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Wastewater Management and Reuse for Agriculture and Aquaculture in India

By

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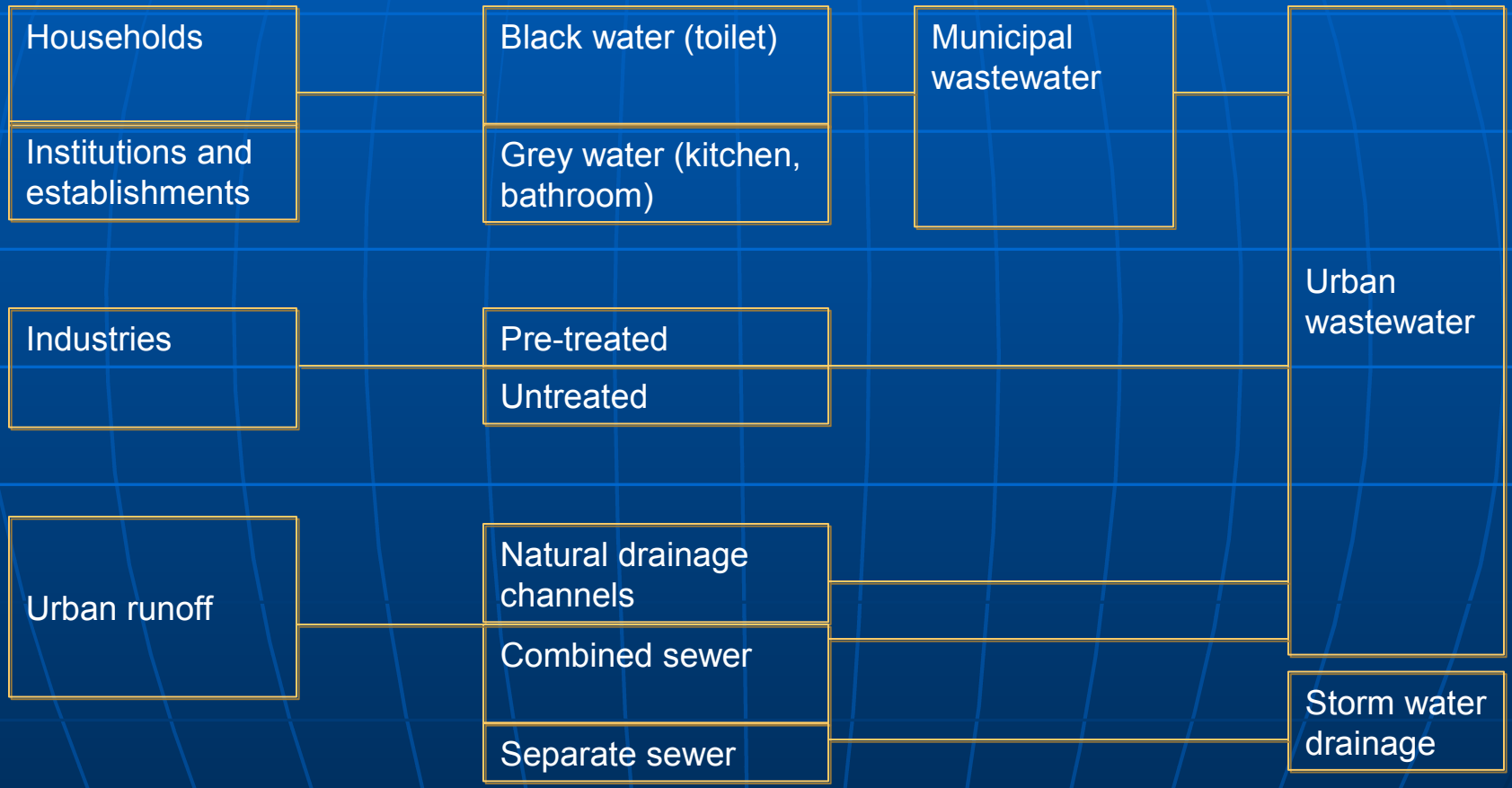
Urban Wastewater Components

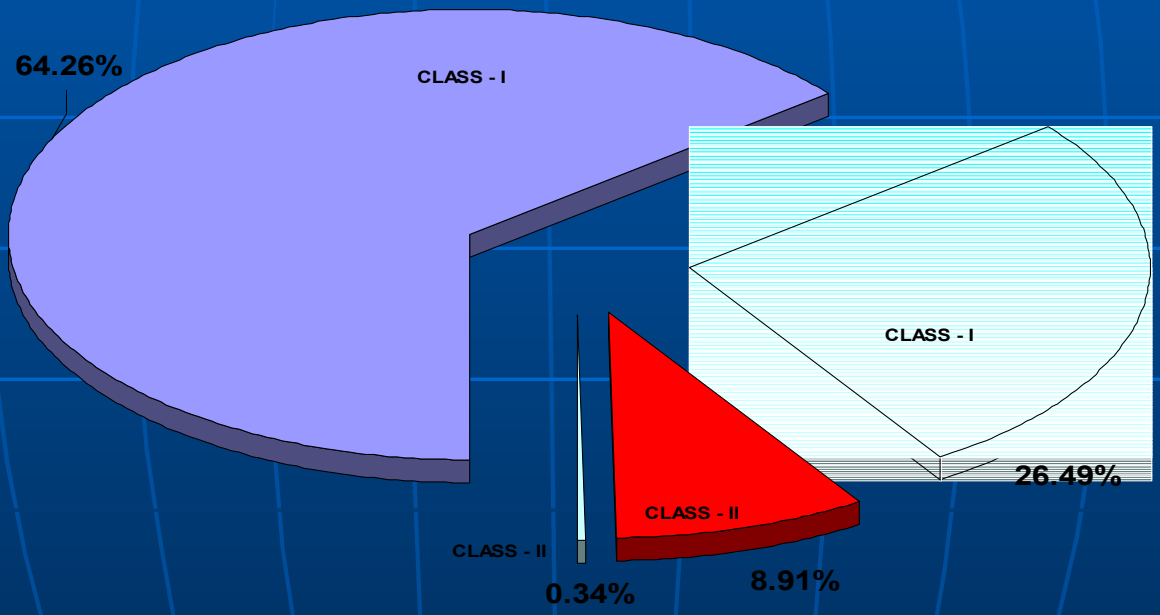


Impacts on Untreated return after Use

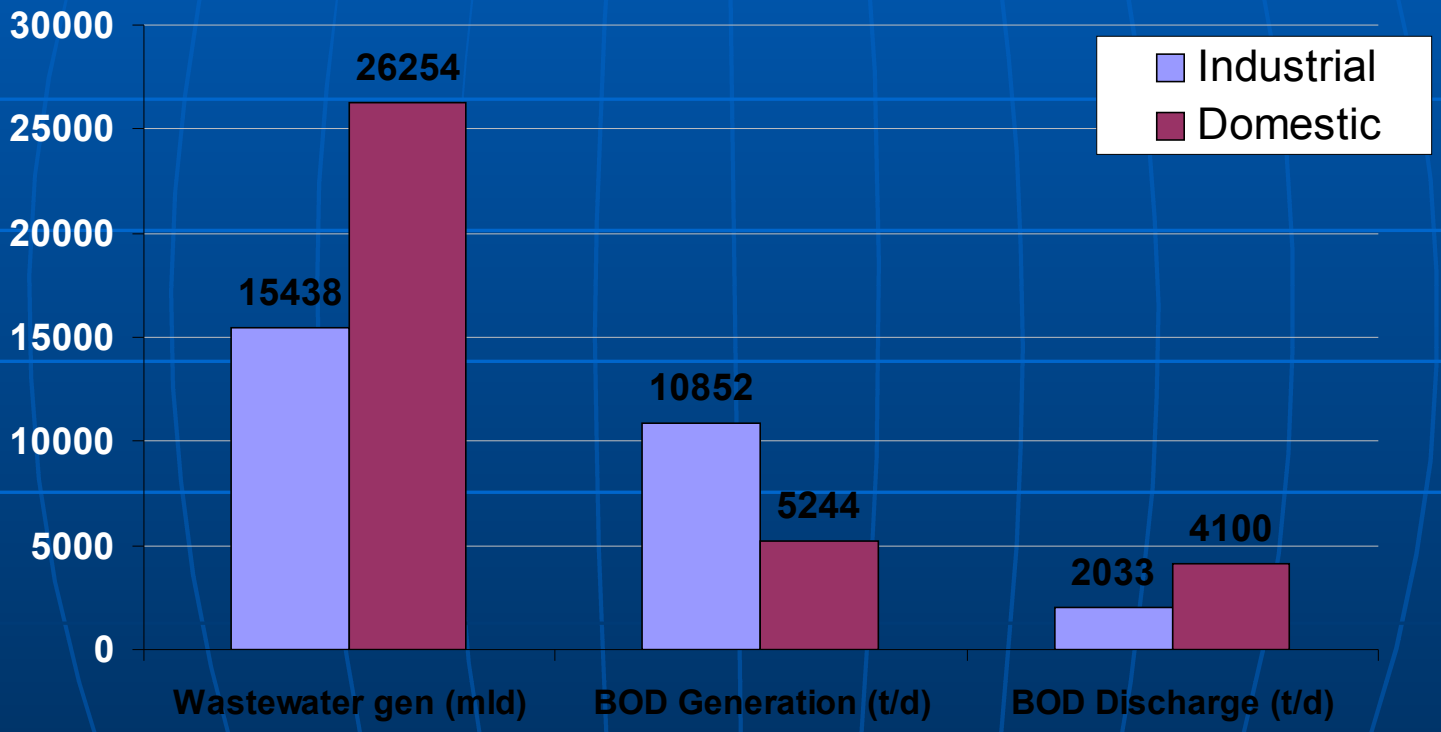
- **Domestic**: 423 Class I Cities and 499 Class II towns harboring population of 20 Crores generate about 26254 mld of wastewater of which only 6955 mld is treated. (*about 25%)*
- **Industrial**: About 57,000 polluting industries in India generate about 13,468 mld of wastewater out of which nearly 60% (generated from large & medium industries) is treated.
- Non-point sources also contribute significant pollution loads only in rainy season with good flows in river system.

Basic Source: CPCB / MoEF

Wastewater Generation and Treatment (mld) in Class - I and Class - II Cities in India



Comparision of pollution load generation from domestic and industrial sources



Generation of Waste Water - India

- Domestic sewage: Major source of pollution for surface water. Contribute pathogens and helps depletion of oxygen in water bodies.
- Sewage, agricultural run-off & industrial effluents contribute large amount of nutrients in surface water causing euotrophication
- Pesticides consumption is about 1,00,000 tonnes/year of which AP, Haryana, Punjab, TN, WB, Gujarat, UP and Maharashtra are principal consumers.
- Industrial waste gets mixed with municipal waste and thus pollute the waterbodies and soil further.

Types of Reuse of Waste Water

- **Urban reuse** – the irrigation of public parks, schools yards, highway, and residential landscapes, for fire protection and toilet flushing in commercial and industrial buildings.
- **Agricultural reuse** – irrigation of non-food/food crops, commercial nurseries, and pasture lands.
- **Aquaculture use-** fish cultivation
- **Recreational impoundments** – such as ponds and lakes.
- **Environmental reuse** – creating artificial wetlands/natural wetlands
- **Industrial reuse** – process or makeup water and cooling tower water.

Wastewater Reuse

Advantages:

- Capital costs are low to medium for most systems and are recoverable in a very short time; this excludes systems designed for direct reuse of sewage water.
- Operation and maintenance are relatively simple except in direct reuse systems where more extensive technology quality control are required.
- Provision of nutrient-rich wastewaters can increase agricultural production in water-poor areas.
- Pollution of rivers and ground waters may be reduced.
- In most cases, the quality of the wastewater, as an irrigation water supply, is superior to that of well water.

Wastewater Reuse

Disadvantages:

- Reuse of wastewater may be seasonal in nature, resulting in the overloading of treatment and disposal facilities during the rainy season
- Health problems such as water-borne diseases and skin irritations, may occur in people coming into direct contact with reused wastewater.
- Gases, such as sulfuric acid, produced during the treatment process can result in chronic health problems.
- Application of untreated wastewater as irrigation water or as injected recharge water may result in groundwater contamination.

Example of Human Waste use

Ancient practice in Eastern Asia and Western Pacific to improve soil fertility

Wastewater use in agriculture	Australia, Federal Republic of Germany, India, Mexico, Tunisia.
Excreta use in agriculture	China, Guatemala, India, United States of America
Wastewater and excreta use in aquaculture	India, Indonesia, Bangladesh

Composition of Wastewater

- Normal domestic and municipal wastewater is composed of 99% water and 0.1% suspended, colloidal and dissolved solids- organic and inorganic compounds, including macronutrients such as nitrogen, phosphorous and potassium as well as essential micro-nutrients.
- Industrial effluents may add toxic compounds, but not in detrimental quantities, and only the boron sensitivity of the crop being irrigated needs consideration.
- Excreta treatment not only destroys pathogenic microorganisms but also converts these nutrients to forms more readily usable by crops and stabilizes the organic matter, producing a better soil conditioner.

Use of Agriculture and Aquaculture in India

City	Direct Use (ha)	Indirect use (ha)	Vegetables	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Ahmedabad	890			Yes	Yes	Yes				Juwarkar et al 1988
Amritsar	1.214				Yes					Juwarkar et al 1988
Bhilai	607		Yes	Yes	Yes					Juwarkar et al 1988
Bikaner	40		Yes		Yes					Juwarkar et al 1988
Calcutta		12.900	Yes	Yes					Yes	Mara and Cairncross 1989; Edwards 2001
Delhi	1.214		Yes		Yes					Juwarkar et al 1988; Farooqui 2002
Gwalior	202		Yes	Yes	Yes					Juwarkar et al 1988
Hubli-Dharwad			Yes			Yes	Yes			
Hyderabad	110	40,500	Yes	Yes		Yes	Yes	Yes	Yes	Buechler and Devi 2002

Use of Agriculture and Aquaculture in India

City	Direct Use (ha)	Indirect use (ha)	Vegetables	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Jamshedpur	113				Yes	Yes				Juwarkar et al 1988
Kanpur	1.300		Yes	Yes	Yes					Strauss and Blumenthal 1990
Lucknow	150		Yes	Yes						Juwarkar et al 1988
Madras	133					Yes				Juwarkar et al 1988
Madurai	77					Yes				Juwarkar et al 1988
Nagpur	1.500		Yes	Yes	Yes	Yes				Juwarkar et al 1988
Trivandrum	37					Yes				Juwarkar et al 1988
Vadodra		14.567			Yes			Yes		IWMI (Bhamoriya 2002)

Use of Waste Water in Irrigated Agriculture reduces the burden on Fresh water withdrawal and agencies had been propagating best options in the recent past

Advantage: 80-90 percent of NO3-N is removed when contaminated water passes through (paddy) fields

Use of Sewage in Agriculture: Some Experiences from Haryana Study by Central Saline Soil Research Institute

Advantages

- Irrigation potential (0.4-1.2 Mha)
- Nutrients potential (0.30 M ton)
- Independent of electricity
- Continuous and thus more reliable than rain/canal water

Characteristics of sewage (SW) and tubewell (TW) waters

Parameters	Units	SW	TW_1	TW_2	TW_3	TW_4	TW_5
Distance (m)	Along		250	500	750	1000	1000
	Longt.		250	250	500	500	600
pH		7.4	7.6	8.4	707	7.2	7.3
EC	(dS m^{-1})	1.74	1.02	1.01	1.12	1.02	1.46
BOD	(mg L^{-1})	169	12	3	7	5	3
COD	(mg L^{-1})	382	ND	6.7	6.7	ND	ND
PO_4-P	(mg L^{-1})	26	1.0	ND	ND	ND	ND
NH_4-N	(mg L^{-1})	3.5	1.4	2.45	ND	ND	ND
NH_3-N	(mg L^{-1})	28	ND	1.05	1.4	2.8	2.4
Cd	(mg L^{-1})	0.02	ND	ND	ND	0.02	ND
Pb	(mg L^{-1})	0.19	0.25	0.05	0.18	0.22	0.35
Ni	(mg L^{-1})	0.12	0.03	ND	0.07	ND	0.04
RSc	(mg L^{-1})	3.4	5.4	6.3	3.2	2.9	3.2

*ND – not detected

Effect of sewage irrigation on yield and quality of cabbage

Dose (%)o		Yield	Density	PLW_{10}	Decay loss
N	P	(t/ha)	(g cm^{-3})	(%)	(%)
Sewage irrigation					
50	50	26.0	1.02	3.4	5.0
50	100	30.0	0.93	2.5	6.1
100	50	35.0	0.97	3.2	5.5
100	100	38.0	1.02	3.7	5.3
Mean		32.2	0.98	3.2	5.4
Tubewell water					
50	50	16.9	0.86	3.1	3.9
50	100	24.0	0.87	2.2	2.9
100	50	29.0	0.94	2.9	2.2
100	100	34.9	0.87	2.7	Nil
Mean		23.7	0.88	2.7	2.2

PLW_{10} denoted physiological weight loss after 10 days of storage

Contents of heavy metals (mg/kg) in different parts of vegetable plants

Vegetables	Plant part	Pb	Cd	Cr	Ni
Cauliflower	Head	70	Tr	Tr	7.9
	Leaf	150	1.5	0.9	3.4
	Stem	45	Tr	Tr	6.0
	Room	60	1.0	0.8	8.9
Radish	Leaf	30	Tr	0.9	3.6
	Root	12	1.2	1.2	15.0
Brinjal	Fruit	90	Tr	2.0	Tr
	Leaf	64	Tr	1.4	Tr
	Stem	9	1.3	2.3	Tr
	Root	38	0.6	2.0	Tr
Maize	Fruit	Tr	Tr	Tr	Tr
	Leaf	Tr	Tr	49.0	Tr
	Stem	3	1.2	Tr	Tr
	Root	60	0.9	49.0	Tr

*Mean of 10 samples; Tr-Traces

Source: Gupta (2002)

Conclusion of the study by CSSRI, Karnal

- Excessive contents of toxic ions like Cd, Ni, Cr etc and those of pathogenic bacteria in sewage pose serious health risks.
- STP reduces BOD, however, ineffective to reduce the levels of dissolved ions and pathogens.
- Base studies show that sewage from domestic origin is being used as source or irrigation as well as plant nutrients allowing the farmers to reduce or even eliminate chemical fertilisers.
- Mostly wastewater is used for vegetable cultivation, creating employment, however, needs planning to minimize risks to GW contamination.

Conclusion of the study by CSSRI, Karnal

- Enhanced organic matter in sewage-irrigated soils reduces bio-availability of toxic ions through enhanced absorption capacity of soils.
- Analysis of different plant parts show that in the most of crops/vegetables, the edible parts are lesser contaminated thus reduce health risks from their use.
- Further research information is needed on loading rates, irrigation application techniques, absorption capacity of soils and quality to produce to develop appropriate control measures.

Health Risks due to Wastewater Use

UNEP/WHO Guidelines for safe use of wastewater and excreta in agriculture and aquaculture suggests an actual risk when:

- Either an infective dose of an excreted pathogen reaches a field or pond, or the pathogen multiplies in the field or pond to form an infective dose.
- The infective dose reaches a human host
- The host becomes infected; and
- The infection causes disease or further transmission.

Environmental Aspects

- Major pollution problems such as dissolved oxygen depletion, eutrophication, foaming and fish kills can be avoided.
- Conservation or more rational usage of freshwater resources, especially in arid and semi-arid areas; fresh water for urban demand, wastewater for agriculture.
- Reduced requirements for artificial fertilizers.
- Soil conservation through humans build-up and prevention of land erosion.
- Desertification control and desert reclamation through irrigation and fertilization of tree belts.
- Improved urban amenity through irrigation and fertilization of green spaces for recreation and visual appeal.

Epidemiological Evidence

When untreated wastewater is used to irrigate crops, there is a high actual health risk from intestinal nematodes and bacteria but little or no risk from viruses. Thus, treatment of wastewater is a highly effective method of safeguarding public health.

- Crop fertilization with untreated excreta causes significant excess intestinal nematode infection in crop consumers and field workers.
- There is evidence that excreta treatment can reduce the transmission of nematode infection.
- Excreta fertilization of rice paddies may lead to excess schisto-somiasis infection among rice farmers
- Cattle may become infected with tapeworm but are unlikely to contract salmonellosis.

Microbiological Criteria :Agricultural reuse

- For restricted irrigation (all crops except salad crops and vegetables eaten uncooked), WHO recommends the treated wastewater should contain no more than one human intestinal nematode egg/litre such as *human roundworm, whipworm, and hookworms*
- For unrestricted irrigation (salad crops and vegetables eaten raw) WHO recommends the same helminth egg value, and no more than 1000 faecal coliform bact. /100 ml of treated wastewater.
- The guideline limit of faecal coliform bacteria in unrestricted irrigation (not more than 1,000 faecal coliform bacteria/100 ml) is valid, but for restricted irrigation is not more than 10,000 faecal coliform bacteria/100ml is recommended if flood irrigation is used or children are exposed.

Microbiological Criteria: Aquacultural reuse

Aquaculture means "water farming", that covers fish culture and aquatic vegetable culture. WHO recommends that the treated wastewater used for aquaculture should not contain and any viable human termatode eggs (zero per litre), and the fish or aquatic vegetable pond should not contain more than 1000 faecal coliforms per 100 ml. The major human trematodes are:

- *Schistosoma* spp.,
- *Clonorchis sinensis,* and
- *Fasciolopsis buski.*

Resource Planning
- Involve Agriculture, Health, Urban development

Improvement of Existing Practices:
- Enforcement of Guidelines
- Involve all stake-holders
- Monitoring

Policy Options:
- Treatment
- Crop restriction
- Application
- Human exposure control

New Schemes:
- Involving stake-holders
- Enforcement of Guidelines

Monitoring & Evaluation:
- Health Protection measures
- Waste quality
- Crop quality
- Disease Surveillance

PLANNING AND IMPLEMENTATION

Project Planning:
- 20 year planning
- Farmers security of tenure of land
- Professional Inputs
- Joint Management
- Support services – health, marketing, agricultural credit machinery

Economic and Financial:
- Economic appraisal
- Financial planning for all policy options

Legislation:
- Allocation of Power
- New Institution, if needed
- Roles and relationship defined
- Land tenure right
- Public Health
- Agricultural

Some Suggestions for better planning and Implementation - Crop Selection

Category A

- Protection required for consumers, agricultural workers, and the general public. This includes crops likely to be eaten uncooked, spray-irrigated fruits, and grass (sports fields, public parks and lawns)

Category B

- Protection required for agricultural workers only. This includes cereal crops, industrial crops (such as cotton and sisal), food crops for canning, fodder crops, pasture and trees.

Some Suggestions for better planning and Implementation - Crop Restriction

- a law-abiding society exists or the law is strictly enforced;
- a public body controls the allocation of wastes;
- as irrigation project has a strong central management;
- there is adequate demand for the crops allowed under crop restriction, and they fetch a reasonable price;
- there is little market pressure in favour of excluded crops.

Some Suggestions for better planning and Implementation -Wastewater Application

- by flooding (border irrigation): almost all the land surface is wetted;
- by means of furrows: only part of the ground surface is wetted;
- by means of sprinklers: the soil and crops are wetted in much the same way as they are by rainfall;
- by subsurface irrigation: the surface is only slightly wetted, if at all, but the subsoil is saturated; and
- by means of localized (trickle, drip or bubbler) irrigation: water is applied to the root zone of each individual plant at an adjustable rate

Key R&D Questions on Reuse of Waste Water

- What are the dangers of uncontrolled wastewater irrigation in terms of public health and pollution?
- How best the nutrient value of wastewater be assessed? Impose restrictions as appropriate.
- What sustainable practices are being used that can be transferred to benefit poor rural areas?
- From a public health perspective, which crops are the best candidates for wastewater irrigation and which should be avoided?
- *Keeping of course India's desire to move on WTO regimes by participation in the export markets, steadily and aggressively in due course..*

Thank You