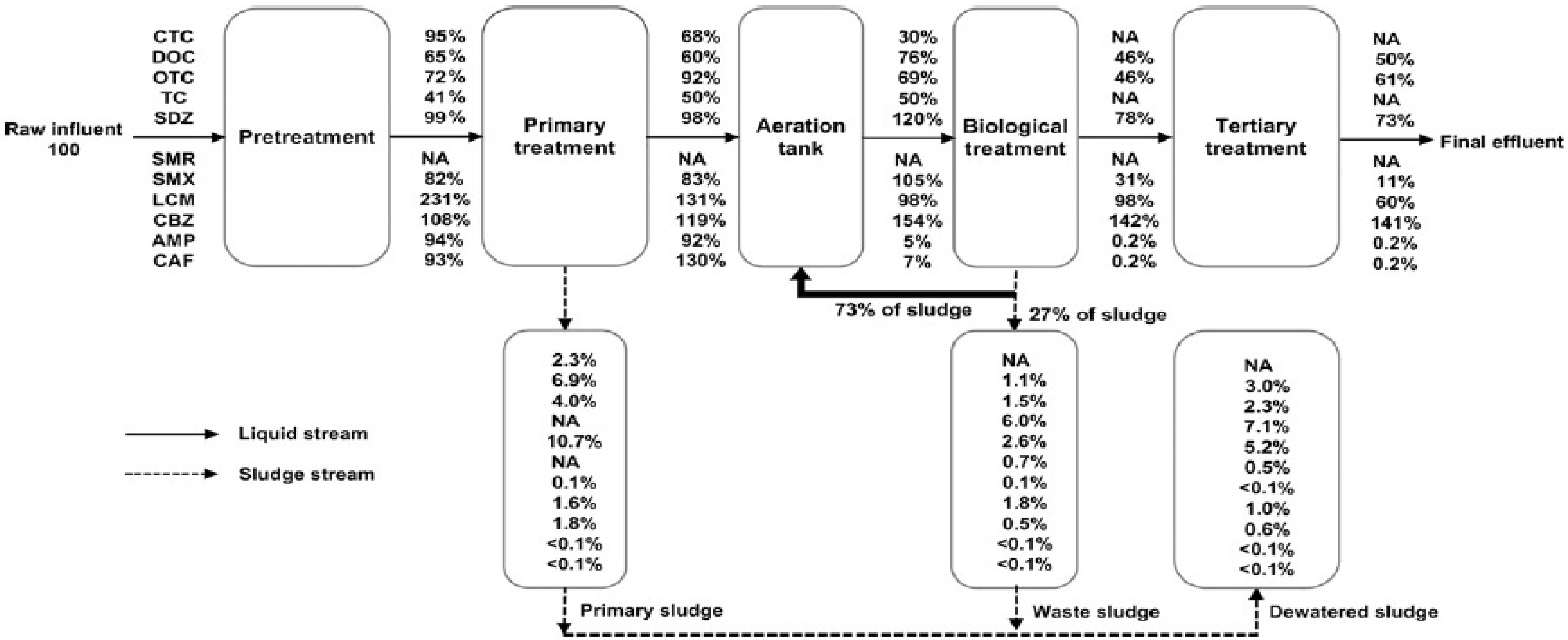


Fig. 4. Percentage (R_i, %, calculated applying Eq. (6)) of detected pharmaceuticals along the WWTP.

tetracycline (TC), demeclocycline (DMC), chlortetracycline (CTC), oxytetracycline (OTC), doxycycline (DOC), meclocycline (MCC), sulfadiazine (SDZ), sulfamerazine (SMR), sulfamethazine (SMZ), SMX, tylosin (TYL), acetaminophen (AMP), erythyromycin (ERY), lincomycin(LCM), carbamazepine (CBZ) and Caffeine (CAF).

- Comment on removal of different organic compounds in different units.
- Which compound is least detected in final effluent and which is mostly detected in final effluent?
- What does it say about their occurrence in sludge?
- Can we relate this to their K_{ow} and K_{oc} properties?

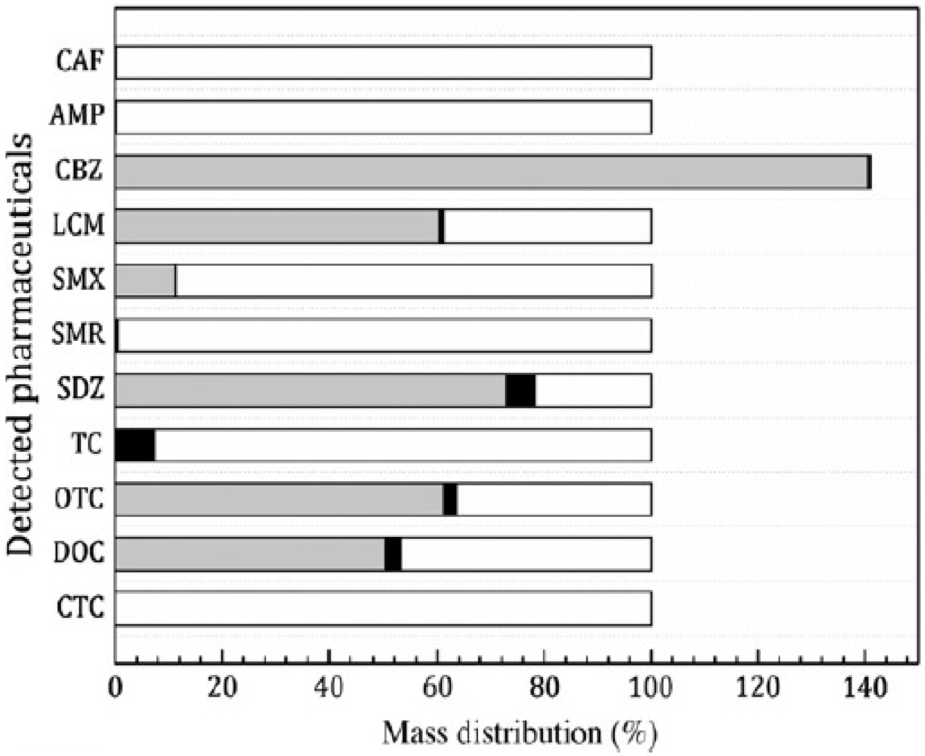


Fig. 3. Mass distribution of the detected pharmaceuticals in the WWTP. The grey-colored bar represents the mass fraction in the final effluent, the black-colored bar represents the fraction in the dewatered sludge, and the white bar represents the loss of pharmaceuticals due to biodegradation.

- Q1: Order chemicals in decreasing order of their potential occurrence in final effluent?
- Q2: Which compound is expected to have smallest K_{OW}?

tetracycline (TC), demeclocycline (DMC), chlortetracycline (CTC), oxytetracycline (OTC), doxycycline (DOC), meclocycline (MCC), sulfadiazine (SDZ), sulfamerazine (SMR), sulfamethazine (SMZ), SMX, tylosin (TYL), acetaminophen (AMP), erythyromycin (ERY), lincomycin(LCM), carbamazepine (CBZ) and Caffeine (CAF).

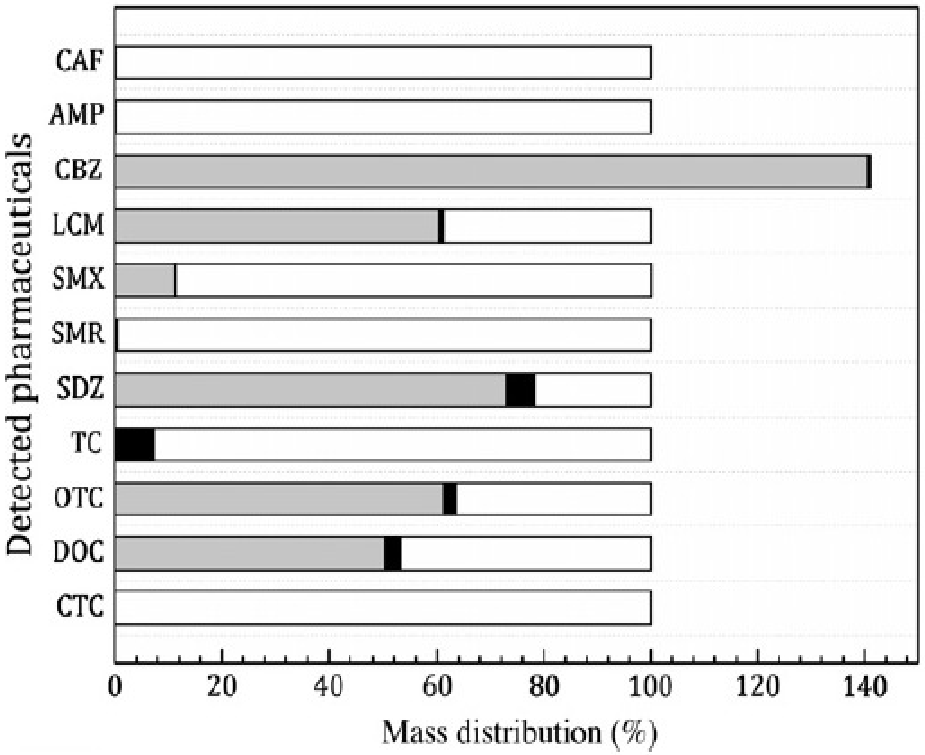
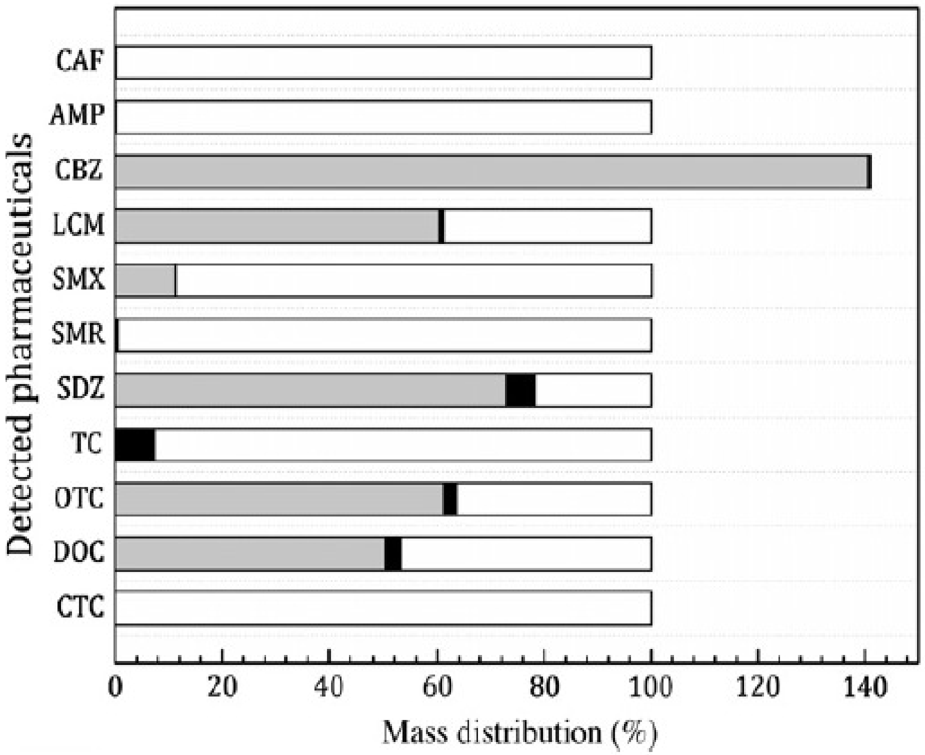


Fig. 3. Mass distribution of the detected pharmaceuticals in the WWTP. The grey-colored bar represents the mass fraction in the final effluent, the black-colored bar represents the fraction in the dewatered sludge, and the white bar represents the loss of pharmaceuticals due to biodegradation.

Presence in final effluent

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
sulfamethoxazole(SMX),
lincomycin(LCM),
carbamazepine (CBZ)



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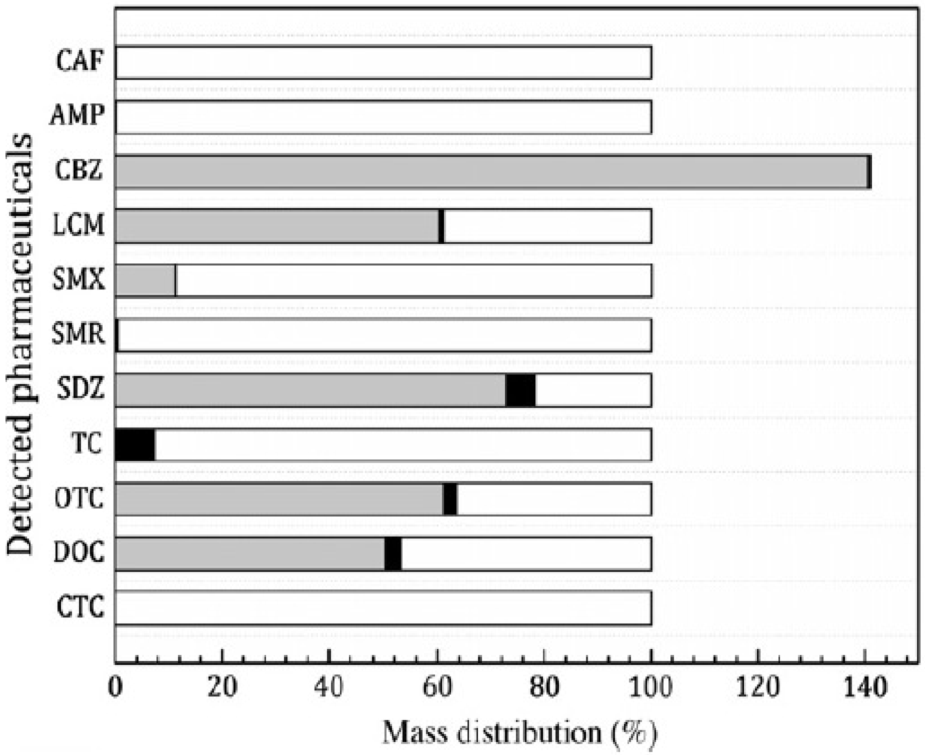
Check presence in surface water if wastewater effluent is mixed with surface water

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
sulfamethoxazole(SMX),
lincomycin(LCM),
carbamazepine (CBZ)



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Check further removal in drinking water treatment plant if surface water is used as raw source water for making drinking water

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
sulfamethoxazole(SMX),
lincomycin(LCM),
carbamazepine (CBZ)

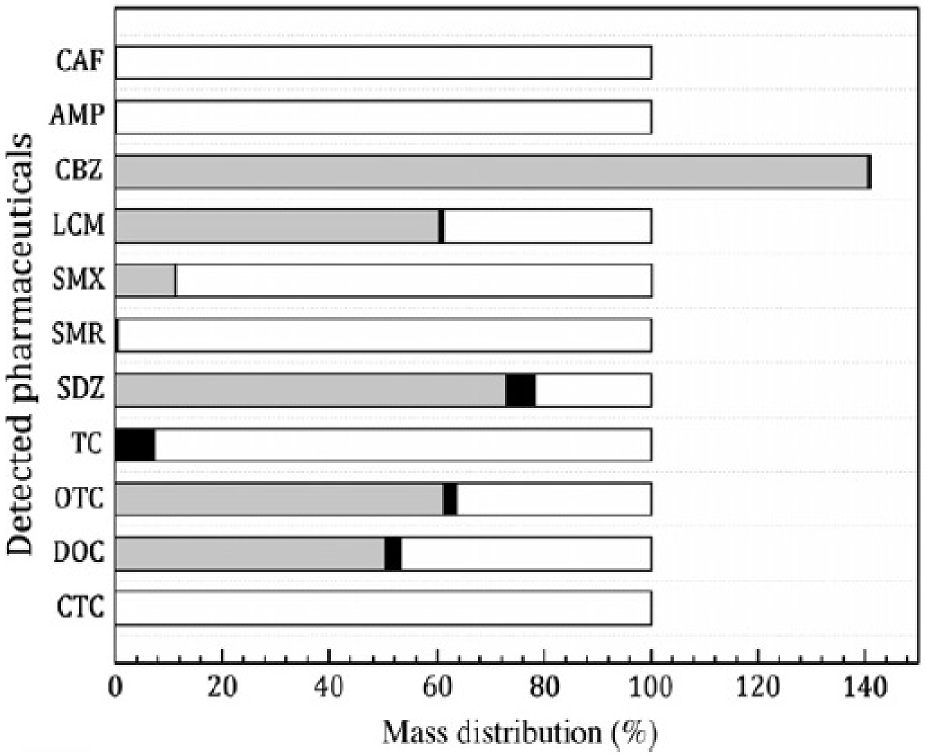


Fig. 3. Mass distribution of the detected pharmaceuticals in the WWTP. The grey-colored bar represents the mass fraction in the final effluent, the black-colored bar represents the fraction in the dewatered sludge, and the white bar represents the loss of pharmaceuticals due to biodegradation.

Presence in sludge

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
lincomycin(LCM),
Tetracycline(TC)

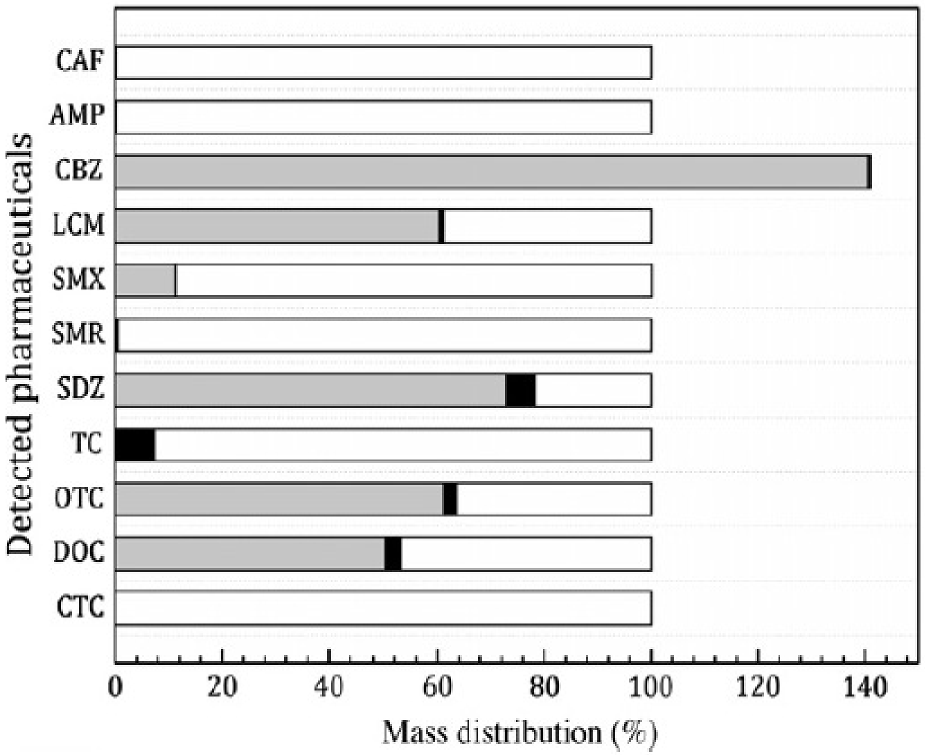


Fig. 3. Mass distribution of the detected pharmaceuticals in the WWTP. The grey-colored bar represents the mass fraction in the final effluent, the black-colored bar represents the fraction in the dewatered sludge, and the white bar represents the loss of pharmaceuticals due to biodegradation.

Check presence in land if sludge is applied there as nutrient source

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
lincomycin(LCM),
Tetracycline(TC)

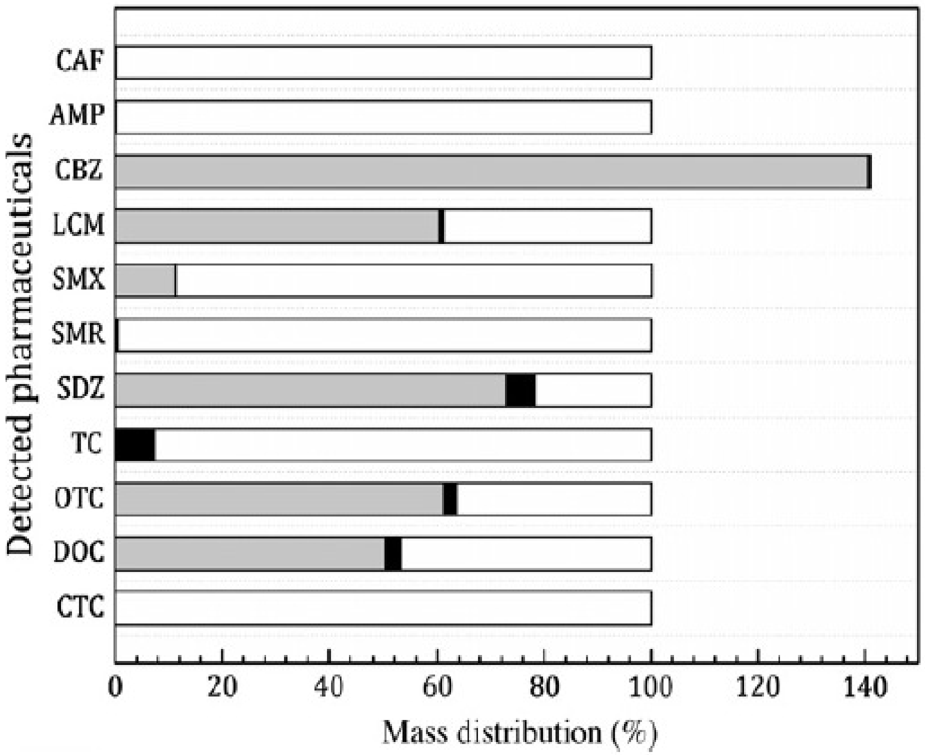
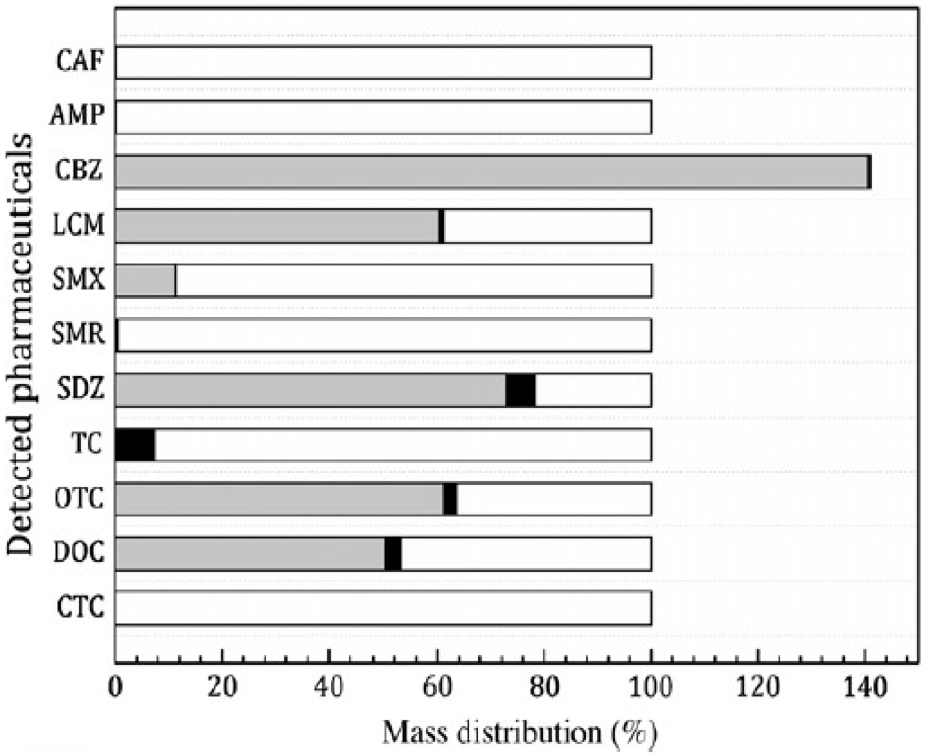


Fig. 3. Mass distribution of the detected pharmaceuticals in the WWTP. The grey-colored bar represents the mass fraction in the final effluent, the black-colored bar represents the fraction in the dewatered sludge, and the white bar represents the loss of pharmaceuticals due to biodegradation.

Check chance of contamination of soil, surface water through runoff and groundwater through percolation if sludge is applied on land as nutrient source

oxytetracycline (OTC),
doxycycline (DOC),
sulfadiazine (SDZ),
lincomycin(LCM),
Tetracycline(TC)



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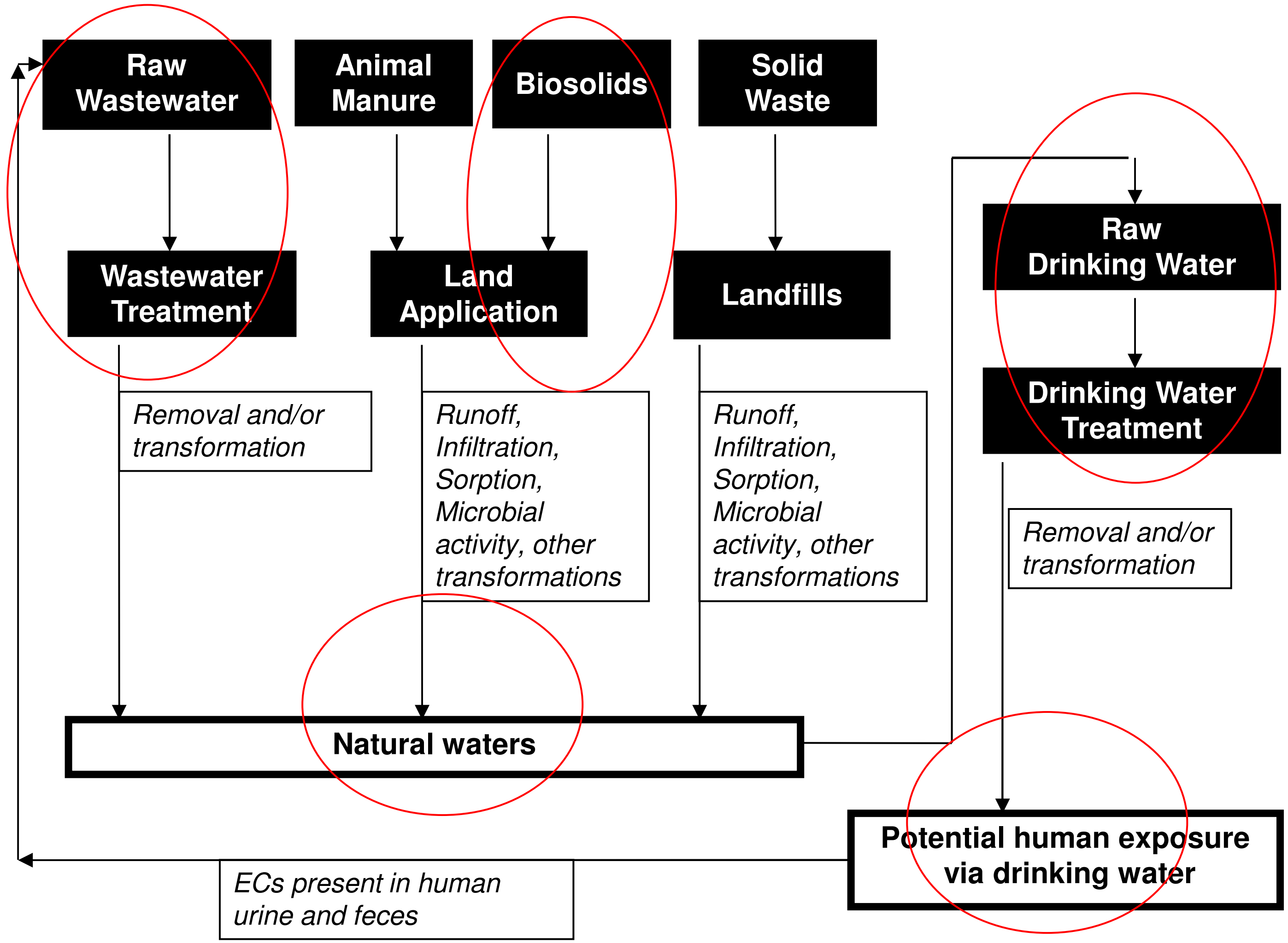
Lost due to biodegradation (i.e., compound can be degraded by bacteria)

CAF
AMP
LCM
SMX
SMR
SDZ
TC
OTC
DOC
CTC

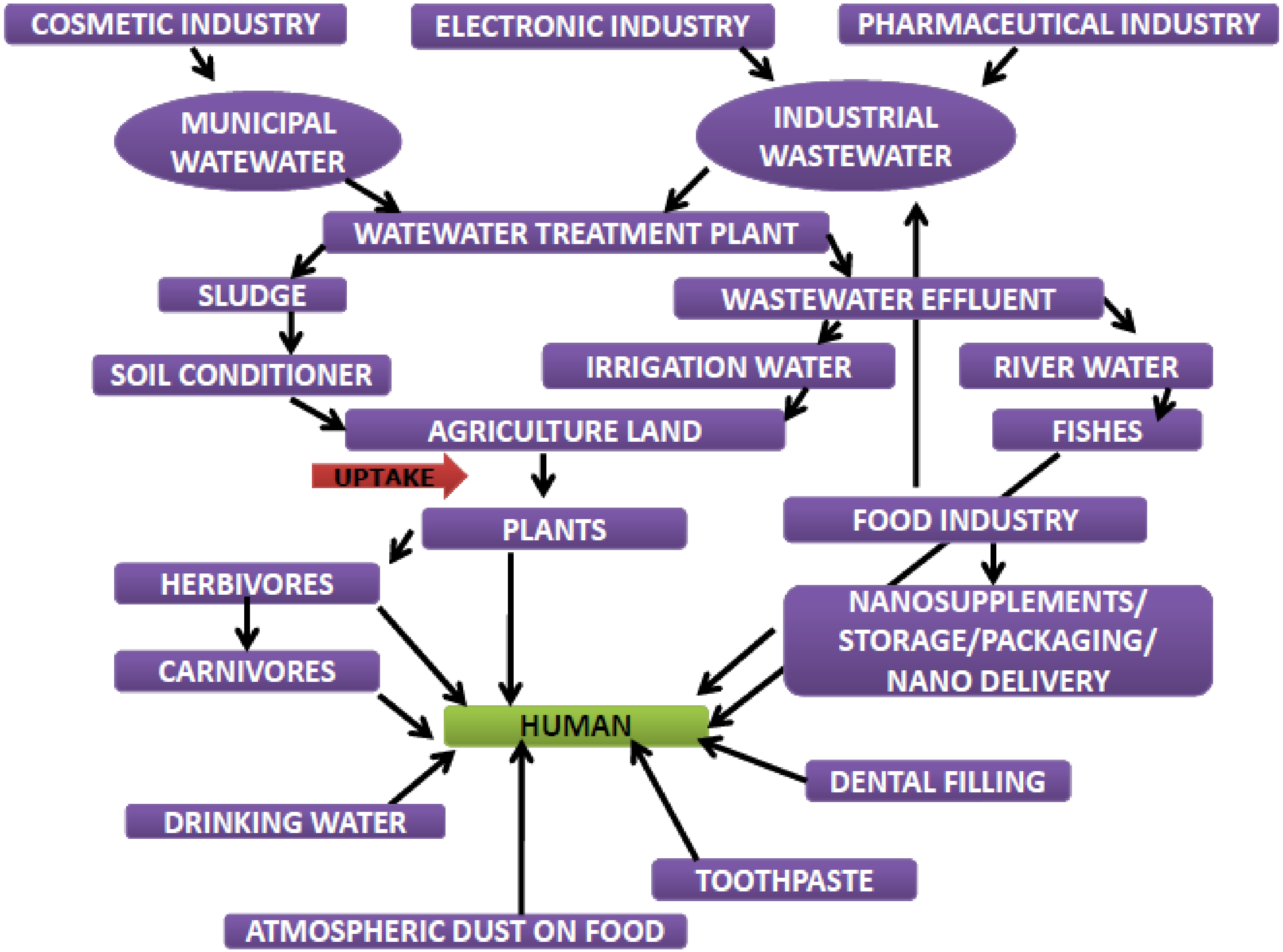
Some can be biodegraded more
And some can be biodegraded less.

Fate of pharmaceuticals in environment and our exposure



A big picture overview

A big picture overview



Singh, D. and Kumar, A. (2015)

Big-picture

Emerging Water Contaminants (EWCs)

1. Pharmaceuticals, Endocrine-disrupting chemicals(ex: triclosan; Bisphenol-A)

2. Nanoparticles (nanosilver, nanoparticles: TiO_2, CuO, Carbon nanotubes)

3. Micro-plastics

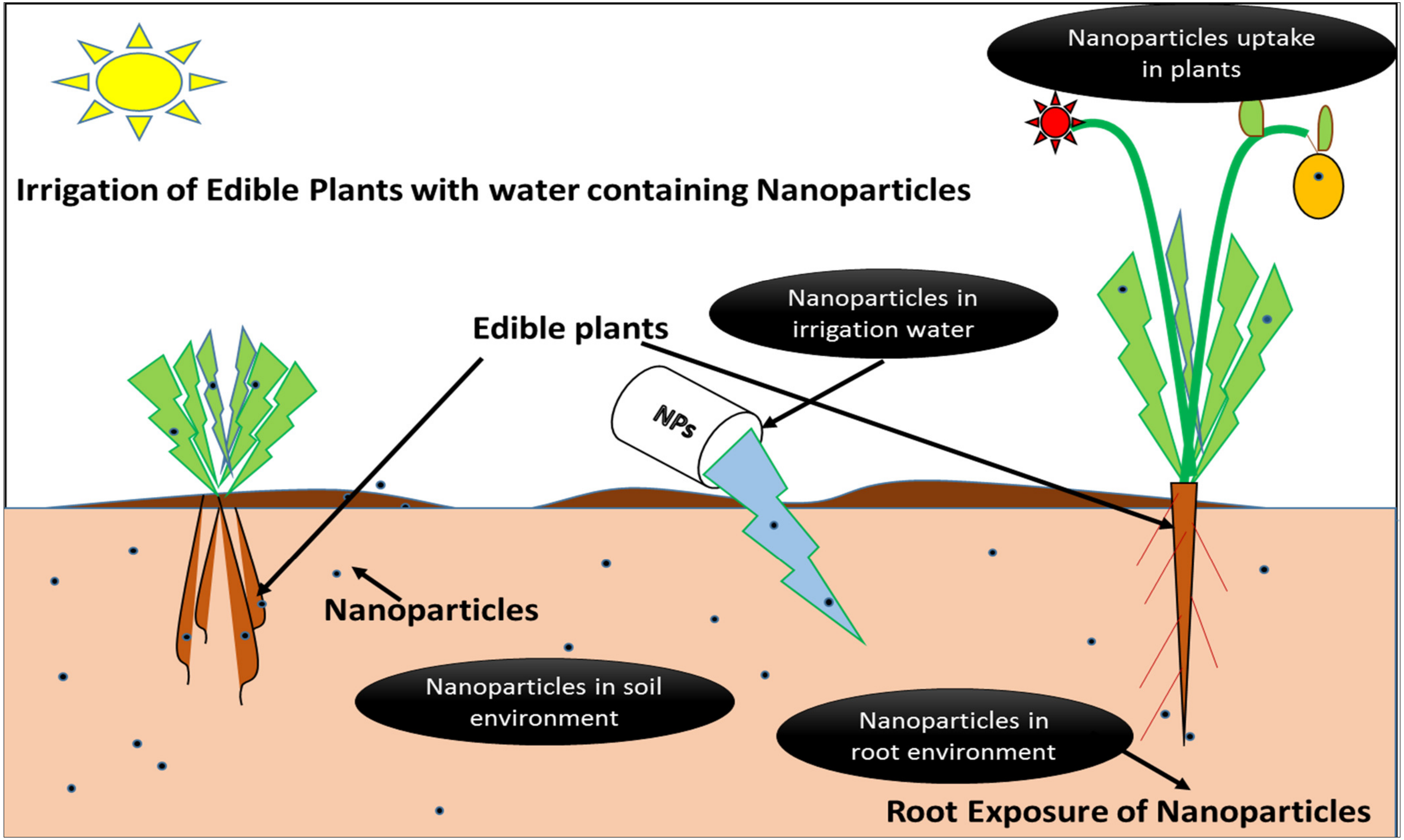
4. Viruses and bacterial pathogens

5. Bioaerosols

Some of these are not regulated

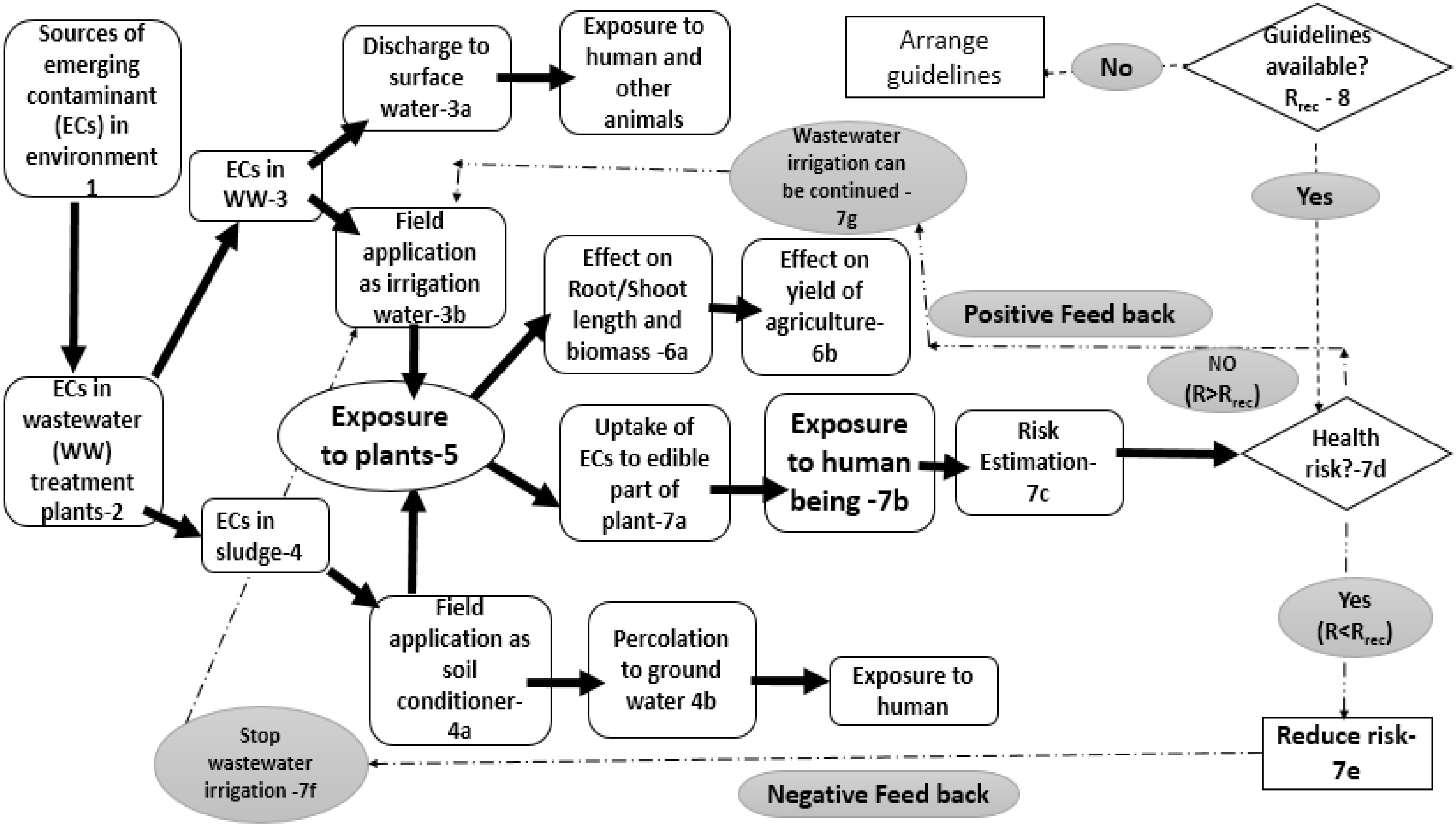
Snyder et al. (2007); Kumar and Xagoraraki (2010a); Boone and Gerba (2007)

Big- Picture Overview



Adapted from the Singh, D. and Kumar, A. **Understanding effect of interaction of nanoparticles with roots on uptake in plants**" Environmental Nanotechnology (Book Chapter - (in press)*

Pieces



Singh and Kumar (2014)

EWCs: Why to worry now?

1. Occurrence (although low concentration)
2. Toxic nature (long-term toxicity unknown)
3. Long-term implications unknowns
4. How to go about? Additional costs? Additional benefits? Cost-benefit? Can we afford?

Solution:

Environmental solutions with the help of all areas