Management and Reuse of Urban Effluents in Agriculture

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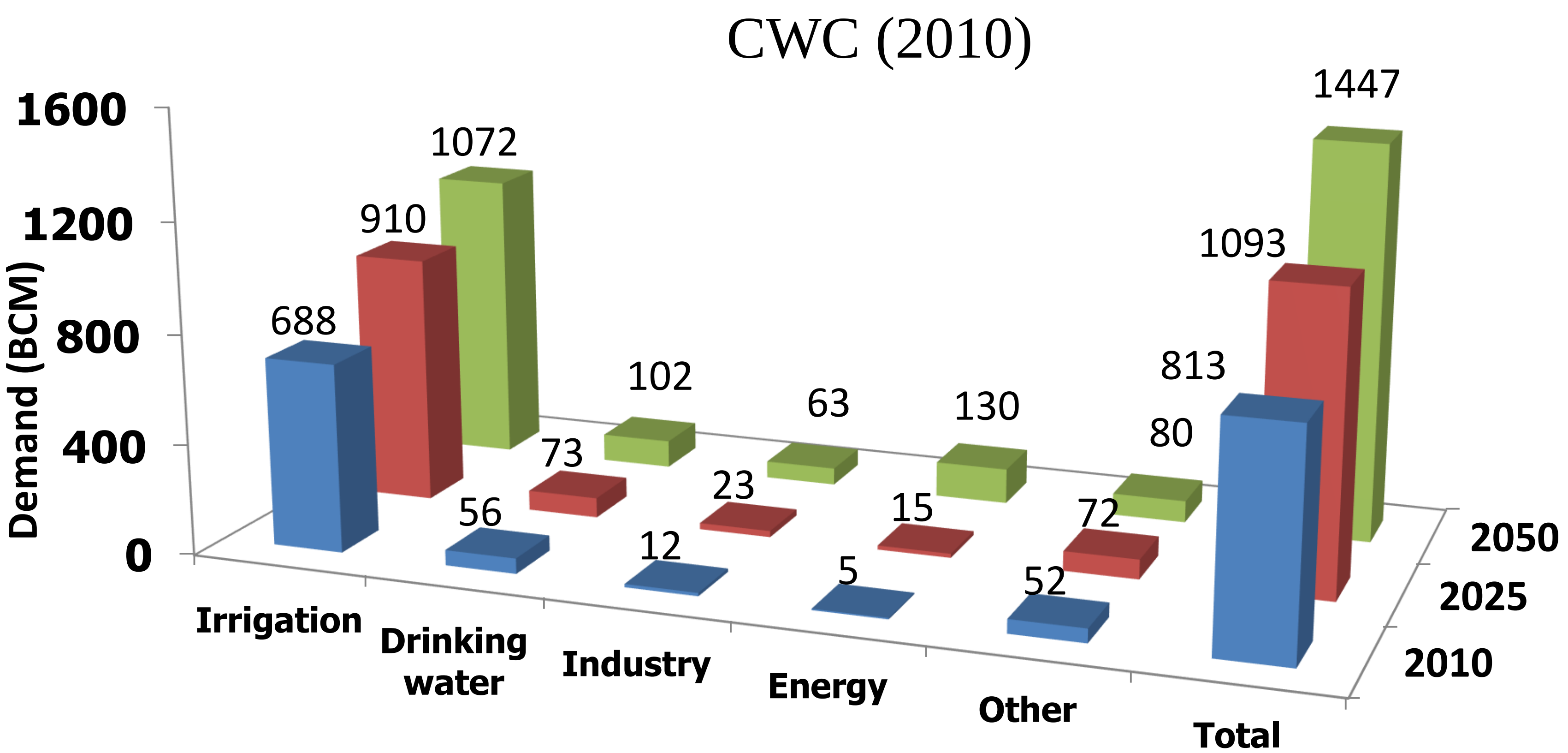

Availability of fresh water for agriculture will reduce from 83% in 1998 to 67% by 2050 (Gupta and Deshpande, 2004).

In fresh water scarcity, need to utilize marginal quality water including urban effluents for irrigation

Wastewater generation & treatment capacity

SEWAGE

- Generation: 72,368 MLD, (185 lpcd, 80% WW)
- Installed Tr. Cap: 31,841 MLD (44%)
- Operational Cap: 26,869 MLD (37%)
- Complied Tr.: 12197 MLD (17%) (*CPCB, 2021*)

FUTURE SCENARIO

- Urban population in 2051: 1093 million
- Waste water generated in 2051: 132 BLD.
- WW Generation in Rural: 50,000 MLD *(Bhardwaj, 2005)*

Composition of wastewater used for irrigation

Parameters	Range
pH	6.8-8.1
EC dS m^{-1}	0.26-8.1
BOD_5 (mg/l)	34-650
COD (mg/l)	86-1486
Total N (mg/l)	20-78
Inorganic P (mg/l)	0.35-26
Total K (mg/l)	4-50
Total coliforms (cfu/ml)	$4x10^5$- $9x10^7$
Faecal Coliform	$2x10^6$- $4x10^6$
Helminthic (Egg/l)	14-150
Cd (mg/l)	Tr.-0.16
Cr (mg/l)	Tr. 8.1
Ni (mg/l)	Tr.-0.37
Pb (mg/l)	Tr.-0.37

- Usually alkaline
- Low-medium salinity
- 99% water
- 1% solid
- 40–50% organics
- 30–40% inert materials (oven dry basis)

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Wastewater irrigation - hazard or lifeline?

COST

- **Contamination of natural resources and food chain**
- **Health Impacts (*Diarrhea, Typhoid, Ascariasis, filariasis, hookworm, roundworm*)**
- **Deaths >2.4 million year^{-1}**
- **DALY lost 70 million year^{-1}**

Heavy metal content in river water and crops

	Zn	Cu	Ni	Pb	Cd	Cr
River Ganga mg L^{-1} (Rai et al., 2012)						
Haridwar	0.1-0.2	0.0-0.2		0.1-0.7	--	0.04-0.2
Kanpur			BDL-6.4	0.4-5.8 (58)		BDL-39
Varanasi	0.5--0.6	1.7-2.0 (40)	0.1-0.9 (45)	--	0.1-0.2 (20)	0.2-1.0 (20)
Safe limit	5	0.05	0.02	0.1	0.01	0.05
Vegetables (mg/kg) Titagarh, WB, Gupta et al., 2007						
Cauliflower	97	16	59.3	31.0	13.8	86.8
spinach	154	35	69.2	49.8	14.6	34.8
Onion	125	18	47.4	34.3	11.5	46.4
Radish	139	28	62.7	57.6	17.8	78.0
Safe Limit	50	30	1.5	2.5	1.5	20

Long-term impacts of sewage on soil properties

- Increase in EC, ESP though not to the severity
- Increase in OC (0.1-0.8%), Increase in av. N, P, K (11, 44, 17 %)
- Improvement in MBMC and enzymatic activities (Lal et al., 2015)
- Sewage appli. rate determined by N content and crop water req

DTPA extractable heavy metal (mg kg^{-1}) in soils

Source	Tr.	Zn	Cu	Cd	Pb	Ni	Cr
Kolkata 50-60 yrs	SI	308	37	5.2	38	9	16
	NSI	3.6	2.4	0.01	4.2	4.2	3.1
Faridabad (20 yrs)	SI	56	43	1.1	61	3.6	7.5
	NSI	28	23	0.3	29	2.4	3.3
Perm. Lt.		2	5	0.5	5	2	2

SI: Sewage irrigation, NSI- Non-sewage irrigation

Relationship between heavy metal contents in water, soil, plant and milk along Musy river draining Hyderabad city

Element	Sewage	Soil		Plant		Milk
	Mean	Mean	High	Mean	High	Mean
Cd	0.025 (5)	0.4 (0.7)	27.0	0.8	20	0.06 (12.4)
Cr	Tr	1.3 (0.7)	12.2	4.9 (2.5)	92	0.8 (15.6)
Ni	0.062 (1.3)	2.8 (1.4)	46.3	4.3 (2.2)	100	0.2 (3.9)
Pb	0.2 (4.2)	12.6 (2.5)	60.9	19.2 (3.9)	100	0.7 (14.6)
Zn	0.003	11.0 (2.2)	87.8	44.9 (2.2)	88	6.3 (1.3)
Fe	Tr	75.9 (7.6)	92.7	4.6 (3.1)	84	11.9 (39.7)

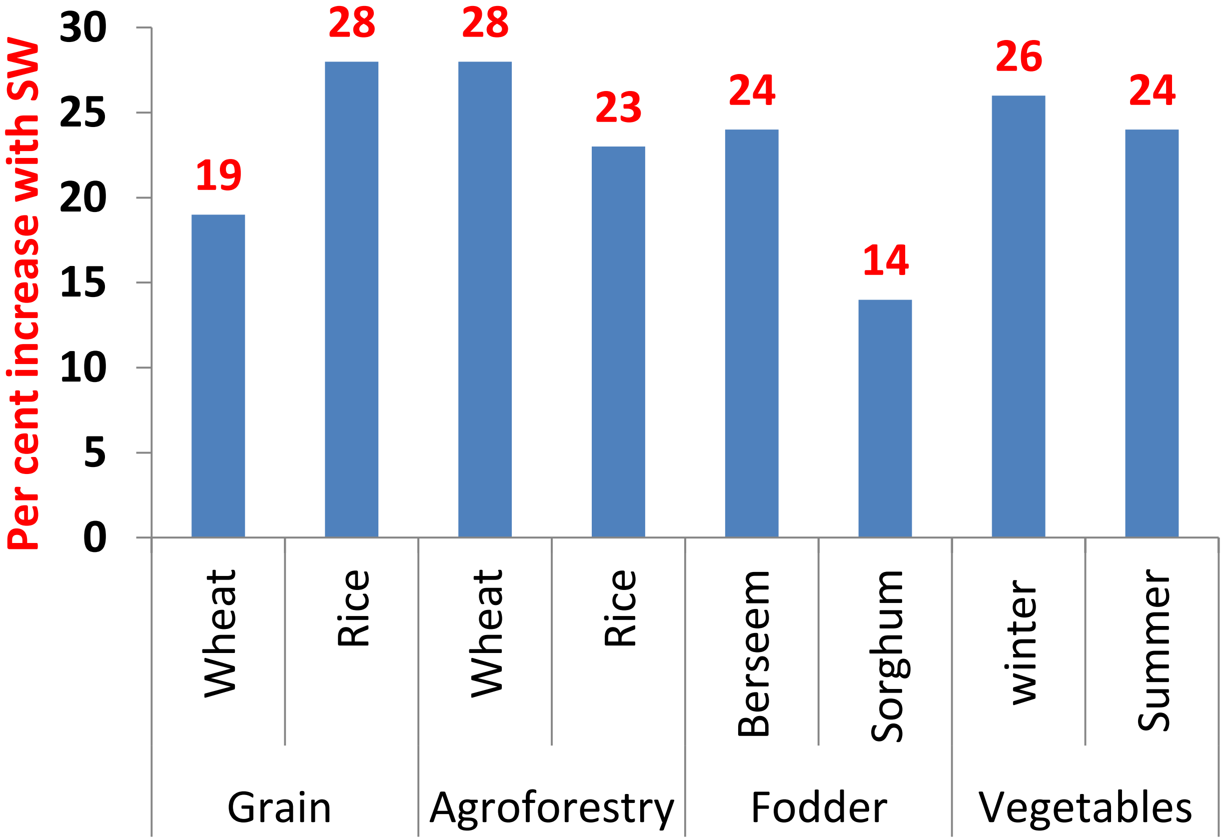
Fig. in parenthesis are no. of times more than normal limit, Tr Traces

- **Crops grown on heavy metal enriched soils show elevated uptake of these metals, though reductions in growth and economic yield are sparsely reported.**
- **Vegetables accumulate more of HM in edible parts than in cereals, pulses, oilseed**

Opportunities from wastewater irrigated land

- **Globally, wastewater irrigated area: 5-20 Mha**
- **No precise estimates available for India.**
- **2 M-ha irrigation (3% of net irrigated area),**
- **4 M ton nutrients (13% of fertiliser nutrients)**
- **280 M- man-days labour**
- **GHG by 74 million Mg CO_2-e per year**

Increase in Productivity in Major Cropping Systems



Minhas and KhajanchiLal, 2015

- **Productivity improvement: 14-28%**
- **8 years of untreated WW use showed that 60, 67, 25 and 80% of NP saved in FGPS, AFS, FPS and VPS, respectively**
- **PWEY FG (1.0)<FPS (1.8)<AFS (5.5)< VPS (19.9)**

Crops grown on wastewater use sites

Study area	Area (ha)	IW Quality	Type of crops
Ahmedabad	33600	Tr.+UTr	Veg., rice, cereals, fodder, fruit, cotton, ornamental
Delhi	1700	T+UTr	Vegetables
Hyderabad	10000	Tr.+UTr	Grass, rice, veg
Kanpur	2500	Tr.+UTr	Cereals, mustard, Veg. flowers
Kolkata	4887	UTr	Fish, paddy, veg

Monthly net Income (Rs/acre) from okra during summer
Delhi GW: Yield 1.5 T, Ex Rs. 7800, TI Rs. 15000, NI Rs. 7200
TWW: Yield 2.5 T, Ex Rs. 9300, TI Rs. 25000, NI Rs. 15700

Kanpur (Net Income INR/ha):
Fodder: GW 15370 WW 22960, Paddy: GW 4455 WW 10621

Winrock International India; YUVA 2006; Amerasinghe et al., 2013

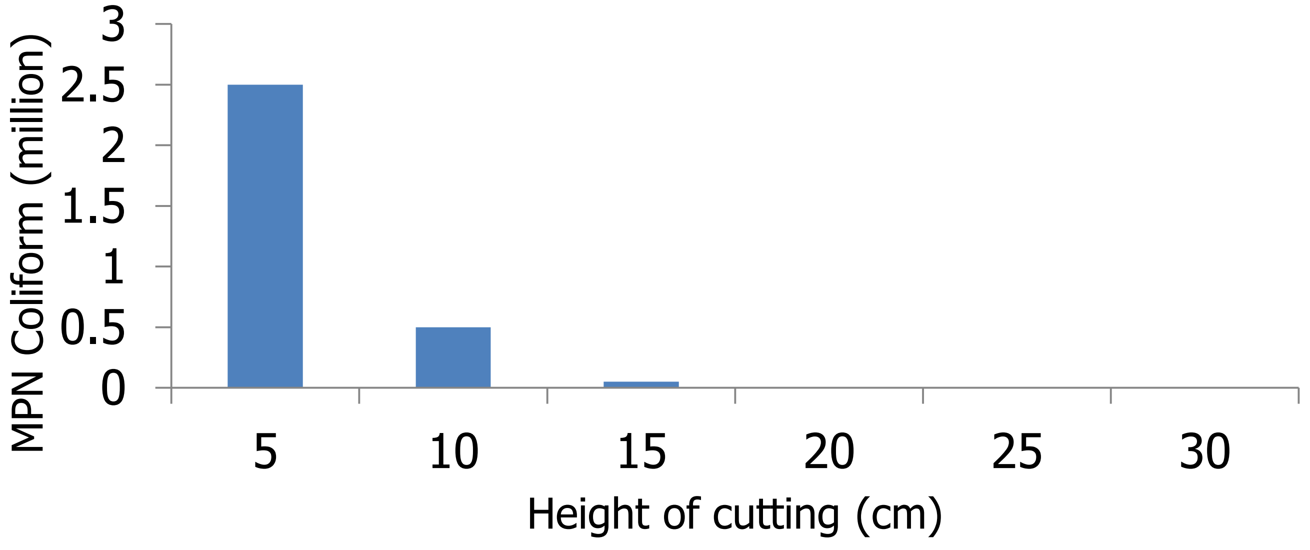
Yield (t/ha) and quality of vegetables irrigated with untreated (SW) and treated wastewater (TSW)

Tr.	Para	Okra	Cabbage	Baby corn	Lettuce	Brinjal	Broccoli	Green onion
SW	Yield	15.3	160	28	51.4	42.0	60	52.1
TSW		13.6	142	23.1	42.6	37.6	53.5	47.1
GW		12.3	138	22.1	40	35.5	53	41.4
% (TSW-SW)/TSW	Yield	-12.5	-12.7	-21.2	-20.7	-11.7	-12.1	-10.6
	Ni, Pb			-27.0		-35 to 45	-25 to33	- 34 to 36
	Pathogen			-73		-70	-68	
% (TSW-GW)/TSW	Yield	9.6	2.8	4.3	6.1	5.9	0.9	12.1

Apart from pathogen load, ADPWL and ADDL was also higher in SI crops

Management and remediation strategies

Conjunctive use of groundwater and wastewater



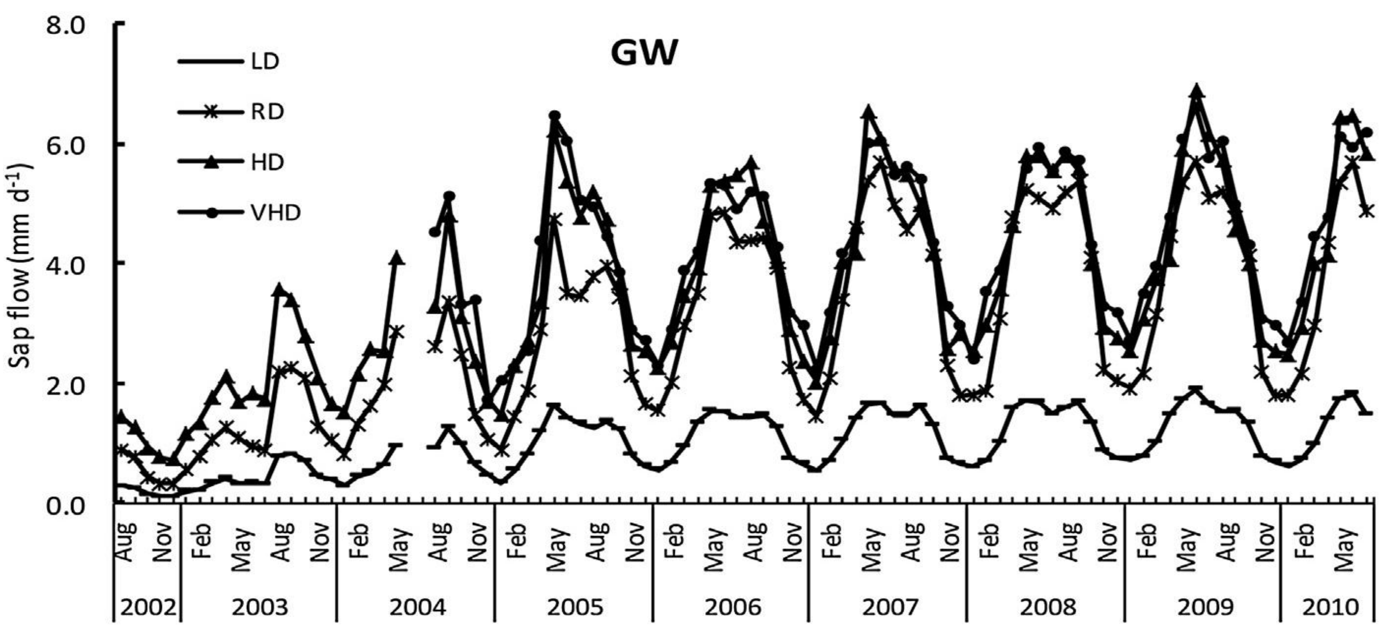
Effect of cutting management of sorghum fodder on coliform count

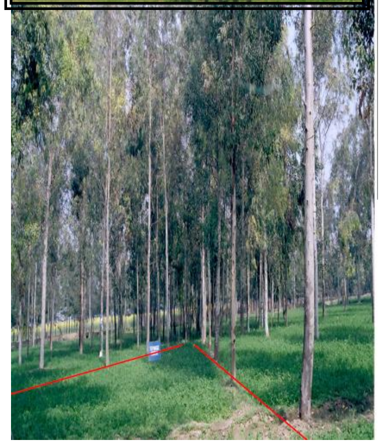
Effect of planting method and washings on *F. coliform* contamination of sewage irrigated ridge gourd

Treatment		Fecal coliform (MPN/100g)	
Bed planting		Range	Mean
	Middle	$< 2\text{-}5.0 \times 10^3$	8.1×10^1
	Side	$2.1 \times 10^2\text{-}2.6 \times 10^4$	3.4×10^2
Ridges		$< 2\text{-}2.4 \times 10^4$	8.5×10^2
Washings	0	$1.1 \times 10^3\text{-}2.6 \times 10^5$	1.3×10^4
	1	$< 2\text{-}3.0 \times 10^3$	1.3×10^2
	2	$< 2\text{-}1.4 \times 10^2$	1.1×10^1
	3	<2	<2
Cabbage after leaf removal	Nil	$<2\text{-}3.4 \times 10^3$	1.8×10^2
	1	$2\text{-}2.6 \times 10^3$	2.9×10^1
	2	<2	<2
	3	<2	<2

Biodrainage potential of Eucalyptus for wastewater disposal

Annual sap flow values of 7-10 years old Eucalyptus ranged between 418–473, 1373–1417 and 1567–1628 mm under low (163 stems ha^{-1}), recommended (517 stems ha^{-1}) and high (1993 stems ha^{-1}) stocking density using heat pulse method . Eucalyptus plantations are potential sites for year round disposal of sewage. The disposal rate is 1.5 fold than the annual crops ***(Minhas, Yadav and Khajanchi Lal, 2015)***





Monthly average of mean daily sap flow values per tree of Eucalyptus

Non-edible Alternatives

Medicinal & Aromatic Plants (Lemon grass)

(Lal et al., 2013)

- Herbage yield SW>CW>TW>GW
- Yield increased with N level.
- Oil content: 10.7-13.1 ml/kg of dry biomass.
- 50% saving of NPK in SW and CW
- No HM in essential oil

Cut Flowers

Cd removal: Chrysanthemum>gladiolus> marigold

Gladiolus: High tolerance and Cd content in saleable part holds potential to clean moderately contaminated soil

Lal et al., 2008)

Turfgrass

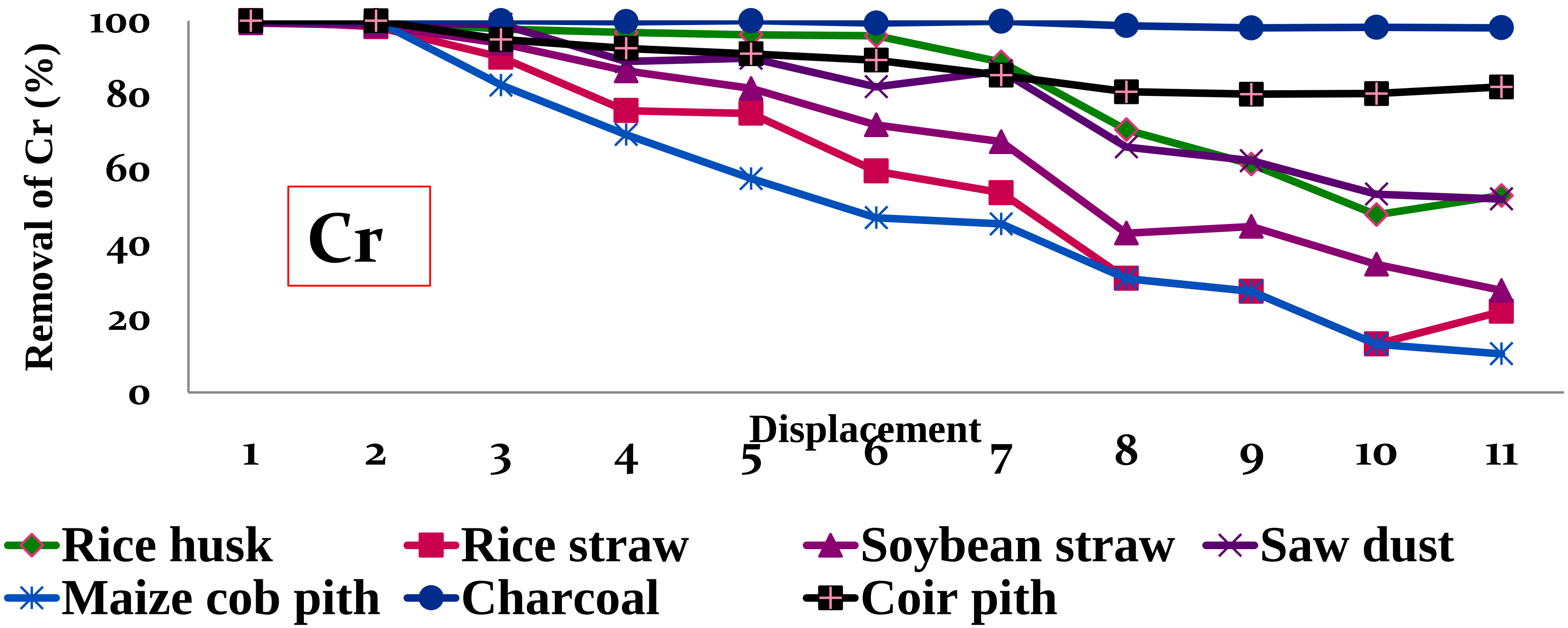
With Jute Base

Adapted to swamps, saltpans.
Tea tree oil : Essential oil extracted has camphoraceous odour , used in cosmetics, skin washes, antimicrobial properties

***Melaleuca alternifolia* or Tea tree**

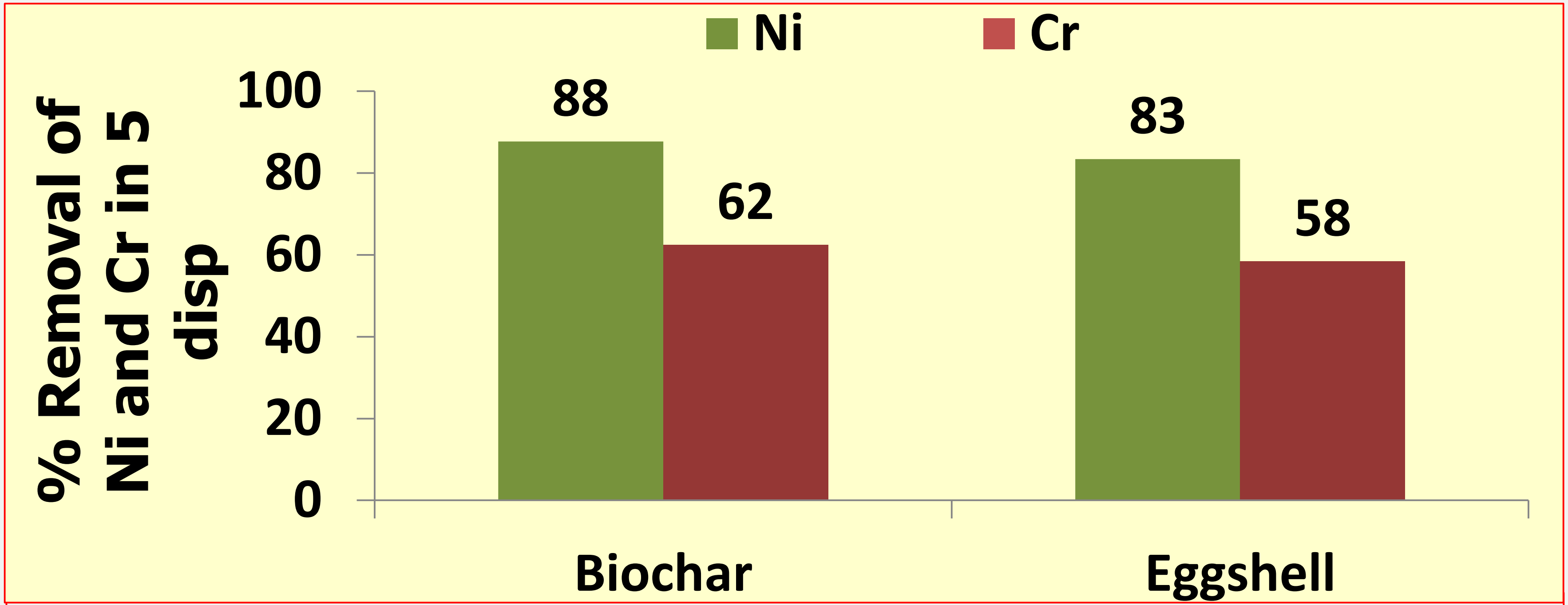
Potential of agri-waste bio-adsorbents for heavy metal removal from wastewater

Saw Dust | Rice Husk | Coir Pith | Rice Straw



% Removal of Cr using bioadsorbents

Bio-char for heavy metal removal from wastewater



Bio-char for heavy metal removal from wastewater

Major functional group OH, aliphatic C–H, C=O, COOH, C=C (aromatic)

Vermiculite Sandwiched Bed System (VSBS)

- **VSBS used media as pebbles, soil and vermiculite for treating tannery effluent**
- **Vermiculite layer of the VSBS system accumulated highest concentrations of Cr, Na and SO_4 from tannery effluent**

Constructed wetlands or Gravel Bed Hydroponics system

For reclamation of wastewater from biogas slurry, sewage and septic tanks

Three main units: Sedimentation tank, Treatment channels (Pharagmites), Crop channels (Oil seeds)

Removal efficiencies: Suspended solids: 90%, COD 84% and BOD 89%.

Pathogens (total and Feacal coliform, Salmonella and Shigella): 99%

- **Just 1% energy requirement**
- **Zero-chemical application**
- **Zero-sludge generation**
- **50-65% reduced treatment cost**

Kaur, R.2013

Bioremediation

Efficient microbes for nutrient and HM reduction

- ***Chlorella vulgaris* -95%** **N and P reduction in wastewater**

- **Microalgae pond with an anaerobic fixed-bed reactor- reduced 90, 84 and 86% of N, NH_3 and P from distillery wastewater**

- **BOD and COD reductions by**

  Bacterial culture: ***Enterobacter intermedius* ; *Alcaligenes cupidus***

  Fungal culture: ***Aspergillus flavus***

- **Efficient microbial for heavy metal removal**

Pb	***T. longibrachiatum***
Cd	***Fungal isoltae FS-7 for Cd***
Ni	***A. terreus for Ni***
Cr	***Fungal isolate FS13 for Cr***

Aspergillus

Safe & maximum allowable limits of trace elements (mg/kg)

	Cd	Cr	Cu	Ni	Pb	Zn
Soil	3-6	-	135-270	75-150	250-500	300-600
Water	0.01	0.05	0.05	-	0.1	5
Plant	1.5	20	30	1.5	2.5	50
Sewage sludge	5	-	300	50	100	1000

Wastewater reuse Indian standards

	CPHEEO			MoEFCC
	Hort.	Edible crops	Cooked/ Non-edible	
pH	6.5-8.3	6.5-8.3	6.5-8.3	6.5-9.0
EC dS/m	<2.1	<2.1	<2.1	--
BOD (mg/l)	10	10	20	10
COD (mg/l)	AA	AA	30	50
TN (mg/l)	10	10	10	10
TP (mg/l)	2.0	2.0	5.0/2.0	--
Coliform (MPN/100ml)	Nil	Nil	230FC	<100FC
HE (eggs/100ml)	<1	<1	<1	--

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Policy guidelines

- Treatment at source (CETP for industries), No mixing
- Strengthening of sewage farms
- Crop restriction (only crops that are not eaten directly)
- Waste application techniques (drip irrigation) and allow sufficient time for pathogen die-off prior to harvest.
- Exposure control (protective equipment, good hygiene)
- Produce washing/rinsing/disinfection and cooking
- Introduction of wastewater use permit for farmers
- Regular awareness campaign
- Promote decentralized, affordable treatment systems
- Polluter pays the principal

Thank You