MCGM CENTRE FOR
MUNICIPAL CAPACITY BUILDING AND RESEARCH®

(An Initiative by Brihanmumbai Municipal Corporation)

State Level Training Institute for Urban Local Bodies

In association with

CENTRE FOR WATER AND SANITATION, CEPT UNIVERSITY

Organizes Training on

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Course Code : ENV3RE11

11, 12 & 13 Jan 2023 (3 Days Residential Program)

MCMCR POWAI CAMPUS, MUMBAI 400 072

Program Module:

Day – 1 (Classroom Sessions)	Day – 2 (Technical Exhibitions)	Day – 3 (Field Visit)
Reuse & Recycle of Wastewater under AMRUT 2.0 & SBM-U 2.0	Presentations by Exhibitors	Banganga STP, Mumbai
Standards for Recycle & Reuse of Wastewater	Technical Exhibition	Colaba STP, Mumbai
Wastewater Technology Selection Parameters for Recycle & Reuse of Wastewater		Certificate Distribution
Nature Based or Mechanised Wastewater Treatment Technologies Selection for 'Fit for Purpose' application		
Business Model for Recycle & Reuse of Wastewater		

11, 12 & 13 Jan 2023 (3 Days Residential Program)
MCMCR POWAI CAMPUS, MUMBAI 400 072

AMRUT 2.0

Making Cities Water Secure

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

AMRUT 2.0 & SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Indian Constitution - 243W

Indian Constitution - 243W

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Indian Constitution - 243W

243W. Powers, authority and responsibilities of Municipalities, etc.-

Subject to the provisions of this Constitution, the Legislature of a State may, by law, endow-

(a) the Municipalities with such powers and authority as may be necessary to enable them to function as institutions of self-government and such law may contain provisions for the devolution of powers and responsibilities upon Municipalities, subject to such conditions as may be specified therein, with respect to-(i) the preparation of plans for economic development and social justice;**(ii) the performance of functions and the implementation of schemes as may be entrusted to them including those in relation to the matters listed in the Twelfth Schedule**;

(b) the Committees with such powers and authority as may be necessary to enable them to carry out the responsibilities conferred upon them including those in relation to the matters listed in the Twelfth Schedule.

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Indian Constitution - 243W

"TWELFTH SCHEDULE (Article 243W)

1. Urban planning including town planning.
2. Regulation of land-use and construction of buildings.
3. Planning for economic and social development.
4. Roads and bridges.
5. **Water supply for domestic, industrial and commercial purposes.**
6. **Public health, sanitation conservancy and solid waste management.**
7. Fire services.
8. Urban forestry, protection of the environment and promotion of ecological aspects.
9. Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded.
10. Slum improvement and upgradation.
11. Urban poverty alleviation.
12. Provision of urban amenities and facilities such as parks, gardens, playgrounds.
13. Promotion of cultural, educational and aesthetic aspects.
14. Burials and burial grounds; cremations, cremation grounds and electric crematoriums.
15. Cattle pounds; prevention of cruelty to animals.
16. Vital statistics including registration of births and deaths.
17. Public amenities including street lighting, parking lots, bus stops and public conveniences.
18. Regulation of slaughter houses and tanneries."

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

SDG 2030

SDG 2030

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

SDG 2030

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- **INDIAN CONSTITUTION 243W**
- **SDG 2030**
- **NUSP 2008**
- SLB
- **AMRUT 2.0**
- **SBM U-2.0**

NUSP 2008

NUSP 2008

NUSP 2008

Sanitary and Safe Disposal

100 % of human excreta and liquid wastes from all sanitation facilities including toilets must be disposed of safely. In order to achieve this goal, the following activities shall be undertaken:

a. Promoting proper functioning of network-based sewerage systems and ensuringconnections of households to them wherever possible;
b. **Promoting recycle and reuse of treated waste water for non potable applicationswherever possible will be encouraged.**
c. Promoting proper disposal and treatment of sludge from on-site installations (septictanks, pit latrines, etc.);
d. Ensuring that all the human wastes are collected safely confined and disposed ofafter treatment so as not to cause any hazard to public health or the environment.

NUSP 2008

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

SERVICE LEVEL BENCHMARKS

Sewage Management (Sewerage and Sanitation)	
Proposed Indicator	Benchmark
Coverage of toilets	100%
Coverage of sewage network services	100%
Collection efficiency of the sewage network	100%
Adequacy of sewage treatment capacity	100%
Quality of sewage treatment	100%
Extent of reuse and recycling of sewage	20%
Efficiency in redressal of customer complaints	80%
Extent of cost recovery in sewage management	100%
Efficiency in collection of sewage charges	90%

SLB

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Atal Mission for Rejuvenation and Urban Transformation 2.0

AMRUT 2.0

AMRUT 2.0

Making Cities Water Secure

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

The **AMRUT 2.0** guidelines have been formulated with the aim of assisting States/ UTs for making our cities **Aatma Nirbhar** and **'water secure'**. Several stakeholder consultations across 36 States/ UTs have been conducted as well as inputs from the key players such as development banks, private sector players, water sector consultants as well as NGOs have been taken into consideration.

MoHUA in partnership with States aims to achieve functional tap connections to all households, undertaking water source conservation/ augmentation, rejuvenation of water bodies and wells, recycle/re-use of treated used water and rainwater harvesting, **Mission will extend the ease of living by upscaling universal coverage in water supply from 500 cities to about 4,800 statutory towns** and universal coverage of sewerage and septage management to 500 AMRUT cities,

Mission has a reform agenda with focus on strengthening of urban local bodies and water security of the cities. Major reforms are reducing non-revenue water to below 20 %; **create a 'new tap of water' through recycle of treated used water to meet at least 20% of total city water demand and 40% for industrial water demand at State level**; 24x7 water supply; raising funds through issuance of municipal bonds and rejuvenation of water bodies.

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Mission has a reform agenda focused towards financial sustainability and water security of ULBs. **Meeting 20% of water demand through recycled water**, reducing non-revenue water to less than 20% and rejuvenation of water bodies are major water related reforms. Reforms on property tax, user charges, and enhancing credit worthiness of ULBs and urban planning are other important reforms.

Capacity building programs will be conducted for all stakeholders including contractors, plumbers, plant operators, students, women and citizens. **Technical institutions will be roped in for assessment of Mission outcomes.**

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Admissible elements of Projects

- Sewerage network
- Interception and Diversion (I&D) infrastructure
- Sewage Treatment Plants (STPs)
- **Tertiary Treatment with end-to-end reuse plan (preferably in PPPmode)**
- Faecal sludge and Septage management (FSTP cum STP Plant & collection mechanism)
- Provision/ augmentation and rehabilitation of s**ewerage systems with end-to-end treatment and reuse**
- **Tapping of used water for recycling**
- **Identifying the bulk users of recycled used water and facilitating sale of used water to potential users** (e.g. industrial clusters such as textile/ leather/ paper/power plants/railways, etc.)
- Smart solutions like SCADA•Last mile connectivity to households (Not exceeding ₹3000 per HH)

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Implementation of projects

Projects as per approved SWAP will be planned, tendered, awarded and implemented by ULBs. Where ULBs do not have adequate capacity, specialized parastatal agencies will implement the projects. In order to ensure efficient implementation of projects, the States/ UTs, ULBs should follow an approach wherein end-to-end support for project design, development, implementation and management is provided to ULBs/ States/ UTs by external entities (PDMCs). **Maintenance and upkeep of the assets created will be responsibility of the State/ UT/ ULB.** Smart elements will be part of the projects.

Projects being proposed in State Water Action Plan (SWAP) will have O&M for at least five years to be funded by way of levy of user charges or other revenue streams. Project cost will exclude O&M. **ULBs shall fund O&M through an appropriate cost recovery mechanism** in order to make them self-reliant and cost effective.

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Recycle of treated used water to meet at least 20% of total city water demand and 40% of industrial water demand at State level

Issue of Policy Guidelines by State for Recycling and Reuse of treated used water and its resolution by ULBs will be a State level reform. **Mechanism of institutionalisation to check the quality, treatment capacity of STP, treated used water recycled, percentage of recycled water used by city, industrial, agriculture and other demand, whether the treated used water is released in water bodies will also be assessed.**

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Pey Jal Survekshan will foster healthy competition among ULBs, wherein following parameters will be assessed:

i. Water supply management & innovative practices,
Ii. Compliance of water supply service level benchmarks w.r.t. coverage, quality, quantity, and user charges reforms,
Iii. Reduction in Non-Revenue Water (NRW) through District Metered Areas (DMAs) and training to check leakages,
Iv. Operational efficiency of sewage and water treatment plants,
v. Rejuvenation of water bodies and wells,
Vi. **Evaluation of collection, treatment, and reuse of treated used water.**

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Synergies for effective outcomes

Rural-Urban Synergy

Water markets for reuse of treated used water shall be ascertained in rural urban continuum. Co-treatment of sewage/ septage from nearby villagesin spare capacities of STPswill be explored by ULBs.

Urban-Urban synergy

Water supply projects may be techno-economically sustainable, if planned for a cluster of ULBs which are adjacent to each other. For example, a common intake line may be laid from a far-away water source for a group of ULBs

Synergy among Missions

Swachh Bharat Mission (SBM), Smart City Mission(SCM) and National Urban Livelihood Mission (NULM) have components common with AMRUT 2.0. Sanitation and FSSM are components of SBM and water supply with smart elements is a component of SCM.

AMRUT 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

- INDIAN CONSTITUTION 243W
- SDG 2030
- NUSP 2008
- SLB
- AMRUT 2.0
- SBM U-2.0

SBM-U 2.0

SBM-U 2.0

SBM-U 2.0 is needed, with the following areas of focus:

● to achieve the vision of a "Garbage Free" Urban India, more focus is required to be given to issues such as source segregation, collection & transportation, and processing, including effective management of Construction & Demolition waste, plastic waste management including reduction in single use plastic, and remediating all legacy dumpsites;

● to sustain the ODF status and prevent slippage, there is a need to ensure that all fecal sludge and waste(used) water are safely contained, transported, processed and disposed off, so that **no untreated fecal sludge or used water pollutes the ground or water bodies;**

● intensified focus is required to be given to IEC and behavior change through citizen outreach and jan andolan, as well as capacity building and skilling of all relevant stakeholders, towards achieving the Mission's objectives.

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Mission : Overall Vision, and Specific Objectives

Sustainable Sanitation and treatment of used water

i. holistic Sanitation, with end-to end solutions (from discharge, containment, evacuation, transportation to safe disposal of all effluents from toilets);

ii. **treatment of used water before discharge into water bodies, and maximum reuse of treated used water;**

iii. eradication of hazardous entry into sewers and septic tanks, and sustaining elimination of manual scavenging, through mechanization of sewer and septic tank cleaning operations;

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Used water management Objective:

To ensure that no untreated fecal sludge or used water is discharged into the environment, and all used water (including sewerage and septage, grey water and black water) is safely contained, transported and treated, along with maximum reuse of treated used water, in all cities with less than 1 lakh population.

The following components would be eligible for funding:

i. desludging equipment, for scheduled and need-based desludging of all septic tanks;

ii. interception and diversion of drains (I&D) (including last mile connectivity for nearest sewer network);

iii. construction of Sewage Treatment Plants (STPs)/ STP cum Fecal Sludge Treatment plants (FSTPs) for used water treatment.

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Urban-Rural convergence

Infrastructure projects will be taken up on cluster basis to cater to groups of neighboring ULBs and rural areas, so that common waste processing facilities are utilized efficiently.

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

USED WATER MANAGEMENT

Sets out the overall approach to be taken by ULBs to put in place systems and processes to ensure that no untreated waste/used water is discharged into water bodies, along with reuse of treated used water.

In the current scenario in India, only 40% of urban population have access to sewerage system, while the remaining 60% is dependent on unregulated on-site sanitation systems.

In the first phase of SBM (U), there were no funds earmarked for waste water management for towns. Based on learnings from the seven years, **used water management for towns less than 1 lakh population has been newly added as a component under Swachh Bharat Mission-Urban 2.0 and Govt of India's AMRUT 2.0 Mission has funds earmarked for used water treatment including Faecal Sludge management, for cities with more than 1 lakh population.**

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Components of Used Water Management Systems

Management of Used Water includes collection, conveyance, treatment & recycling/ disposal of all the above stated flows.

Offsite System consists of sewage conveyance and treatment at STP

System of intercepting & collecting sewage from municipal drains (where sewer network is absent) and to divert it to STP for treatment.

Onsite treatment system (OTS) is a privately owned and maintained sewage disposal system (other than municipal body) that treats used water and produces partially treated water. However, some packaged onsite sewage treatment systems are also available.

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

SBM-U 2.0

Components of Used Water Management Systems

Sewage is treated in STP and faecal sludge can be treated either at STP or STP-cum-FSTP or standalone FSTP. Further, the treatment may be centralized or decentralized treatment.

Sewage Treatment Plants (STP) are used for treatment of used water coming out from Domestic, Commercial, institutional establishments etc.

Faecal Septage Treatment Plants (FSTPs) are used for treatment of faecal septage being periodically removed from septic tanks of domestic, commercial, institutional establishments etc. to maintain their efficiency.

Septage can be economically treated at STPs with certain minor modifications saving CAPEX, OPEX & land requirement.

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

SBM-U 2.0

Capacity Building and Skill Development

Administrative Officials of ULBs:

• Focus on developing implementation capacity and change management functionalities by creating targeted capacity building training, e-learning courses and online workshops.

• Comprehensive approach to human resource development with a sensitization towards the social, economic and technological environment for effective implementation and service delivery under the Mission.

PHE and Technical Officials of the ULBs

• Technical officials and staffs will be provided hands on technical training, access to e-learning courses, workshops, field visits and knowledge exchange exposure visits to enhance their capacity to effectively implement objectives of SBM-U 2.0. Courses will be focused on the latest technologies, which are sustainable, environmentally friendly, and context appropriate.

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Components of Used Water Management Systems

The treated used water may be used by ULB either for self-consumption, or sold, for the following purposes:

1. Non-potable purposes like flushing toilets, gardening etc.
2. Agricultural purposes
3. Horticulture purposes
4. Industrial purposes
5. Municipal purposes like dust mitigation, road washing, construction activity, etc.
6. Water body rejuvenation

It is targeted to recycle and reuse at least 20% of treated used water for above mentioned purposes.

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Provision for adequate Used Water Treatment Facility in each ULB:

It may be noted that each ULB needs to plan for adequate used water (grey water + black water) treatment facility with provision to treat septage as well.

Creating adequate used water treatment facility is an important component and aligned with mission objective to ensure that used water is discharged to water body or over land only after proper treatment ensuring compliance to environmental discharge standards.

This is necessary to comply with Legal and Regulatory requirements under Hon'ble NGT O.A no. 673/2018 and Honb'le Supreme court WP(C) 375.2012. as well as WATER (Prevention and Control of Pollution) Act 1974.

Accordingly, all towns will need to prepare a DPR containing the provision of minimum one STP (for 70% of current population).

SBM-U 2.0

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

STP Technology:

As regards **selection of Used water treatment technology**, it will be open to ULB/State Government to **select any proven technology as brought out in the CPHEEO** Manual/Advisories from time to time. In case States come across any other technology not listed in CPHEEO Manual/Advisories, the same should be referred to CPHEEO for evaluation and inclusion in the Advisories. **State Governments are encouraged to select nature-based sewage treatment technologies (alone or in combination of two to attend desired treated effluent quality), where feasible, to economise Capex & Opex**.

In this context, it may be mentioned that global experiences have established STPs to be the most effective method for treating used water (grey water and black water). Hence, States/ UTs may take informed decisions regarding technology to be used for treating their used water so that the Mission's objective of "no untreated used water polluting water bodies" is realized.

SBM-U 2.0

SUMMARY

No untreated used water including faecal sludge is discharged into the water bodies or open environment. However, there exist several challenges like lack of financial resources, institutional capacity and technical know-how to plan, design, construct and operate these treatment facilities.

To overcome the technical challenges, for selection of different Used Water Treatment options, that are suiting to ULBs in Indian climatic conditions.

This training is organized considering above said challenges and suggests more sewage treatment options.

Fit for Purpose Technologies for Recycle & Reuse of Wastewater

Prakash Shirsat

Deputy Director (MCMCR)

Email: dydirector.mcmcr@mcgm.gov.in

Mob: 9823223007

Capacity Building Training under Amrut 2.0 on ‘Fit for Purpose Technologies for Recycle and Reuse of Wastewater

Standards for Recycle and Reuse of Wastewater

Dr. Uday G. Kelkar, P.E., BCEE
&
Ajit Savadi

NJS Engineers India Pvt. Ltd.

January 11, 2023

Characteristics of Wastewater

- pH – 6.5 to 9.0
- BOD – 140 to 210 mg/L – Typically designed for 250 Mg/L
- TSS – 200 to 450 mg/L
- COD – 100 to 200 mg/L
- Total Nitrogen 35 to 55 mg/L
- Ammonia as N < 15 to 35 mg/L
- Fecal Coliform – 100,000 MPN or higher

NJS

Regulatory Standard for New Sewage Treatment Plants -

Discharge Standards NGT New – to be adopted

- pH – 6.5 to 9.0
- BOD – 10 mg/L or less
- TSS – 20 mg/L
- COD – 50 mg/L
- Total Nitrogen < 10 mg/L
- Ammonia as N < 5 mg/L
- Fecal Coliform – 100 MPN/100 mL or 230 MPN/100 mL?

Standards notified in 2017

- **pH – 6.5 to 9.0**
- **BOD – 20 / 30 mg/L**
- **TSS – 50 / 100 mg/L**
- **Fecal Coliform 1000 MPN/100 mL?**
- **Very interesting to note these relax standards are applicable to larger Metros who has funds or means to do reuse and will require higher costs when reuse is added in the future**

NJS

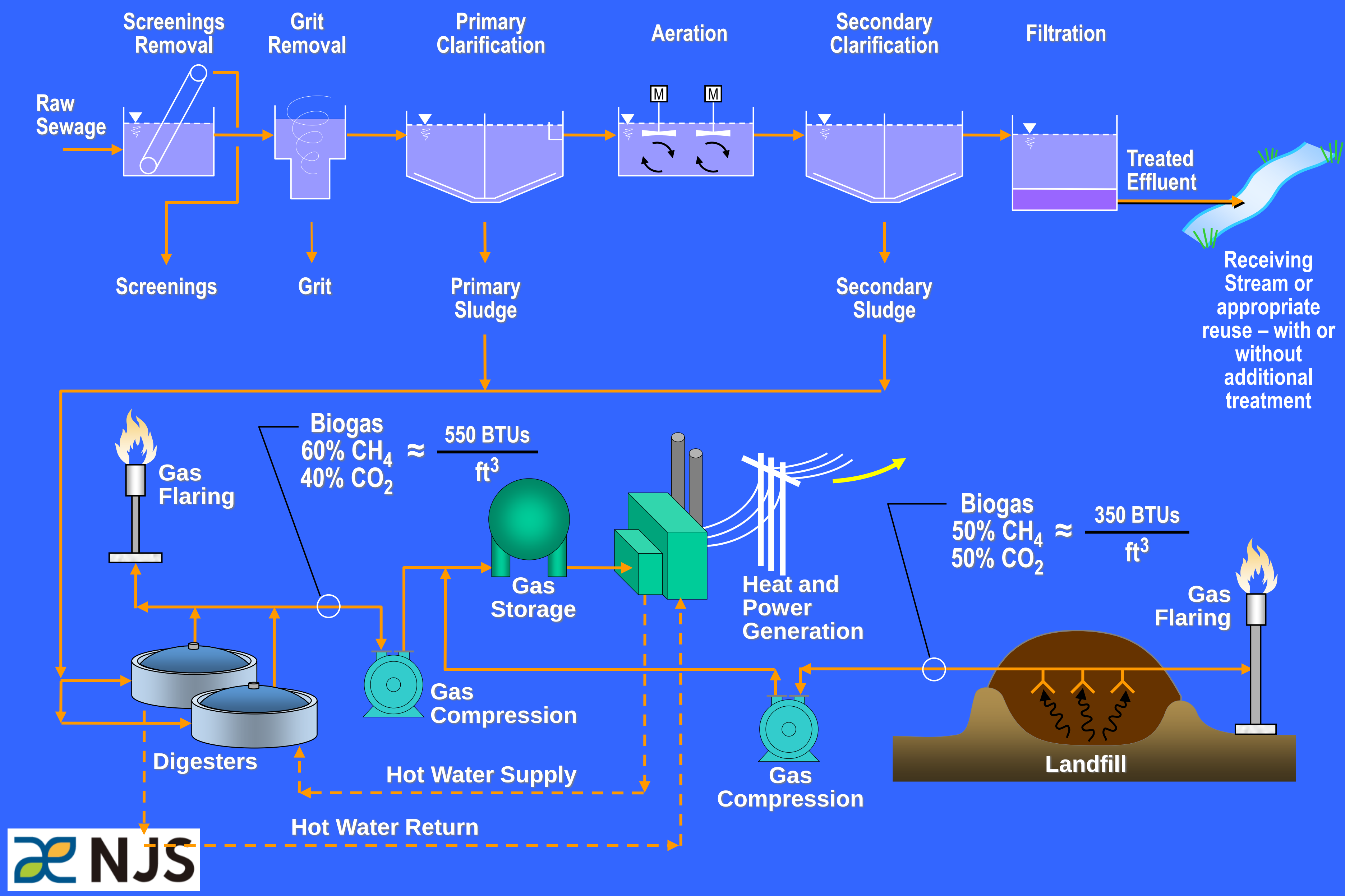
Unit Operations in Wastewater Treatment

Biological

Aerobic Process **Energy Consumers**	Suspended Growth →	Activated Sludge (ASP) →	CSTR, Plug flow, Sequencing Batch reactor, oxidation ditch, Orbal, Biolac, Cyclic ASP, Extended Aeration, aerobic/aerated lagoons
	Attached Growth →	Trickling Filter and Trickling filter with solids contact system	Rotating Biological Contactors (RBC) ASP with fixed film packing
	Submerged Attached Growth →	Down flow attached growth process, upflow submerged attached growth, fluidized bed bioreactor, membrane separation aerobic process	
Anaerobic Process **Energy Producers**	Suspended Growth	Anaerobic contact process, anaerobic sludge blanket process-UASB, anaerobic baffled reactor system,	
	Attached Growth	Up-flow packed bed attached growth, and expended bed reactors, anaerobic fluidized bed reactors, anaerobic lagoons, membrane separation anaerobic process	

Combination of aerobic and anaerobic process are used in tertiary treatment for the removal of nitrogen and phosphorus from the wastewater

NJS



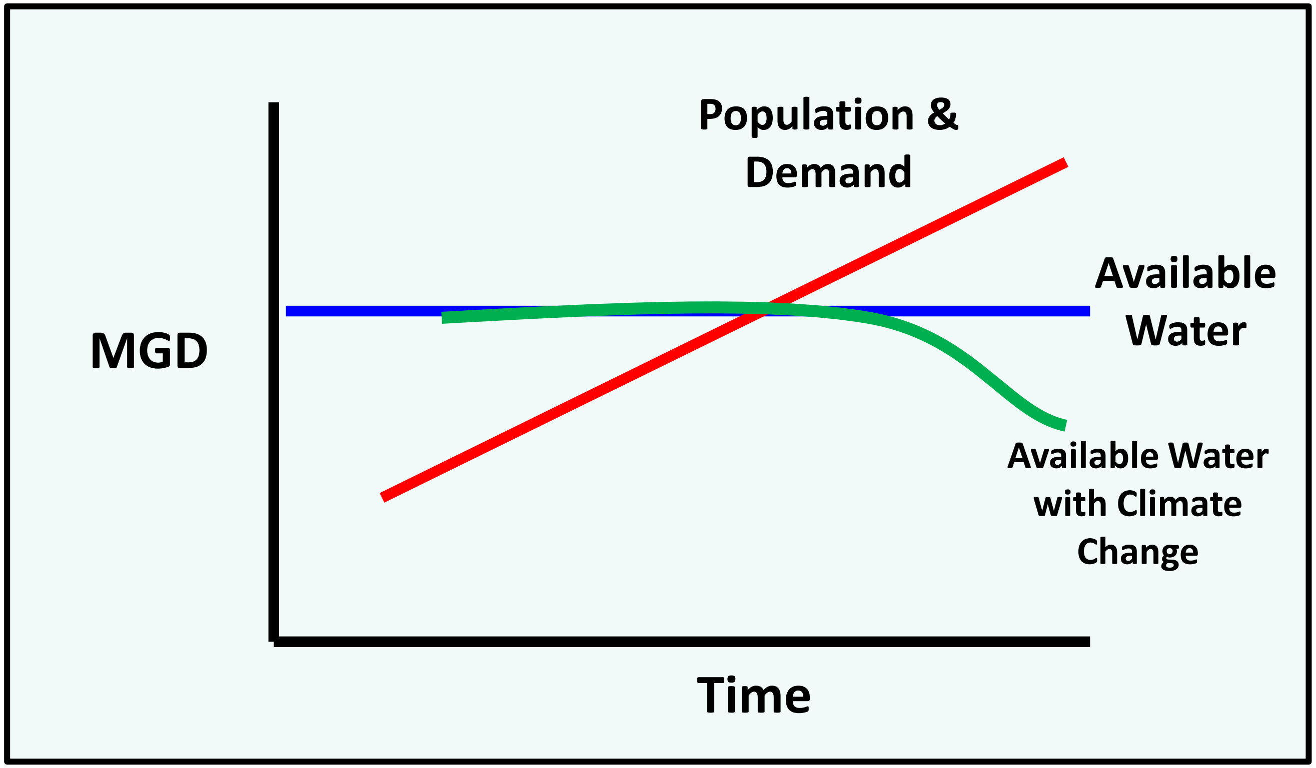
Screenings Removal
Grit Removal
Primary Clarification
Aeration
Secondary Clarification
Filtration
Raw Sewage
M
M
Treated Effluent
Screenings
Grit
Primary Sludge
Secondary Sludge
Receiving Stream or appropriate reuse – with or without additional treatment
Biogas
60% CH_4
40% CO_2
≈ $\frac{550\ BTUs}{ft^3}$
Gas Flaring
Gas Storage
Heat and Power Generation
Biogas
50% CH_4
50% CO_2
≈ $\frac{350\ BTUs}{ft^3}$
Gas Flaring
Gas Compression
Digesters
Hot Water Supply
Hot Water Return
Gas Compression
Landfill
NJS

Table – 8: Typical range of effluent quality after secondary treatment *(Ref: Metcalf & Eddy/AECOM, "Water Reuse – Issues, Technologies, and applications", Page 314, Table – 7.7)*

			Range of effluent quality after indicated treatment			
			Conventional activated sludge[b]	Activated sludge with BNR[c]	Membrane bioreactor	
1	**2**	**3**	**4**	**5**	**6**	**7**
Total suspended solids (TSS)	Mg/L	120-400	5-25	**5-20**	≤1	≤15.0
Biochemical oxygen demand (BOD)	Mg/L	110-350	5-25	**5-15**	<1-5	≤10.0
Chemical oxygen demand (COD)	Mg/L	250-800	40-80	**20-40**	<10-30	≤40.0
Total organic carbon (TOC)	Mg/L	80-260	10-40	**8-20**	0.5-5	≤8.0
Ammonia Nitrogen	Mg N/l	12-45	1-10	**1-3**	<1-5	≤2.50
Nitrate Nitrogen	Mg N/l	0-trace	10-30	**2-8**	<10[d]	≤2.50
Nitrite nitrogen	Mg N/l	0-trace	0-trace	**0-trace**	0-trace	0 - trace
Total nitrogen	Mg N/l	20-70	15-35	**3-8**	<10[d]	≤7.5
Total Phosphorous	Mg P/l	4-12	4-10	**1-2.0**	0.5-2.0[d]	≤1.0
Turbidity	NTU		2-15	**2-8**	≤1	≤5.0
Volatile organic compounds (VOCs)	µg/l	<100- >400	10-40	**10-20**	10-20	≤15.0
Metals	Mg/l	1.5-2.5	1-1.5	**1-1.5**	Trace	≤1.5
Surfactants	Mg/l	4-10	0.5-2	**0.1-1**	0.1-0.5	≤0.50
Total dissolved solids (TDS)	Mg/l	270-860	500-700	**500-700**	500-700	-
Trace constituents	µg/l	10-50	5-40	**5-30**	0.5-20	≤25.0
Total coliform	No./100ml	$10^6 – 10^9$	$10^4 – 10^5$	**$10^4 – 10^5$**	<100	$10^4 – 10^5$ (without chlorination)
Protozoan cysts and oocysts	No./100ml	$10^1 – 10^4$	$10^1 – 10^2$	**0 – 10**	0 – 1	0 - 10
Viruses	PFU/100ml[e]	$10^1 – 10^4$	$10^1 – 10^3$	**$10^1 – 10^3$**	10^0 - <10^3	$10^1 – 10^3$

[b]Conventioanl secondary is defined as activated sludge treatment with nitrification
[c]BNR is defined as biological nutrient removal for the removal of nitrogen and phosphorous
[d]With BNR process
[e]Plaque forming units

Population Is a Key Factor in the Water Scarcity Paradigm



What are major concerns on Reuse Water

- Usage Type of recycled water?
- Availability of Treatment Technologies?
- Operability and Reliability?
- No Confidence in Gov. or private O&M operators?
- Consistently meeting water quality Standards?

Important Issues to be Address

- The Problem
- Source Water Quality
- Regulatory and performance compliance
- Contingency planning
- Distance of bringing raw water
- Pumping head required and cost of producing the treated water
- Subsidy issue – Industrial v/s domestic costs
- Conflict
- Policies
- Perception, Risk and Branding

NJS

Reuse Categories

- Unrestricted Urban Reuse
- Restricted Urban Reuse
- Agricultural Reuse for Food and Non-Food Crops
- Recreational Impoundments
- Intrusion Barrier
- Environmental Wetlands

NJS

Reuse Categories (continued)

- Industrial Reuse
- Groundwater Recharge
- Indirect Potable Reuse
  - Spreading Basins
  - Injection
  - Surface Water Augmentation
- Direct Potable Reuse

NJS

Reuse Categories – being Applied in India

- Unrestricted Urban Reuse - may be
- Restricted Urban Reuse - not specifically
- Agricultural Reuse for Food and Non-Food Crops – Indirect with monitoring
- Recreational Impoundments - None
- Intrusion Barrier - None
- Environmental Wetlands - few

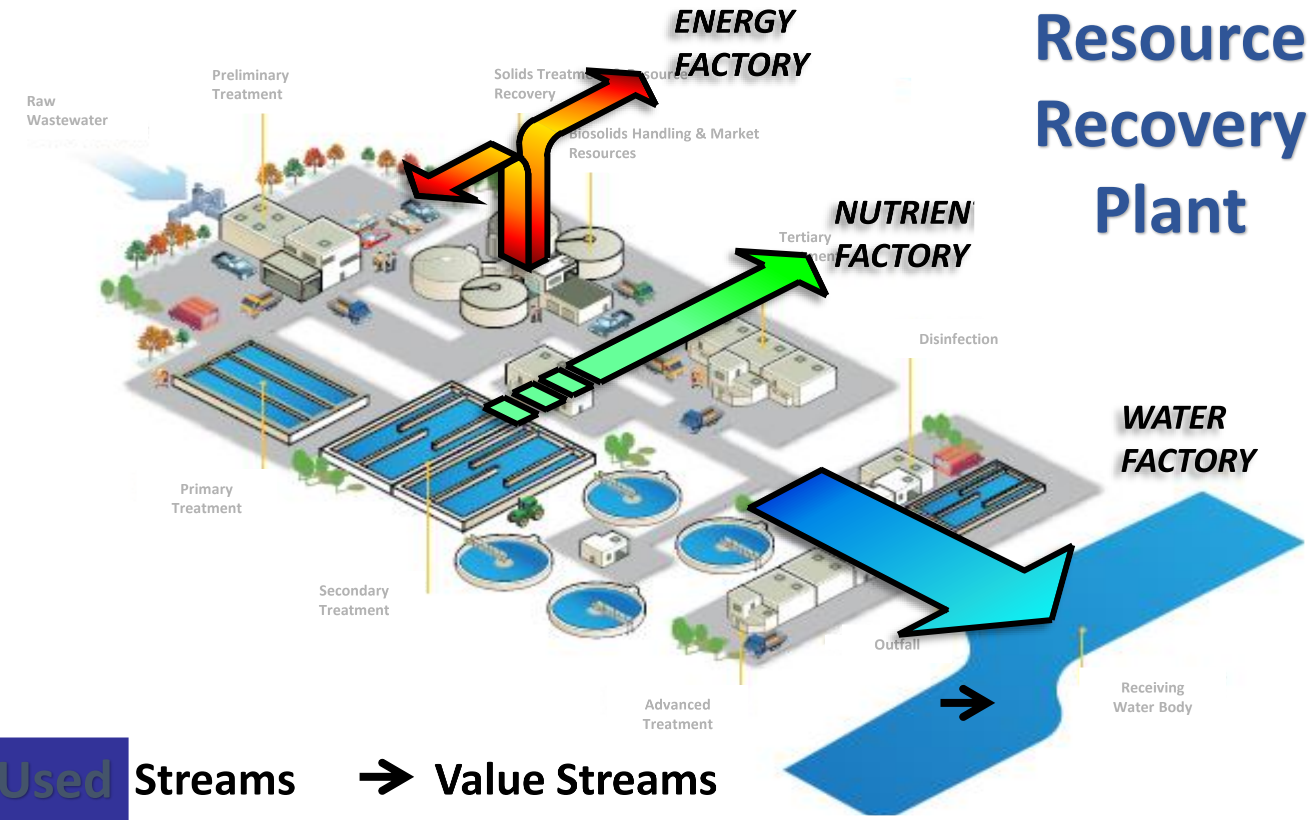
Reuse Categories (continued)

- Industrial Reuse – Yes, specific areas but few – Welspun, MSPGCL, RCF, CPCL. Pragati Power and new Power plant initiatives.
- Groundwater Recharge – Some by design
- Indirect Potable Reuse – none / not by design – Agra WTP is an exception
  - Spreading Basins, - Injection
  - Surface Water Augmentation – none
- Direct Potable Reuse – none

NJS

Treating Used water: Responding to the "New Normal" and the Pathway to One Water

Resource Recovery Plant



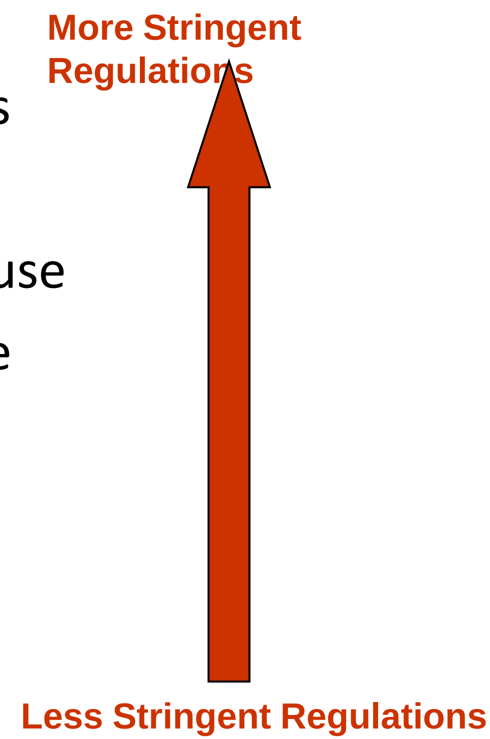
Used Streams → Value Streams

Regulations and Guidelines Vary Depending on Type of Reuse

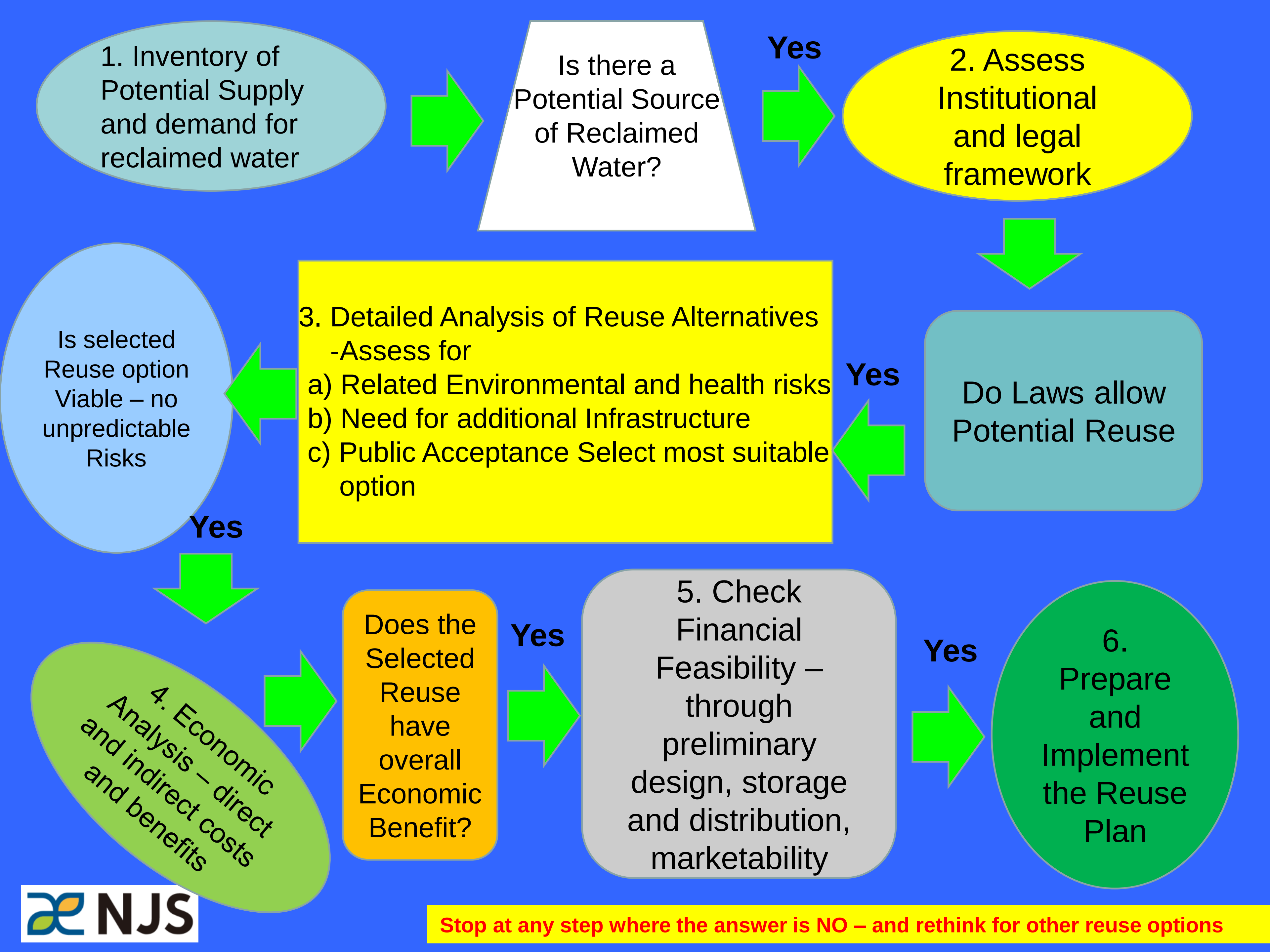
(no national regulations in the U.S.)

Type of Reuse

- Potable Reuse
- Agricultural Reuse on Food Crops
- Unrestricted Recreational Reuse
- Unrestricted Urban Irrigation Reuse
- Restricted Urban Irrigation Reuse
- Restricted Recreational Reuse
- Industrial Reuse
- Environmental Reuse
- Agricultural Reuse on Non-food Crops



Example: California's non-potable reuse regs involve treatment type and water quality (i.e., total coliforms and turbidity).

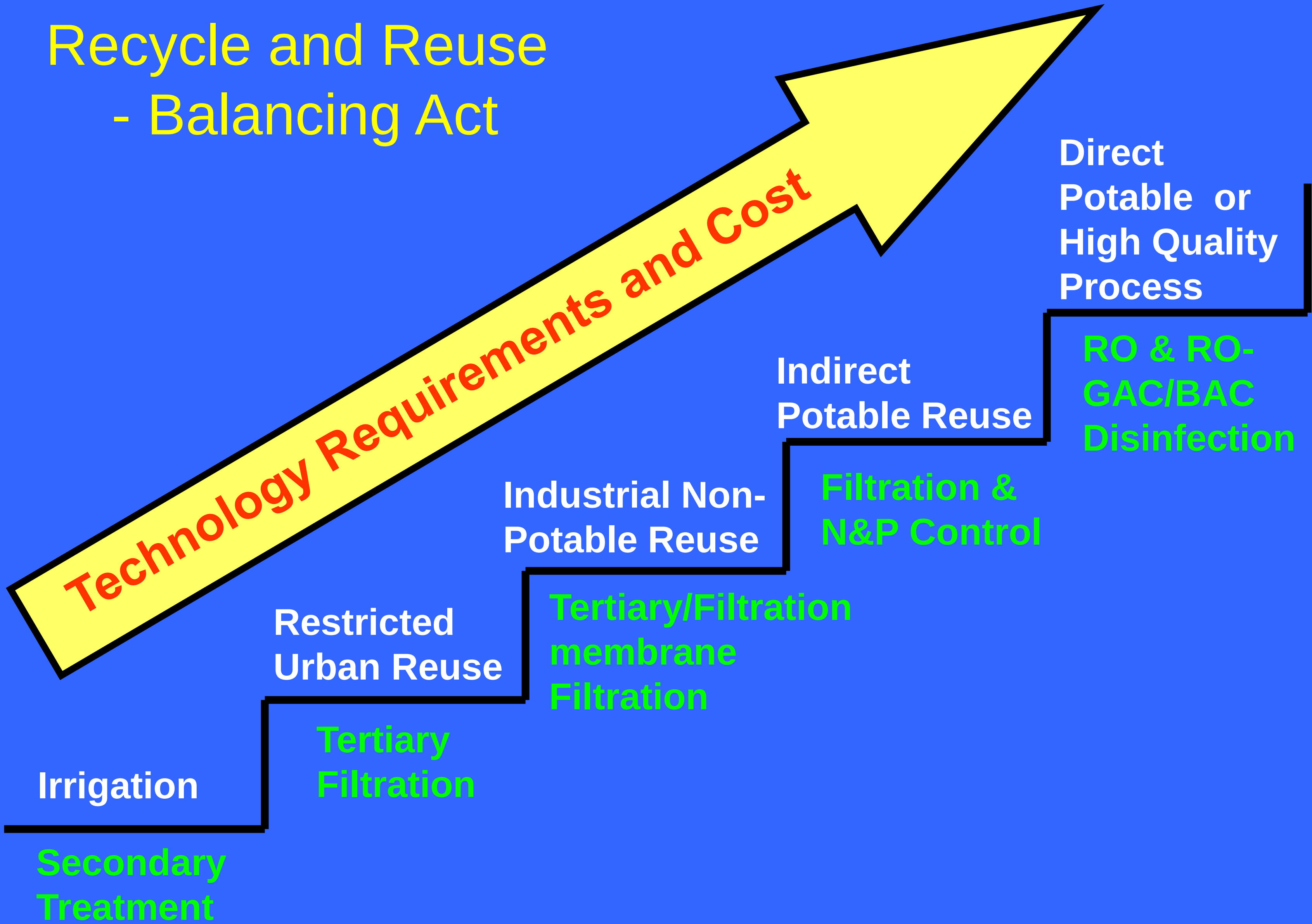

1. Inventory of Potential Supply and demand for reclaimed water
Is there a Potential Source of Reclaimed Water?
Yes
2. Assess Institutional and legal framework
Do Laws allow Potential Reuse
Yes
3. Detailed Analysis of Reuse Alternatives -Assess for
a) Related Environmental and health risks
b) Need for additional Infrastructure
c) Public Acceptance Select most suitable option
Is selected Reuse option Viable – no unpredictable Risks
Yes
4. Economic Analysis – direct and indirect costs and benefits
Does the Selected Reuse have overall Economic Benefit?
Yes
5. Check Financial Feasibility – through preliminary design, storage and distribution, marketability
Yes
6. Prepare and Implement the Reuse Plan
NJS
Stop at any step where the answer is NO – and rethink for other reuse options

Technology selection criteria

- Reliable (proven and established)
- Recycled water quality and its consistency
- Wastewater generation from treatment process
- Operator requirement / automation
- Space requirement (may not be important for industrial areas due to appropriate allocation of land)
- Capital cost, O&M cost (Lifecycle cost)

NJS

Recycle and Reuse
- Balancing Act



Existing Standards for Reuse in India (CPCB, MOEF)

Class	Designated Best Use	Criteria
A	Drinking water source without conventional treatment but after disinfection	Dissolved Oxygen : 6 mg/l or more Biochemical Oxygen Demand : 2 mg/l or less Total Coliform : 50 MPN/100 ml
B	Outdoor bathing (Organised)	Dissolved Oxygen : 5 mg/l or more Biochemical Oxygen Demand : 3 mg/l or less Total Coliform : 500 MPN/100 ml
C	Drinking water source with conventional treatment followed by disinfection	Dissolved Oxygen : 4 mg/l or more Biochemical Oxygen Demand : 3 mg/l or less Total Coliform : 500 MPN/100 ml
E	Irrigation, industrial cooling and controlled waste disposal	Electrical Conductivity : 2250 mhos/cm Sodium Absorption Ratio: 26 Boron : 2 mg/l

NJS

Proposed Water Quality for Reuse

User	Required Water Quality	Indian Standard
Agricultural	Irrigation	E
Domestic	Public access	C
Industrial	Per industry requirements	Negotiate with industries
Groundwater recharge	Indirect potable	E – with nitrification
Reservoir Recharge and source water Augmentation	Indirect potable	C – with nitrogen and phosphorus removal

NJS

Comparison of Agricultural Reuse Guidelines

Parameter	India Irrigation	WHO (A)	EPA Food	EPA Non-food
Fecal coliform	NS	≤ 1000	Nil	≤ 200
Intestinal nematodes	NS	≤ 1	NS	NS
BOD_5	≤ 100	NS	≤ 10	≤ 30
Suspended solids	≤ 200	NS	≤ 30	≤ 30
Residual chlorine	NS	NS	≥ 1	≥ 1
TDS	≤ 2100	NS	NS	NS

NJS

Comparison of India Land Application Rules to WHO and EPA Guidelines for Unrestricted Reuse

Parameter	India	WHO		EPA
	Land App.	A	Prop.	Urban
F. Coli form	NS	≤ 1000	≤ 1000	Nil
Nematodes	NS	≤ 1	≤ 0.1	NS
TSS	200			<5
TDS	2100			NS
BOD_5	100			≤ 10
Residual chlorine	NS			≥ 1
SOCs	Numerous			

NS = No Standard

Recycle/ Reuse Standards

Agriculture (Food and Non-food Crop)

Parameter	Units	Value
Intestinal nematodes	No./liter	**< 1**
Fecal coliforms	No./100 ml	**Nil (for crop eaten raw) & ≤ 230/100 ml (for crops eaten cooked or non-edible crops)** **** with new regulation of 100 MPN/100 ml this can be directly adopted**
pH		**6 – 9**

NJS

Recycle/ Reuse Standards

Urban Non-Potable Reuse

Parameter	Units	Value
BOD_5	mg/L	≤ 3
Turbidity	NTU	≤ 2
Fecal coliforms	No./100 ml	≤100
Chlorine residual	mg/L	≥ 1
pH		6 – 9

NJS

Recycle/ Reuse Standards

Environmental/ Recreational Reuse

Parameter	Units	Value
BOD_5	mg/L	≤ 10
TSS	mg/L	Nil
Fecal coliform	MPN./100 ml	≤100
pH		6.5 – 8.3
Total Kjeldahl Nitrogen (as N)	mg/L	< 5 for impoundments, < 10 for Horticulture/ Golf Course
Dissolved Phosphorus (as P)	mg/L	1

NJS

Recycle/ Reuse Standards

Industrial Reuse

Constituent, mg/L	Industrial Application				
	Boiler Feed	Pulp and Paper	Textiles	Petroleum and Coal	Cooling Water
Calcium	0.01 – 0.4	20	–	75	100
Iron	0.05 – 1.0	0.3 – 1.0	0.1 – 0.3	1	–
Manganese	0.01 – 0.3	0.05 – 0.5	0.01 – 0.05	–	–
Alkalinity as $CaCO_3$	40 – 350	100	–	125	–
Chloride	–	200 – 1,000	–	300	100
TDS	200 – 700	–	100	1,000	–
Hardness as $CaCO_3$	0.07 – 350	100	25	350	–
Ammonium-N	0.1	–	–	–	1 – 3
Phosphate-P	–	–	–	–	0.6
Silica	0.7 – 30	50	–	–	20
Color (Hazen)	–	10 – 30	5	–	–

NJS

Recommended Water Quality Criteria

Water Quality Parameter	Crop irrigation	Water exchange	Reservoir recharge	Ground-water recharge	Domestic non-potable
BOD_5 mg/L	–	30	≤ 3	≤ 3	≤ 3
TSS, mg/L	–	50	≤ 5	–	–
Turbidity, NTU	–	–	5	–	≤ 2
Fecal coliform, #/100 ml	1,000	10,000	< 10	≤ 500	≤ 500
Intestinal nematodes, #/L	1	1	–	–	–
Total nitrogen, mg/L	–	–	≤ 10	≤ 12	–
Total phosphorus, mg/L	–	–	≤ 0.6	1.0	–
pH	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Chlorine residual, mg/L	–	–	–	–	≥ 1
Drinking water standards	–	–	Yes	As required	–

NJS

Recycle/ Reuse Standards

Groundwater Recharge – in addition to BOD and TSS values

Parameter	**Units**	**Infiltration Basins**	**Vadose Zone Recharge Wells**	**Direct Injection**
Drinking water standards	mg/L	Not applicable	Not applicable	**As applicable**
Total nitrogen	mg/L	≤ 12	≤ 12	**≤ 12**
pH		6 – 9	6 – 9	**6 – 9**

Recycle / Reuse Framework

1. Commitment to responsible use and management of recycled water

System Analysis and Management

2. Assessment of the recycled water system
3. Preventive measures for recycled water management
4. Operational procedures and process control
5. Verification of recycled water quality and environmental performance
6. Incident and emergency management

Supporting Requirements

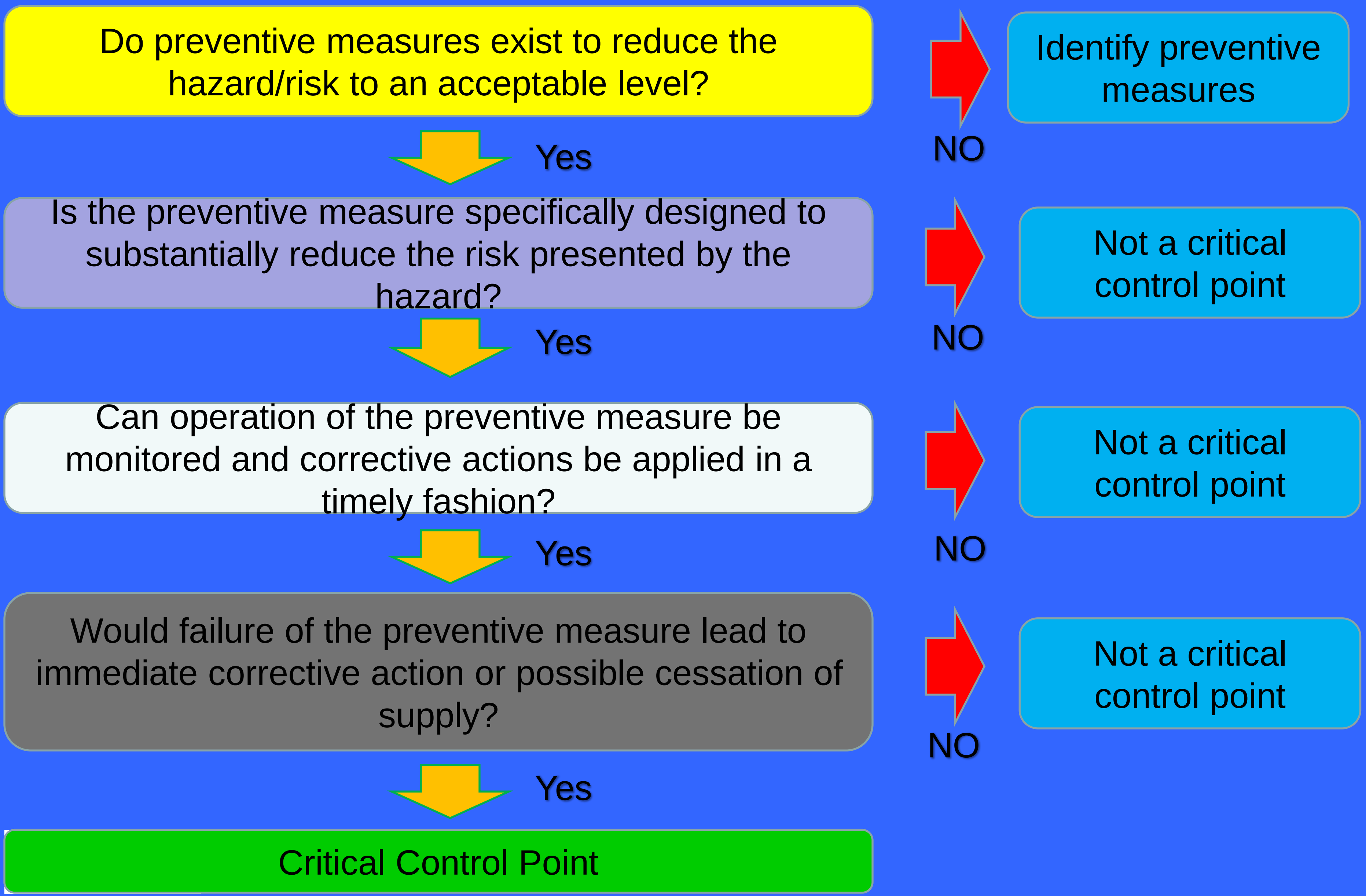
7. Employee awareness & Training
8. Community involvement
9. Research and development
10. Documentation and reporting

Review

11. Evaluation and audit
12. Review and continual improvement

NJS

Typical HACCP Approach



Typical Environmental Risks

Water Source

Treated Sewage

- Sewage Treatment Plant
- Sewer mining
- Centralized onsite treatment
- Greywater centrally treated

Greywater

- Single household with no or minimal treatment

Uses/Pathways

Cross Connection

Fire Control

Intentional discharge (include allocation to the environment)

Irrigation

Storage System

Washing

Unintentional discharge

Receiving environments & major endpoints

Air

Biota
- Aquatic
- Terrestrial

Infrastructure Plants

Septic tank or sewage treatment plant (indirect)

Soiils

Water body
- Surface water
- Groundwater

Key Hazards

Boron

Cadmium

Chloride

Chlorine residuals

Hydraulic loading

Nitrogen

Phosphorus

Salinity

Sodium

PHPs & EDCs

Effects

Concentration

Contamination

Eutrophication

Loss of bio-diversity

Nutrient imbalance

Odour

Pest and disease

Salinity & Sodicity

Toxicity

Waterlogging

NJS

Typical Treatment Requirements for Reuse

Reuse Application	Parameters of Concern	Possible Treatment Technologies
Agricultural irrigation	FC & other pathogens	Disinfection
Water exchange (swap)	None, if treated wastewater meets river discharge standards	–
Reservoir recharge	N, P, DWS	NAS, CFID, NTF, wetlands
Groundwater recharge	N, DWS	NAS, CFID, BAF, NTF, wetlands
Domestic non-potable	T, FC, TRC	GMF, Disinfection

FC – fecal coliform, **N**- nitrogen, **P** - Phosphorus, **DWS** – drinking water standards,

TRC – total residual chlorine, **T** – turbidity

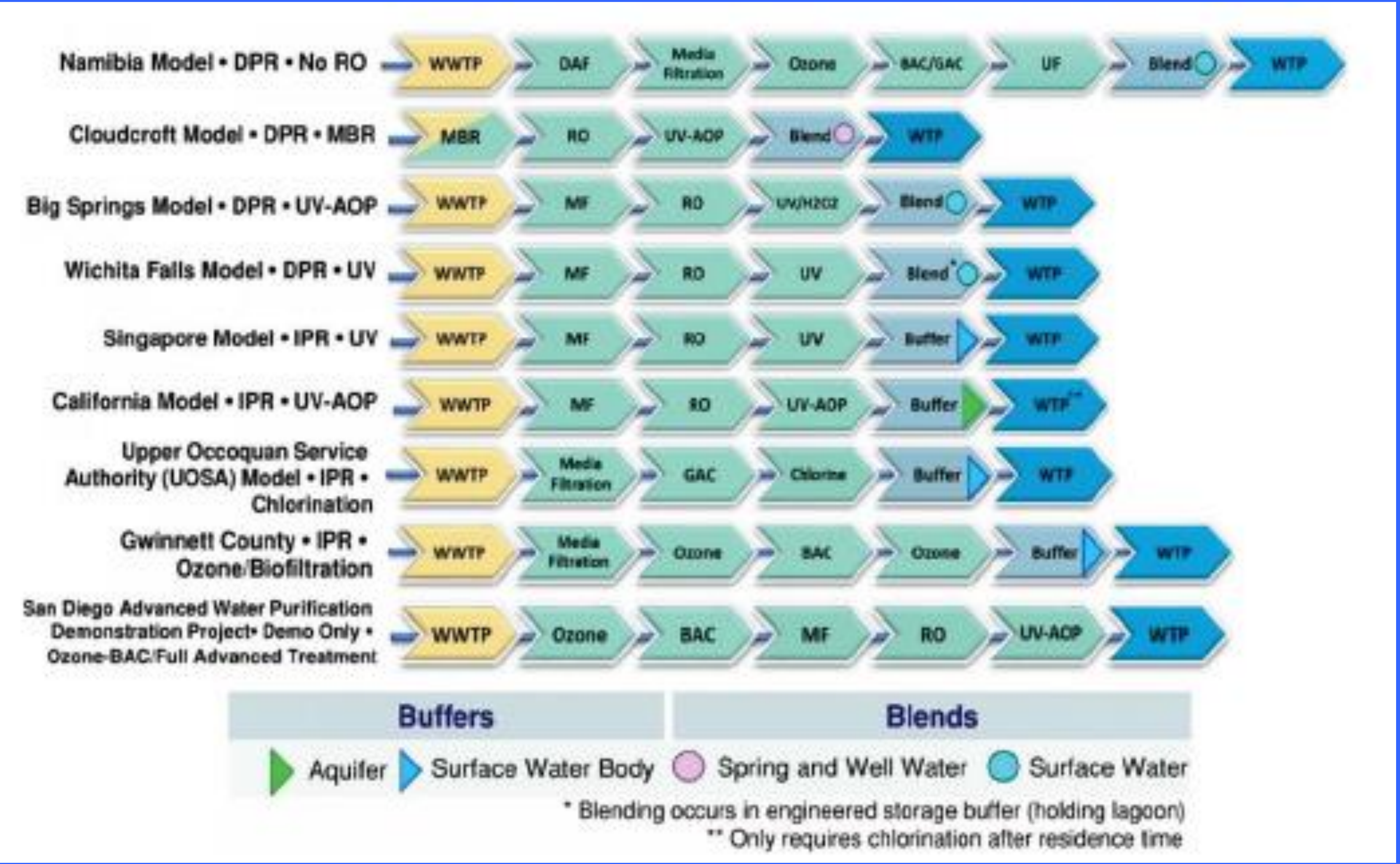
NJS

Indicative Log Removal of Pathogens

	Escherichia coli	Bacterial pathogens (including Campylobacter)	Viruses	Coli Phage	Giardia	Crypto	Clostridium perfringens	Helminths
Treatment								
Primary treatment	0–0.5	0–0.5	0–0.1	N/A	0.5–1.0	0–0.5	0–0.5	**0–2.0**
Secondary treatment	1.0–3.0	1.0–3.0	0.5–2.0	0.5–2.5	0.5–1.5	0.5–1.0	0.5–1.0	**0–2.0**
Dual media filtration with coagulation	0–1.0	0–1.0	0.5–3.0	1.0–4.0	1.0–3.0	1.5–2.5	0–1.0	**2.0–3.0**
Membrane filtration	3.5–>6.0	3.5–>6.0	2.5–>6.0	3–>6.0	>6.0	>6.0	>6.0	**>6.0**
Reverse osmosis	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	**>6.0**
Lagoon storage	1.0–5.0	1.0–5.0	1.0–4.0	1.0–4.0	3.0–4.0	1.0–3.5	N/A	**1.5–>3.0**
Chlorination	2.0–6.0	2.0–6.0	1.0–3.0	0–2.5	0.5–1.5	0–0.5	1.0–2.0	**0–1.0**
Ozonation	2.0–6.0	2.0–6.0	3.0–6.0	2.0–6.0	N/A	N/A	0–0.5	**N/A**
UV light	2.0–>4.0	2.0–>4.0	>1.0 adenovirus >3.0 enterovirus, hepatitis A	3.0–6.0	>3.0	>3.0	N/A	**N/A**
Wetlands — surface flow	1.5–2.5	1.0	N/A	1.5–2.0	0.5–1.5	0.5–1.0	1.5	**0–2.0**
Wetlands — subsurface flow	0.5–3.0	1.0–3.0	N/A	1.5–2.0	1.5–2.0	0.5–1.0	1.0–3.0	**N/A**

Contaminants	In Water As	Maximum Contaminant Level
▪ Pharmaceuticals ▪ Personal Care Products ▪ Endocrine Disrupting Compounds and their metabolites	Multiple organic and inorganic forms	Not applicable - Several compounds are listed on EPA's Contaminant Candidate List II (CCL III)
Sources of Contaminant	Elimination from the body Flushing of unused, or expired product Leachate from landfills Rinse off from showering or bathing Agricultural runoff	
Potential Health Effects	Levels in finished drinking water supplies are 10^3 to 10^6 times lower than therapeutic dose, or effect levels and given that no health effects have been attributed to these compounds at these low concentrations. However, consumer sensitivity (emotional) to the presence of these compounds have brought them to the forefront of the industry and led to the development of testing to evaluate performance capabilities of residential treatment devices.	
Treatment Methods **Point-of-Entry (POE)** **Point-of-Use (POU)**	Active media (carbon), Reverse Osmosis Peroxidation	

Various Treatment Schemes Employed Worldwide for Reuse Applications



Wastewater Reuse Agriculture

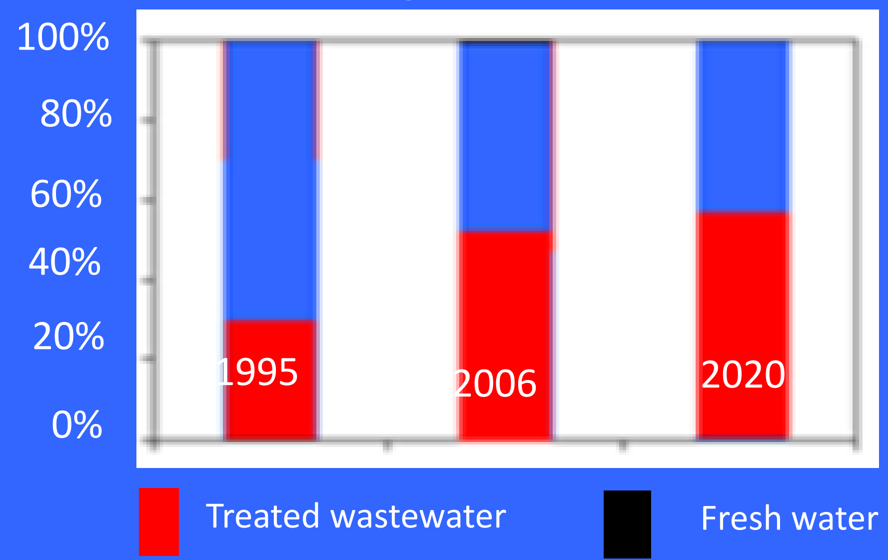
- Potential to irrigate 1-3 Million Ha
- 40% reduction in fertilizer use
- Nutrient potential of 0.63 – 0.73 tonnes/MLD
- Reduction in GW required for irrigation, resulting in energy savings ~30% in WW irrigated areas

Nutrients in wastewater (Indian cities)	
Nutrient	mg/l
Nitrogen	10-100
Phosphorus	1 – 30
Potassium	16 - 500

ISRAEL'S EXPERIENCE

By 2020 60% of agricultural need met by treated wastewater, freeing water for other uses

Wastewater as a % of total water used for agriculture



Sources: Silva and Scot 2002
Minhas 2002; Qadir and Scott 2010
Naty Barak, World Bank, 2009

NJS

Recycle and Reuse for Agriculture: A valuable resource

- Treated urban wastewater (~38,000 MLD), if channeled to meet irrigation requirements, would provide ~14 BCM of irrigation water
- Potentially irrigate an area ranging between 1-3 million hectares.
- Increase farm income by 30%

Tenth Five Year Plan	Major and Medium	Surface water fed Minor irrigation
Potential created (Mha)	4.59	0.71
WWI potential (Percent)	44%	~300%

Nutrient Potential

- Nutrient potential in WW ranges from 0.63 – 0.73 tonnes/MLD
- Upto 40% reduction in nutrient load possible
- Reduced fertilizer requirement may reduce the Government fertilizer subsidy burden by **~ 100 crores** annually

Energy savings

- Reduction in groundwater pumping, associated energy requirements
- Saving potential of **~ 600 Crores** annually

NJS

Benefits of wastewater reuse for irrigation in select cities in India

City	Crop cultivated	Increase in yield (%)	Decrease in fertilizer use	Increase in pesticide use	Avg. Annual Incremental benefit (Rs./ha)
Indore	Wheat (Rabi) / Vegetables (Summer)	30-40%	50%	Almost double	36,752
Nagpur	Wheat (Rabi) / Vegetables (Summer)	30-40%	33%	Almost double	26,951
Jaipur	Wheat (Rabi) / Vegetables (Summer)	30-40%	50%	Almost double	37,790
Bangalore	Rice (Rabi), Sapota, Flowers (Summer)	30-40%	100%	Almost double	33,849
Ahmedabad	Rice and wheat (Rabi)	-	-	-	-14,640
Delhi	Okra	67%	60%	Increased by 50%	8,500
Kanpur	Paddy and wheat	Decrease in yield	-	-	6,166 (paddy) 954 (wheat)

NJS

Limitations to Industrial Reuse

- While economically viable, industrial reuse is limited by the availability of industrial clusters in the vicinity of the treatment plant
- CPCB has identified 88 industrial cluster in 20 States in India. Industrial reuse in these areas may be viable.

S.No	Potential for Industrial WW reuse	States	Quantity of WW (MLD)
1.	Nil / Negligible	Andaman & Nicobar Islands; Arunachal Pradesh; Assam; Bihar; Chandigarh; Dadra & Nagar Haveli; Daman & Diu; Goa; Jammu & Kashmir; Lakshadweep; Manipur; Meghalaya; Mizoram; Nagaland; Pondicherry; Sikkim; Tripura	Negligible
2.	5- 20%	Andhra Pradesh; Himachal Pradesh; Karnataka; Kerala; Orissa; Tamil Nadu; Uttarakhand; West Bengal	1,050
3.	20 – 30%	Haryana; Madhya Pradesh	590
4.	30 – 50%	Jharkhand; Maharashtra; Punjab; Rajasthan; Uttar Pradesh	8,000
5.	>50%	Chhattisgarh; Gujarat; NCT of Delhi	4,600

Benefits of wastewater recycle and reuse in agriculture

- Use of treated wastewater for agriculture can help farmers increase their earnings
  - Case studies reveal an average **increase by Rs. 17,000 / Ha per annum** on account of water availability and reduced fertilizer use
  - Potential to **increase of about 30% in the farmer's income** when the farmer uses of freshwater alone
- Channeling the entire quantum of treated wastewater towards agriculture has the potential to **support 1-2 million farmers.**

NJS

Challenges for Agricultural Reuse

- Irrigation water charges in India (13th FC recommendation) are
  - Rs. 1,175/Ha - Major irrigation command areas;
  - Rs. 588/Ha - Minor irrigation command areas
- Charges amount to ~ **10-25 paise / kL**.
- The O&M cost of treating WW is significantly higher
- Treated wastewater used for irrigation presents many benefits to consumers, city governments and states
  - **Assured and reliable water supply**,
  - **Nutrients** present in wastewater,
  - **Avoided costs of groundwater pumping**
  - **Avoided fertilizer subsidies**

Utilities and city governments will need to explore sustainable business models aimed at different user categories, working in partnership with various State Government Departments and Agencies

NJS

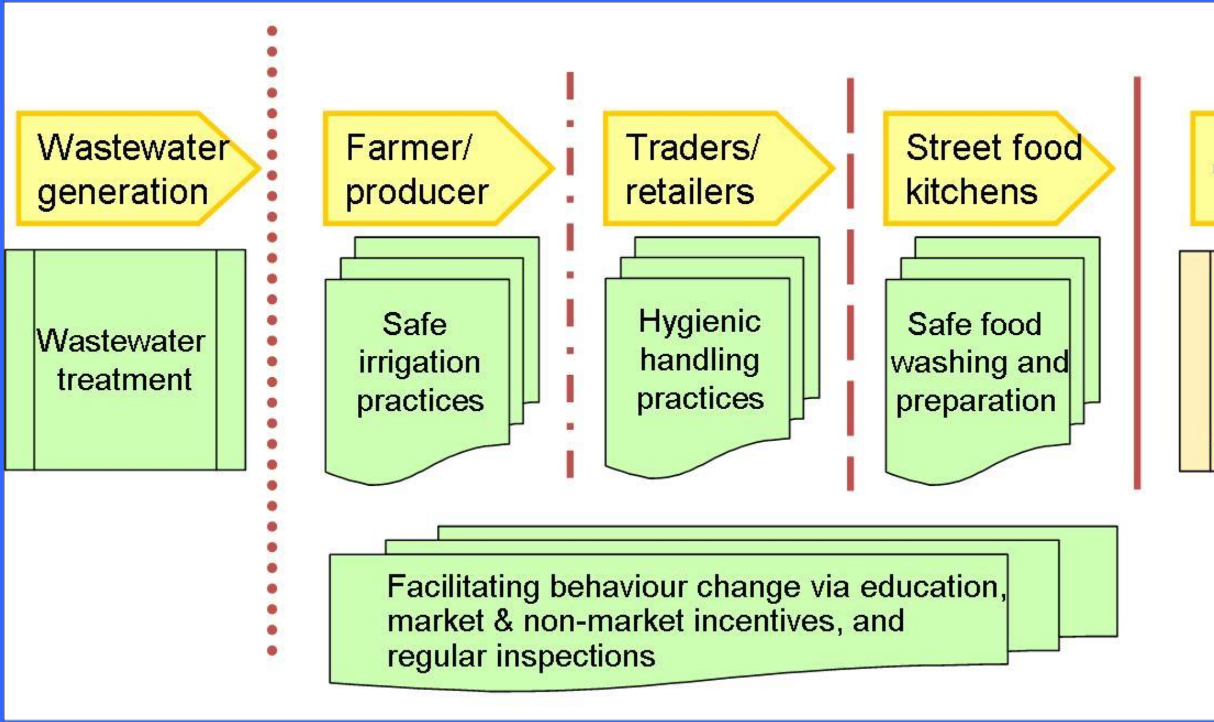
Health Considerations – Recycle and reuse of Wastewater

Risk of reuse for human and environment

- **Two significant risk factors:**
  - Risk of consumption of food contaminated with fecal matter (pathogens) or chemicals from industrial effluents (heavy metals, ….).
  - Occupational risk of farmers in contact with water.
- **Wastewater treatment can address both, especially if**
  - industries have to treat their waste before release into any public sewers or treatment plants,
  - multiple barriers are used to take care of situations where farmers use a mix of untreated and treated wastewater or post-harvest contamination occurs.

NJS

Multi-barrier approach for farmers and consumers as recommended by WHO



Source: Amoah *et al*. 2011)

These additional safety measures (similar to the HACCP approach) can have a significant risk reduction potential where treatment is not comprehensive or failing with a high return on investment of US$ 4.9 per US$ invested (IWMI, 2014).

WHO Guidelines (3rd Edition)

- Maximize the protection of human health and the beneficial use of important resources
- Guidelines provide an integrated preventive management framework for maximizing public health and environmental benefits of waste/wastewater use.

Volume 1: Policy and regulatory aspects

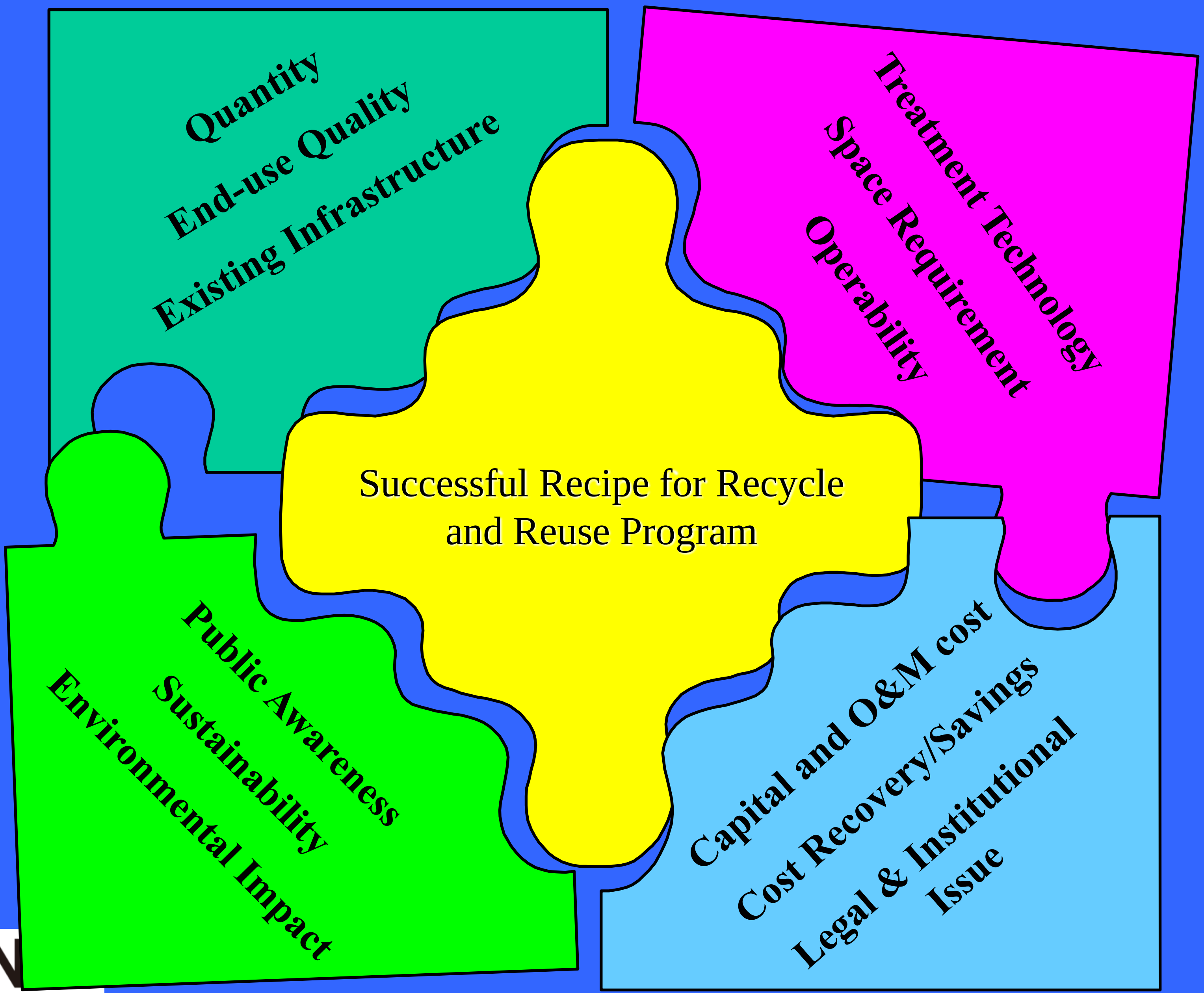
Volume 2: Wastewater use in agriculture

Volume 3: Wastewater and excreta use in aquaculture

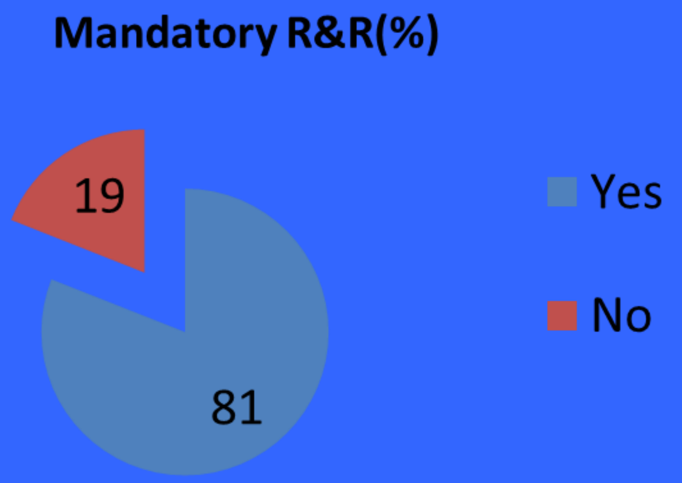
Volume 4: Excreta and greywater use in agriculture

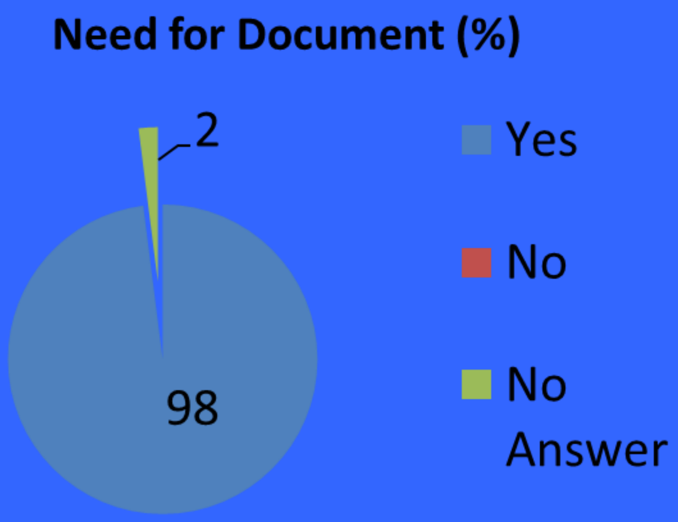
NJS

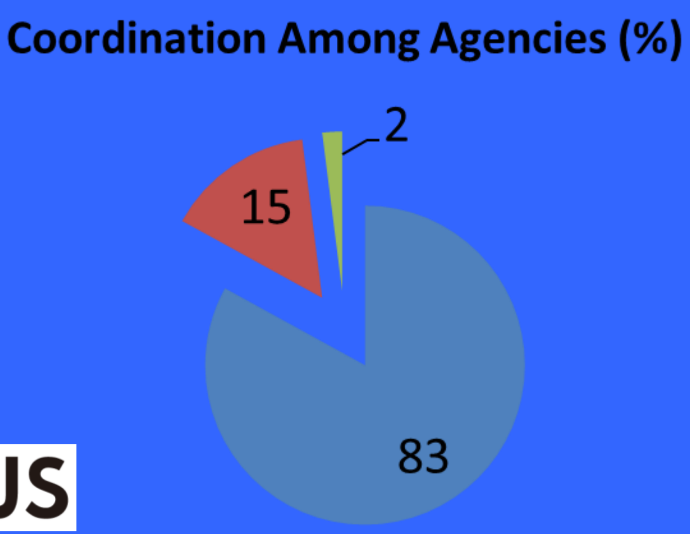
Recipe for Success

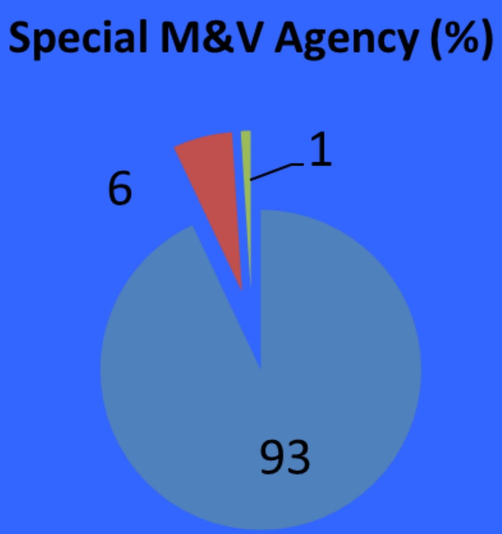


Survey Analysis-Regulatory Issues

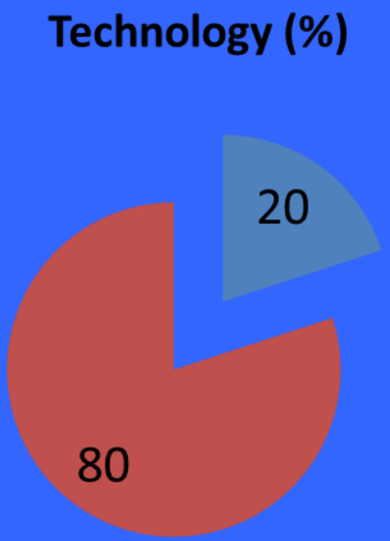


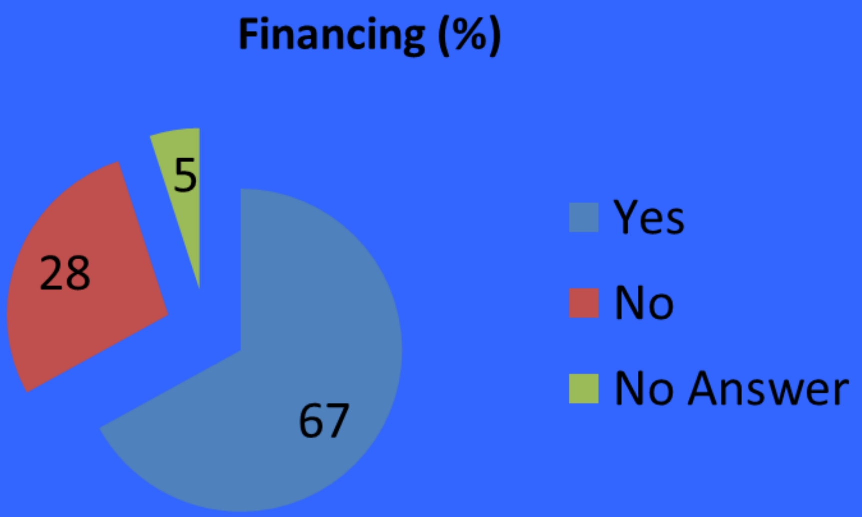


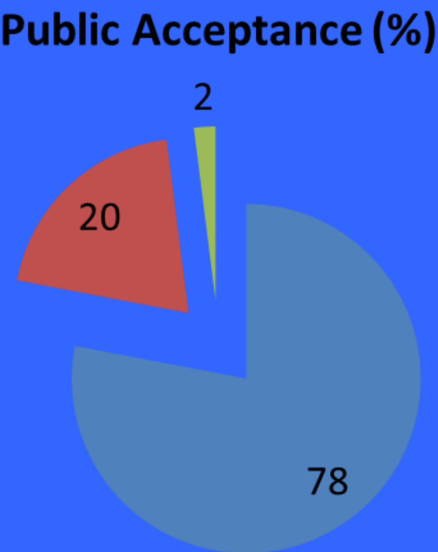




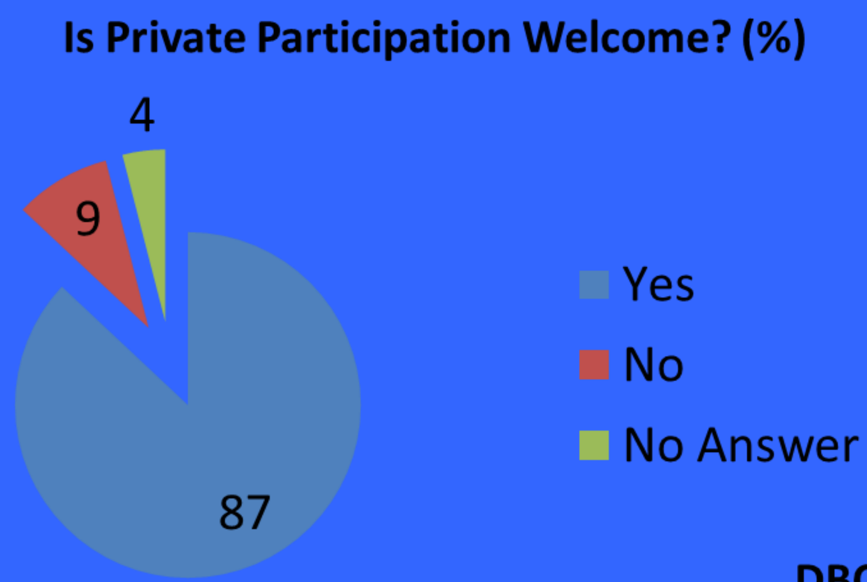
Survey Analysis-Other Issues

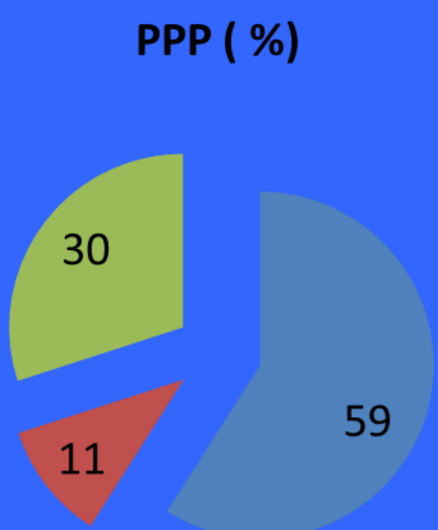


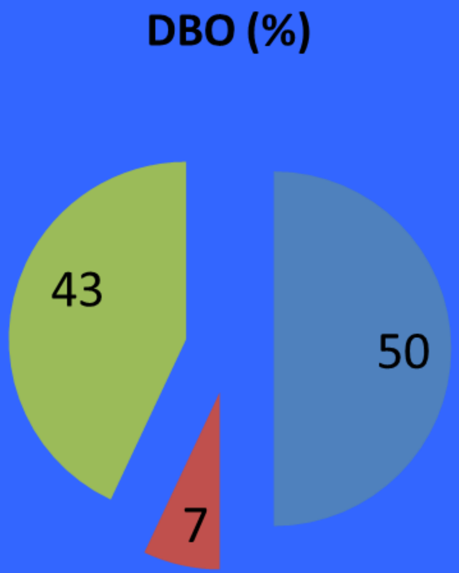




Survey Analysis-Models







Thank You

Contact Information

Dr. Uday G. Kelkar, P.E., BCEE
Cell: +91-9822401962

Ajit Savadi
Cell:+91-9727764800

uday@njsei.com
Ajit.Savadi@njsei.com

NJS

Capacity Building Training under Amrut 2.0 on 'Fit for Purpose Technologies for Recycle and Reuse of Wastewater

Business Model for Recycle and Reuse of Wastewater

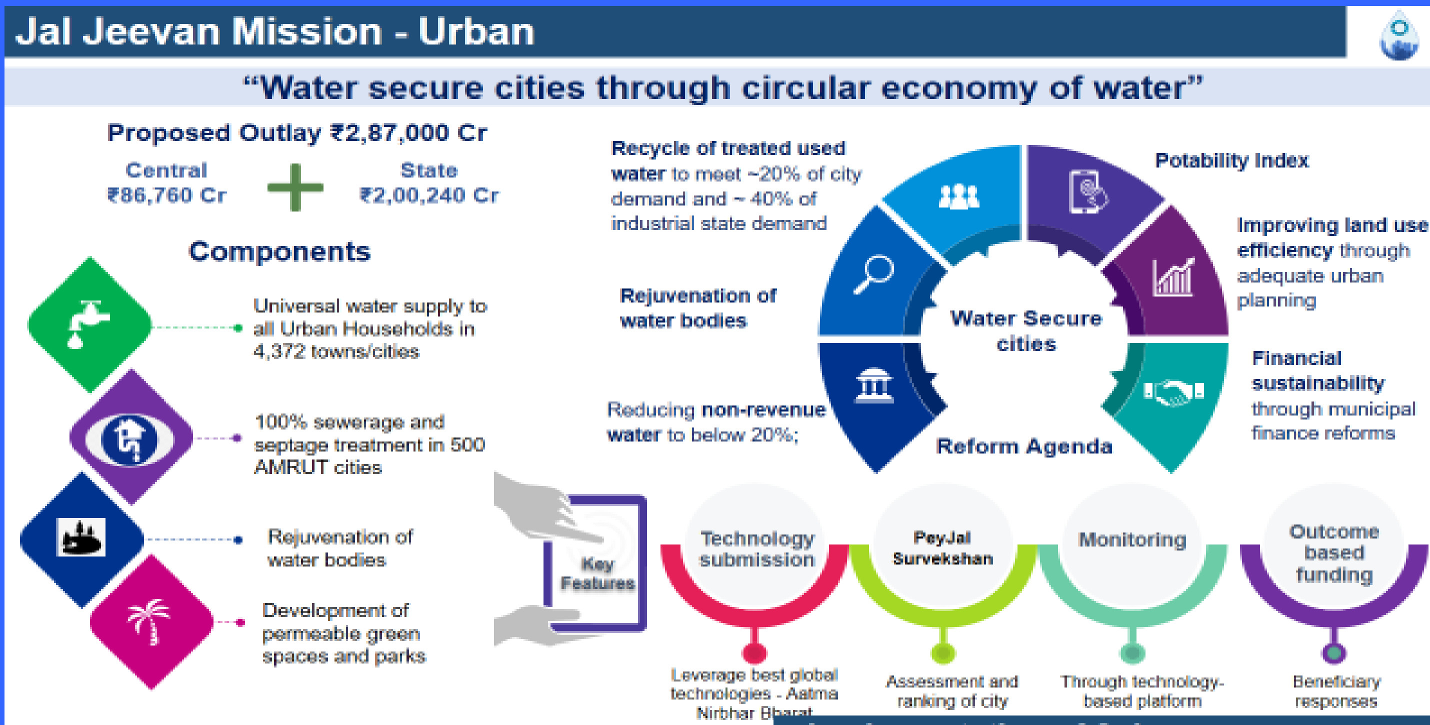
Dr. Uday G. Kelkar, P.E., BCEE
&
Ajit Savadi

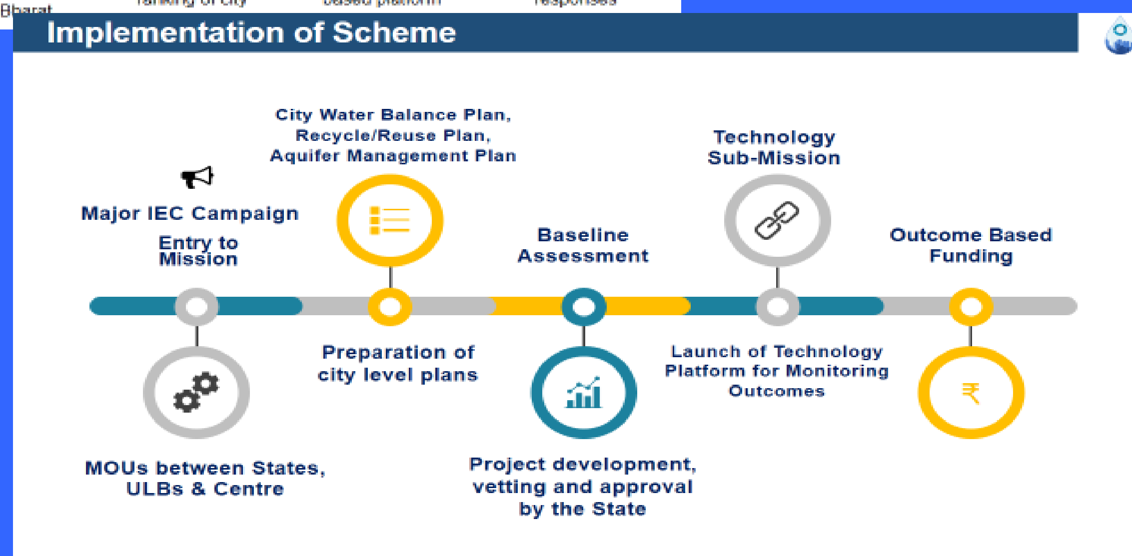
NJS Engineers India Pvt. Ltd.

January 11, 2023


"No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade."
– United Nations, 1958

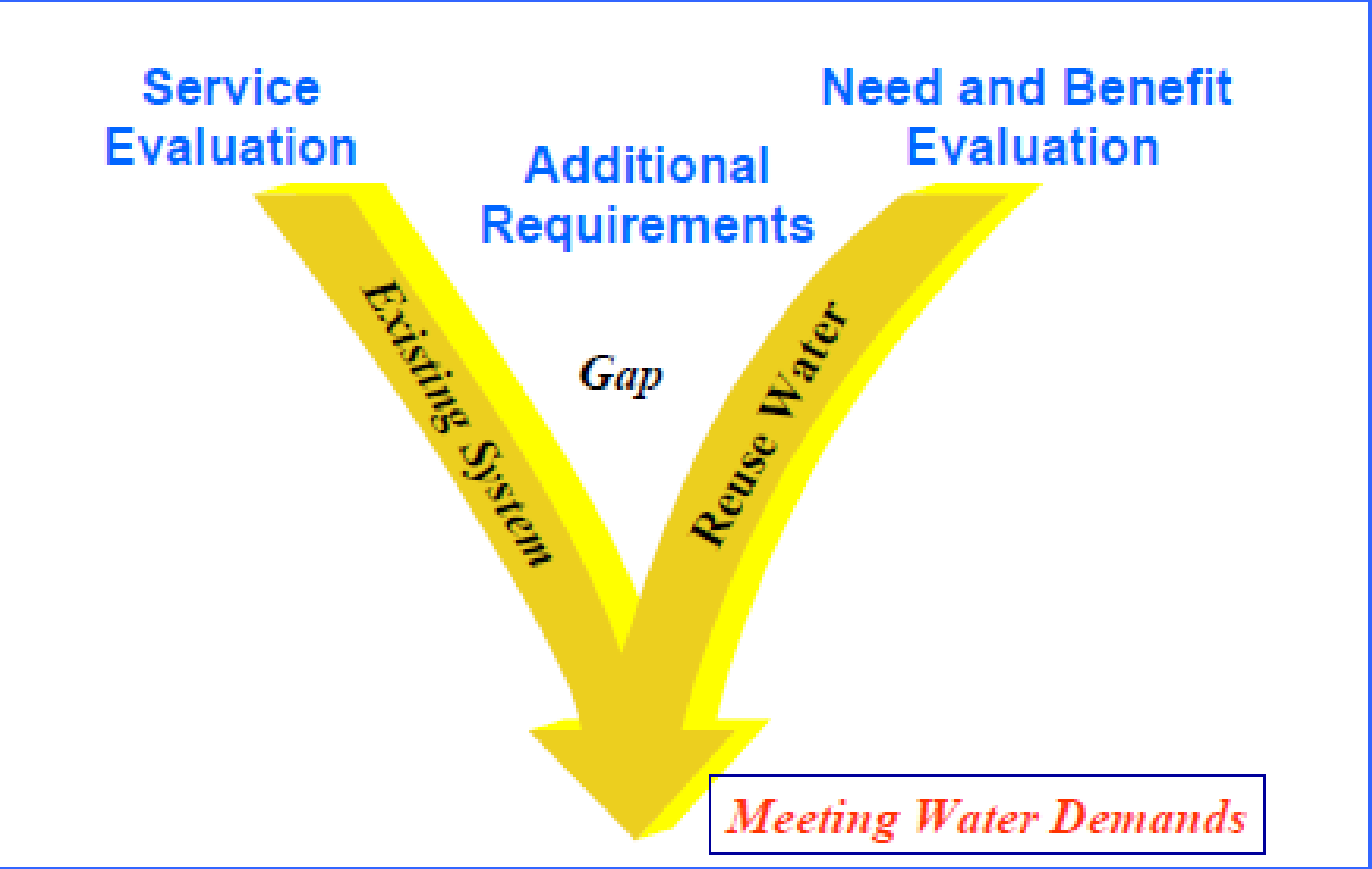
Focus on Water Sustainability – Water Secure Cities – as of 2021-2022 Financial Budget





Adapted From: MoH&UA
2021-2022 Financial Budget & Planning – AMRUT 2

Conduct a GAP Analysis for Reuse

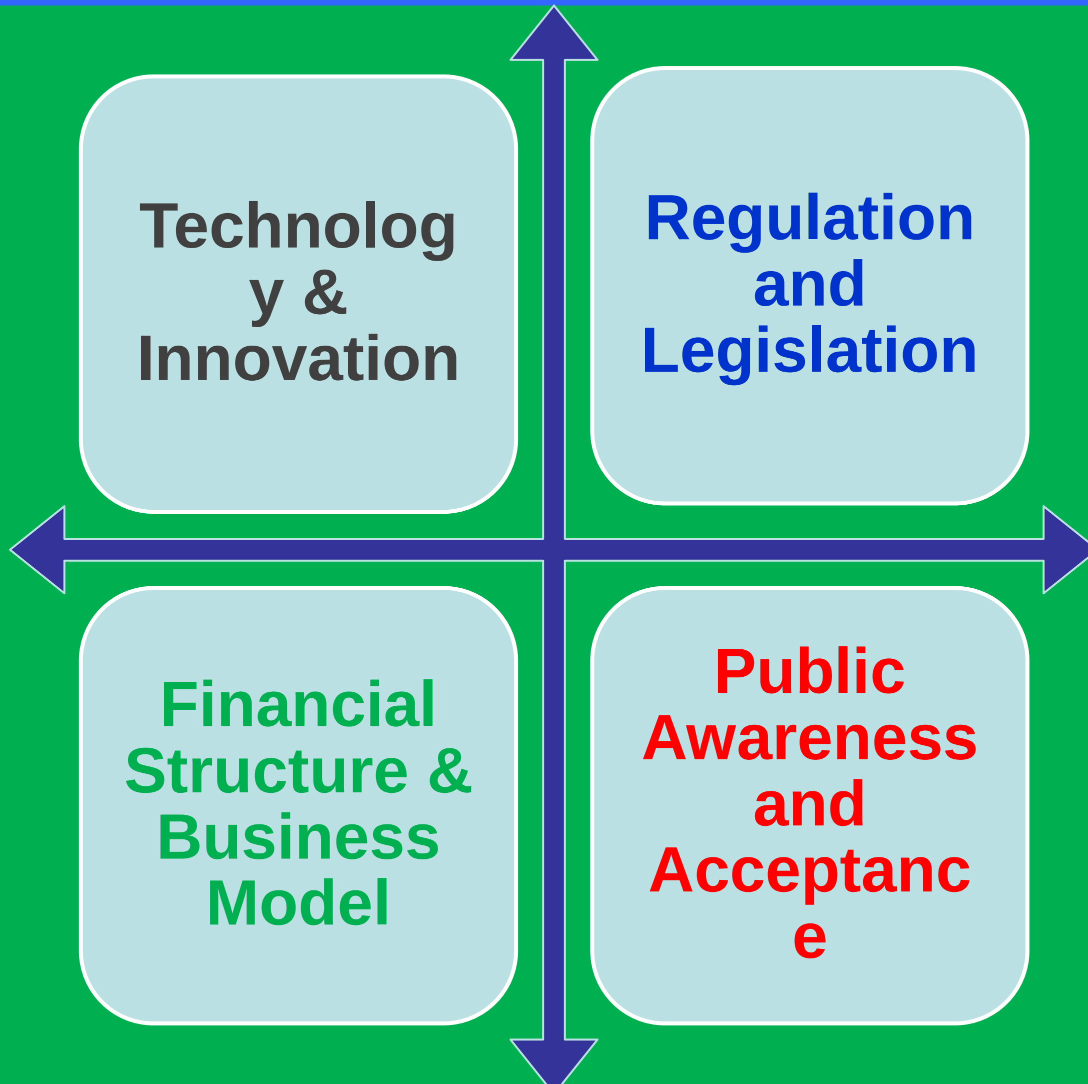


What are major concerns on Reuse Water

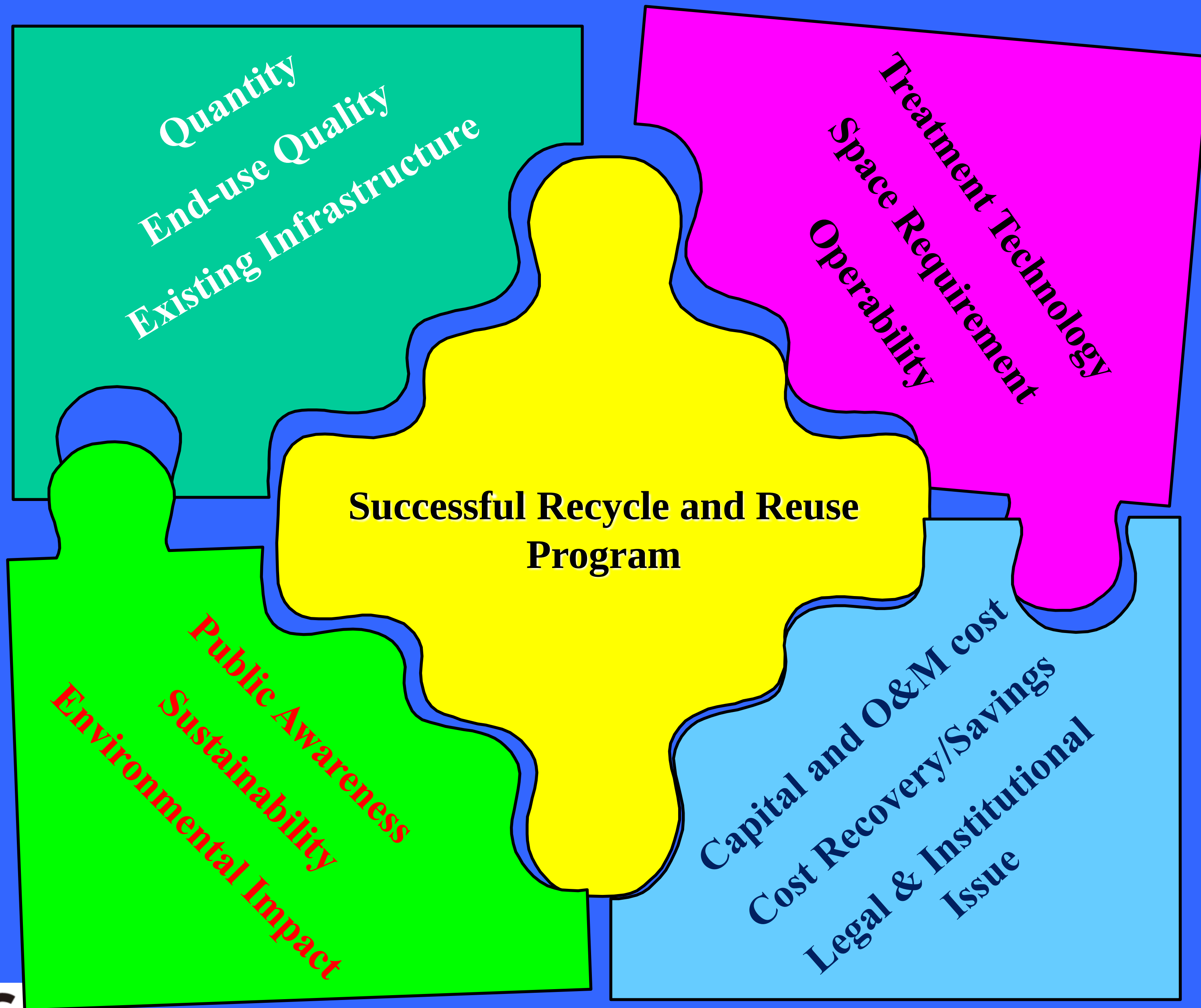
- Usage Type of recycled water?
- Availability of Treatment Technologies?
- Operability and Reliability?
- No Confidence in Gov. or private O&M operators?
- Consistently meeting water quality Standards?
- Health Issues? or

NJS

Specific Needs of India within the Four-point Framework – towards Reuse



Recycle and Reuse – Action Items



Technology selection criteria

- Reliable (proven and established)
- Recycled water quality and its consistency
- Wastewater generation from treatment process
- Operator requirement / automation
- Space requirement (may not be important for industrial areas due to appropriate allocation of land)
- Capital cost, O&M cost (Lifecycle cost)

NJS

Challenges to adoption

Category of challenge	Sub-category	Description
Financial	▪ Insufficient access to capital	▪ End user cannot access financial resources to pay for the necessary up-front costs of a lever
	▪ High upfront costs	▪ Upfront costs are too high even if access to capital is possible
	▪ High transaction costs	▪ The logistical cost of deploying a particular lever is prohibitively high
Political	▪ Negative impact on constituencies	▪ Certain levers (e.g., dams in specific areas) might disrupt the lives or adversely affect interests of constituents
	▪ Pricing distortion due to subsidies	▪ Levers are not attractive because end-user does not feel the impact of the true cost of water
Structural & organizational capacity	▪ Fragmentation of opportunity	▪ Certain levers require implementation and buy-in from many end-users to reach water-saving potential
	▪ Limited management capacity	▪ The existing capacity in government or private sector is not sufficient to carry out proposed projects
	▪ Unclear or fractured lines of authority	▪ The responsibility to implement a lever lies across agencies without a clear line of authority
Social & behavioral	▪ Water has low "mind-share" for end-user	▪ Improving water efficiency is not a key element of end-user decision-making
	▪ Difficult for end-user to measure consumption	▪ Lever adoption is not reinforced because it is hard to evaluate, measure and verify savings
	▪ Lack of awareness or information	▪ End-users are not aware of how a specific efficiency lever or service can be beneficial

SOURCE: 2030 Water Resources Group

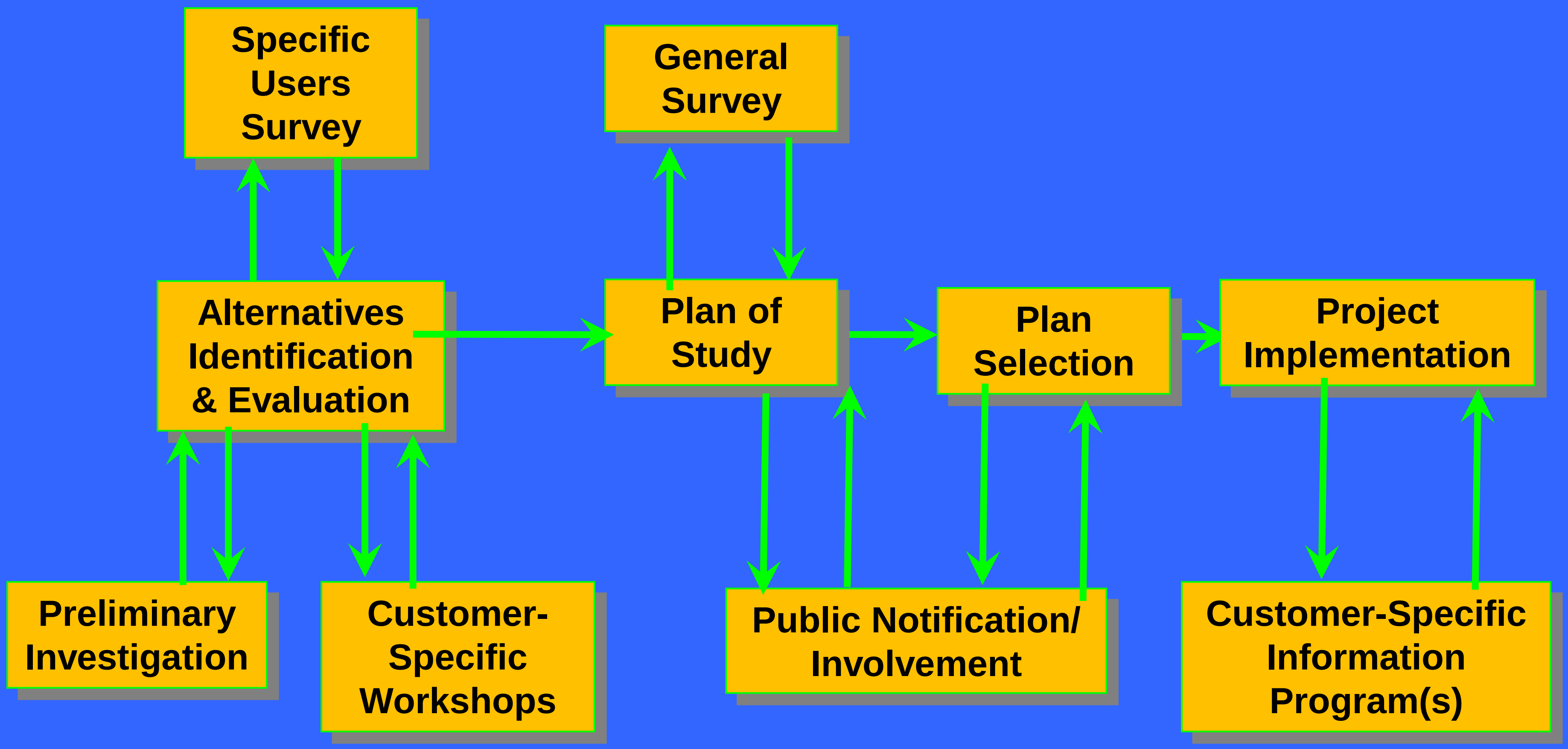
Typical Treatment Requirements for Reuse

Reuse Application	Parameters of Concern	Possible Treatment Technologies
Agricultural irrigation	FC & other pathogens	Disinfection
Water exchange (swap)	None, if treated wastewater meets river discharge standards	–
Reservoir recharge	N, P, DWS	NAS, CFID, NTF, wetlands
Groundwater recharge	N, DWS	NAS, CFID, BAF, NTF, wetlands
Domestic non-potable	T, FC, TRC	GMF, Disinfection

FC – fecal coliform, **N-** nitrogen, **P** - Phosphorus, **DWS** – drinking water standards,

TRC – total residual chlorine, **T** – turbidity

Public Participation Program for Water Reuse System Planning



NJS

"Mother Nature has been recycling water for millions of years. Now It is time we have, too."

Recycled Water Provides Benefits :

- A new source of water for Industry and Consumer
- Protection to the natural environment
- Savings in energy consumption by reducing pumping cost
- Increasing future water reliability
- Cleaner rivers and lakes in the Region
- Adequate water supplies for urban growth needs

Regulation of Water Recycling :

A robust and independent regulatory framework, overseen by public health authorities, is necessary for the long-term success of a water-recycling program. Examples of existing regulations and criteria for water reuse exist in countries where there has been a long history of water reclamation and reuse.

What Is Recycled Water?

Recycled water is high quality treated wastewater effluent; minus pollutants, contaminants and microbes and viruses. Nature recycles water continuously through the hydrologic cycle. The wastewater treatment plant emulates natural processes in a controlled, monitored and reliable manner to produce high quality water for additional cycles of beneficial reuse.

The chemical and microbial quality of tertiary treated recycled water is not different from potable water from which it originated. One of the differences is the concentration of dissolved salt-such as sodium chloride and calcium carbonate–which may be slightly higher concentrations. Whether or not these differences are bad depends on the level of salinity of the treated water and the composition of salts in the water.

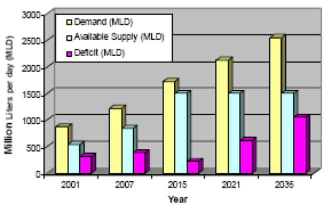
Over the past 40 years, a number of research projects have been conducted in various parts of the world to study the public health issues in using recycled water. The chemical, physical & biological properties of recycled water can be kept within acceptable standards with suitable tertiary and advanced treatment processes. As such, treated recycled water can also supplement the need of potable demand in water scarcity area such as Bangalore, where the option is economically feasible.

Why It Is Necessary to Use Recycled Water In Bangaluru Area?

The Bangaluru City area is water-short now, and all water resources are stressed beyond their capacity including Cauvery River and Arkavathy River. Anticipated population increases and future development will exert even greater stress upon these water supplies – widening the gap between supply and demand. The graphic depiction below dramatically illustrates the impending water crisis in the region. New sources of water are needed to help close the gap that are reliable, least expensive, and technologically feasible. Most importantly recycle and reuse has been practices worldwide for a variety of applications including indirect potable use, e.g., Singapore and other water utilities in USA.

With proper treatment process and with adequate safety systems, high quality reclaimed water can be used safely where it is most appropriate, and in augmenting the existing resources.

Water Demand and Deficit in Bangalore



How Is Recycled Water Treated?

Wastewater from houses and business centres in Bangalore are piped through sanitary sewers to wastewater treatment plants where it progresses through primary, secondary, and tertiary stages of treatment before it is disinfected and discharged to natural rivers and drains within the Bangalore Area that flows downstream and is wasted. Instead of fully wasting the water some part of this water is treated through advanced treatment processes like, ultrafiltration membrane and granular activated carbon and could be reused to augment the water resources. The water that is treated through these advanced processes is most of the times of potable quality

Primary treatment is a gravity process that allows solid matter to either float to the top or settle to the bottom and is then removed as sludge.

Secondary treatment uses microbes to digest dissolved organic matter, remove nutrias such as nitrogen and phosphorus and small waste particles that are too light to settle out. As these microbes eat, grow and die, their bodies fall to the bottom, leaving water that is over 85 percent pure.

Tertiary treatment uses a multilayered filter composed of sand, coal, and stone, to remove remaining suspended particles.

Advance treatment such as Microfiltration/Ultrafiltration, Reverse osmosis etc. can be added to improve removal of bio-chemical parameters even further, making the water 98% pure.

Disinfection involves use of chlorine, ozone or ultraviolet radiation, to destroy bacteria, viruses, and other pathogens that may remain after these treatment steps. At this stage, the water is over 99 percent pure and can be used for nearly all purposes including indirect potable applications.

Water Quality Achievable in Recycled Water

Water quality parameters	Unit	US EPA / WHO[b]	NEWater Factory[c]
Color	Hazen units	15	<5
pH	Unitless	6.5 – 8.5	5.2 – 6.2
Conductivity	µS/cm	--	39.6 – 71.1
Alkalinity	Mg/l as $CaCO_3$	--	8
Total Dissolved Solids	Mg/l	500	22 – 41.3
Hardness	Mg/l as $CaCO_3$	--	<5
Fluoride	Mg/l	1.5	0.18 – 0.22
Nitrite	Mg/l as N	0.91	0.38
Nitrate	Mg/l as N	10	0.49 – 1.65
Ammonia	Mg/l	1.5	0.35 – 0.57
Chloride	Mg/l	250	3.6 – 10.9
Turbidity	NTU	5	<0.1
Aluminium	Mg/l	0.2	0.09
Iron	Mg/l	0.3	<0.003
Manganese	Mg/l	0.05	<0.003
Sulfate	Mg/l as SO_4	250	0.16 – 0.54
Zinc	Mg/l	3	<0.004
Silica	Mg/l as SiO_2	--	0.21 – 0.32
Phosphate	Mg/l as P	--	0.011 – 0.044
Sodium	Mg/l	200	5.1 – 9.6
TOC	µg/l	--	60 – 90
Total Coliform	Counts/100ml	ND[d]	<1
Fecal Coliform	Counts/100ml	ND[d]	<1
Clostridium perfringens	Cfu/100ml	--	<1

[a]Adapted from Singapore Water Reclamation Study (2002)
[b]Lowest limit of either the US EPA 1998 surface water regulations or WHO 1993 guidelines for drinking water
[c]Taken from analytical results for the months of June and July, 2000
[d]ND = Not detectable

"Implementing an Indirect Water Reuse Program in Bangalore"

BWSSB has embarked on a new vision in Augmenting its Water Resources and has initiated a V-valley reuse Project and has initiated a one year pilot-scale ultra-filtration membrane treatment process mimicking the project and is continuously monitoring the treated water quality for a number of chemicals including natural and synthetic compounds and microbial contaminants.

Effluent water quality from the pilot plant indicates that the water is of high quality meeting potable standards.

BWSSB's Integrated Water Resource Management – V-Valley Project:

Under the V-valley Project, BWSSB is interested in augmenting its existing V-valley sewage treatment plant (STP) for enhanced removal of biological oxygen demand, and nutrients such as nitrogen and phosphorus from the secondary treated effluent. The 135 MLD secondary treated effluent will then be processed through tertiary process of media filtration for further removal of solids and suspended material.

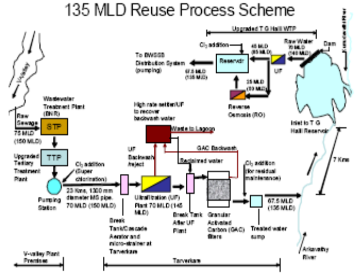
This tertiary treated water will then be chlorinated to achieve a total of 4 hours of disinfection time. The chlorinated water will then be pumped from V-valley plant to 23 Kms via 1300 mm MS pipeline to Tarverkare.

At Tarverkare, the water will be further passed through 0.04 micron nominal pore size, PVDF, ultrafiltration (UF) membrane for removal of colloids, dissolved natural organic matter and any remaining microbial contaminants (which are typically larger than 0.04 micron size). The permeate from the ultrafiltration process will then be passed through Granular Activated Carbon (GAC) beds for the removal of any remaining synthetic organic chemicals, pesticides, endocrine disrupting chemicals (EDCs) and personal care products. To this effluent a small dose of chlorine will be added to maintain the disinfectant level before the high quality water is discharged to the Arkavathy River.

The high quality treated water will then travel through the natural course of Arkavathy River for a distance of seven kilometres before getting merged into the TG Halli Reservoir. The mixed water will have an average of 200 days of retention time in the TG Halli reservoir. With this the TG Halli reservoir will get continuously augmented with the high quality treated water.

As part of the V-Valley project, the existing TG Halli water treatment will be rehabilitated with membrane filtration including partial reverser osmosis (RO) process to 135 MLD. This new rehabilitated water plant will be able to process the water from the TG Halli reservoir in meeting all the drinking water standards before the water is supplied back to BWSSB consumers for

135 MLD Reuse Process Scheme



For additional information and to enquire about BWSSB's plans for use of recycled water for Indirect potable use, please contact:

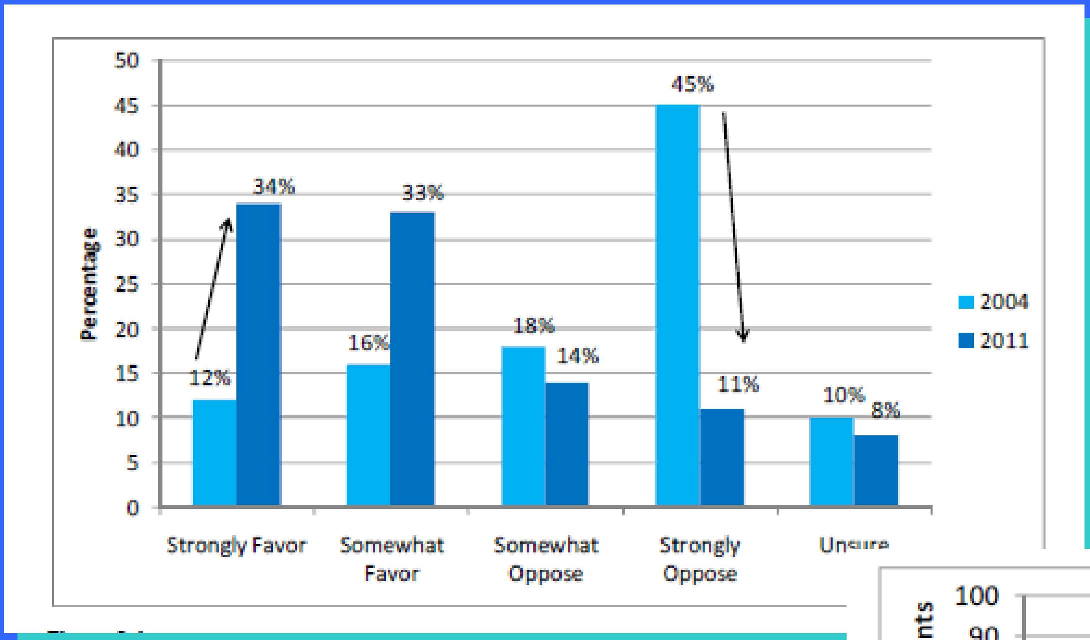
·Bangalore can become water surplus from a water stress region with implementing indirect water reuse and will be the leader in India in showcasing effective application of recycle reuse for indirect potable use.

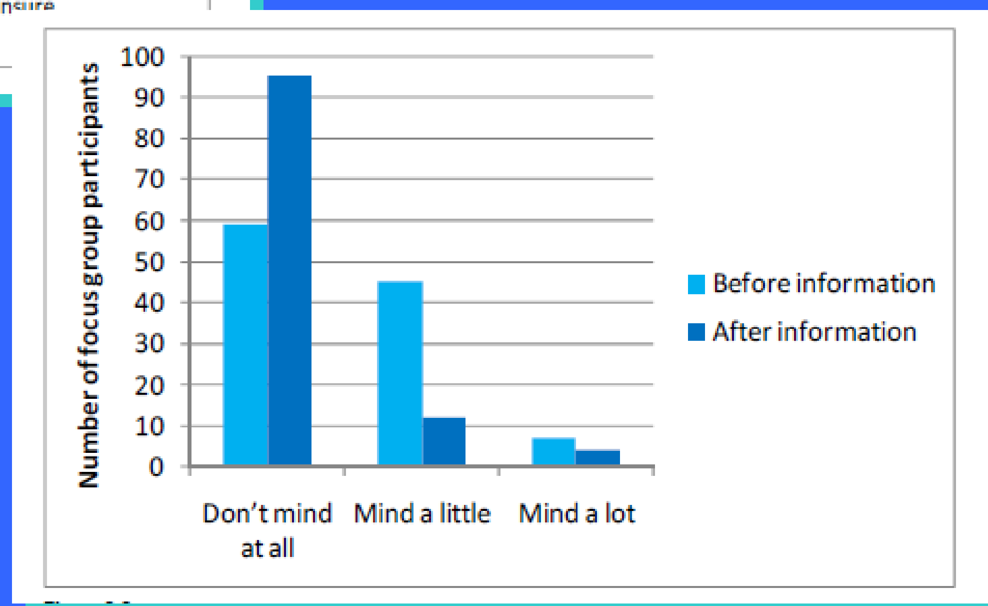
IWRM V-Valley 4000 litres per day Pilot Plant

BWSSB V-Valley Reuse Project
Detailed IEC material and Brochure for Public Awareness Campaigns

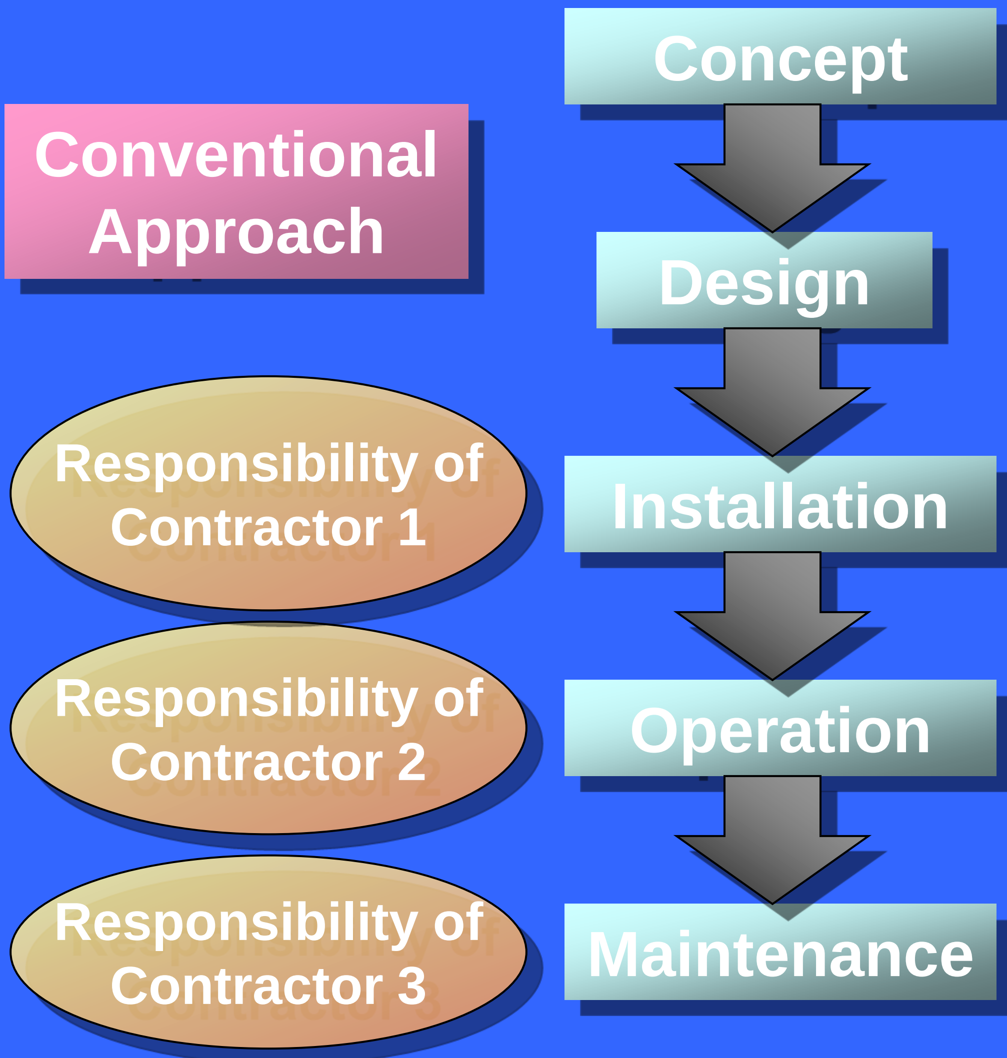
NJS

Public Outreach – How things change





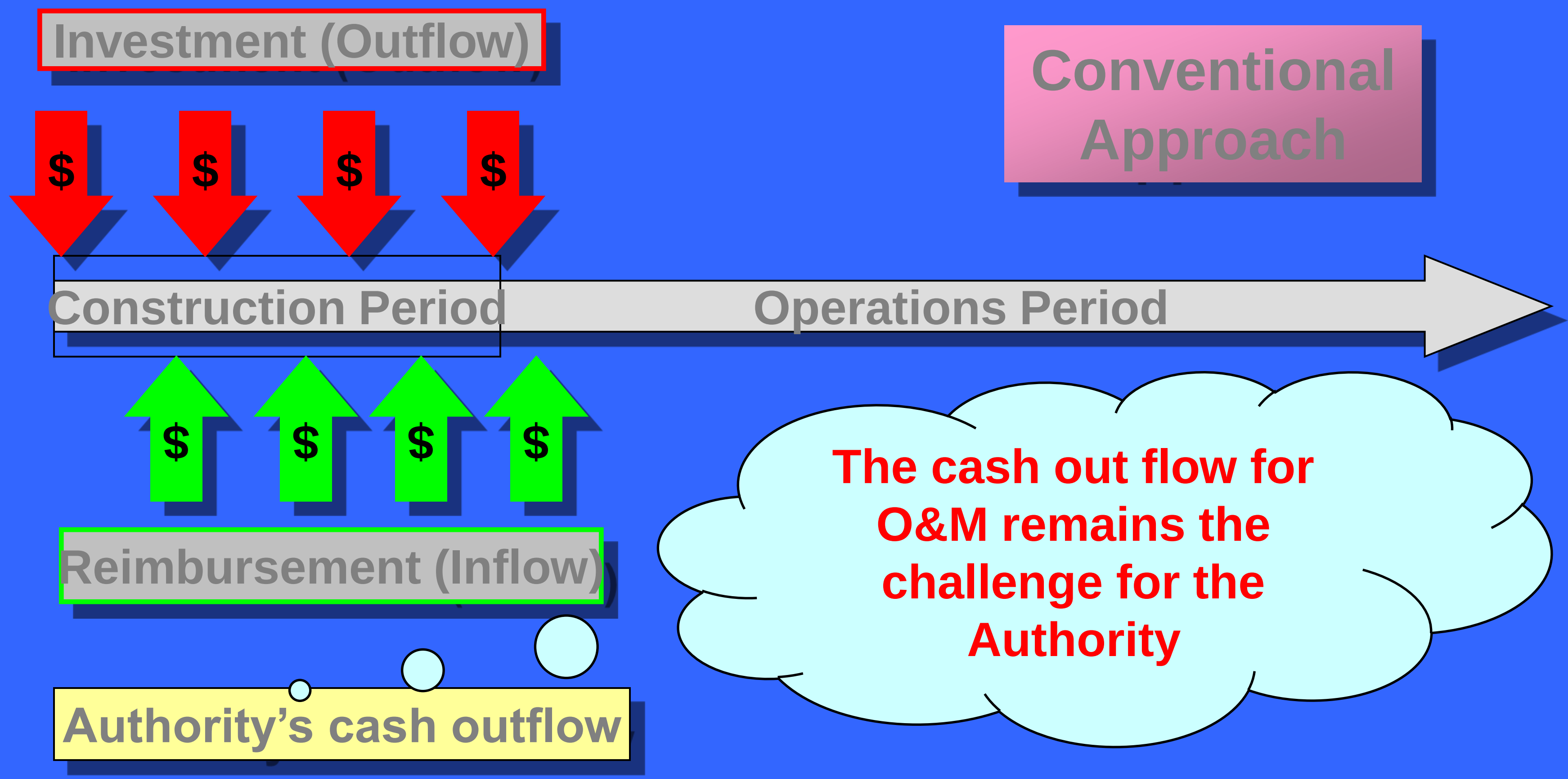
Project Development: Conventional



So, what are the problems ?

1. **Authority has no control on the construction time – Hence, time – overrun**
2. **Authority has no control on the cost – Hence Cost-overrun**
3. **Authority has to pay entire cost by the end of the construction – constraint on cash flow**
4. **Operational involvement**
   1. **Multiple contractors**
   2. **Admin overhead**

Contractor's Cash Flow

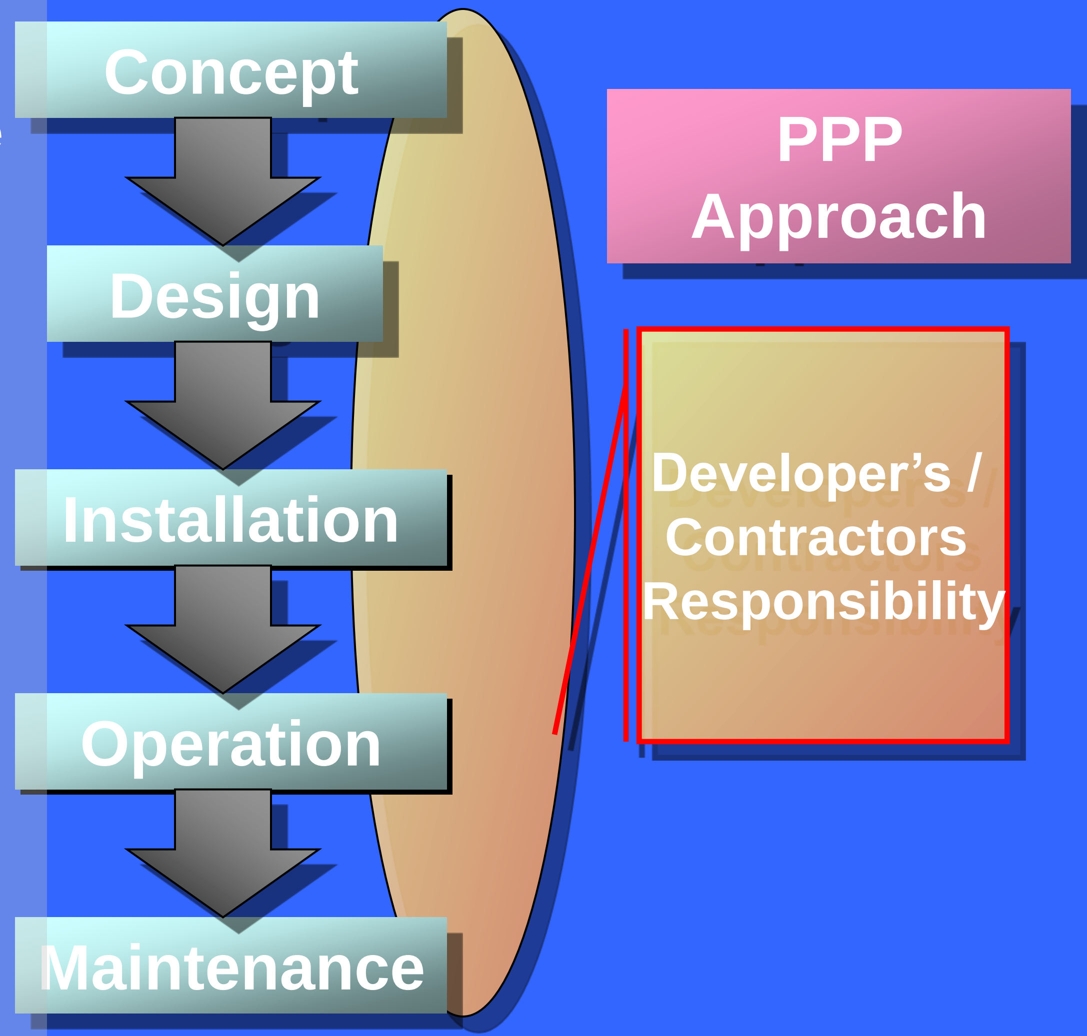


Adapted from IDFC presentation 2009

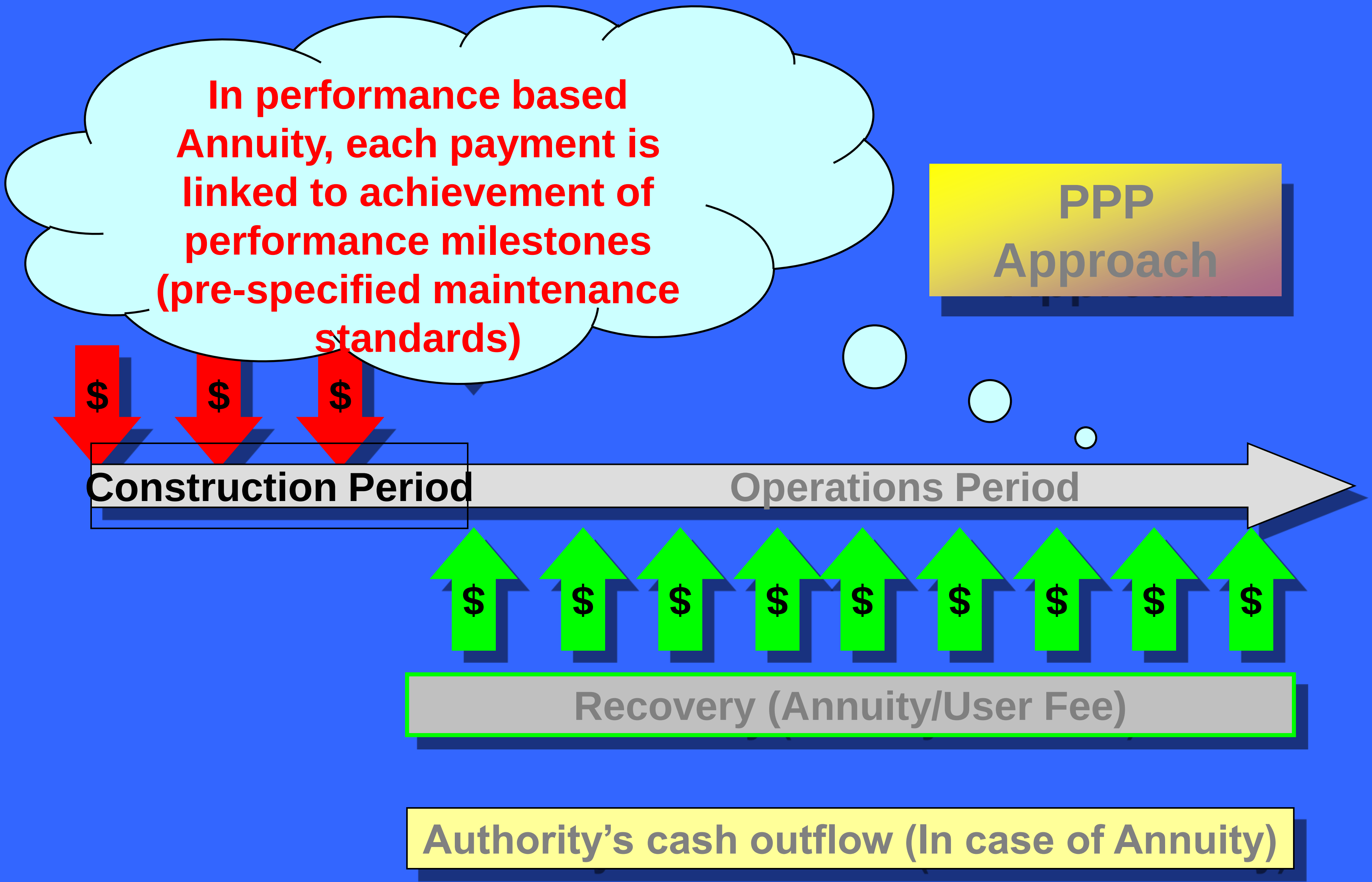
Project Development: PPP /Hybrid Annuity Model (HAM)

So, what about that?

1. Authority only conceives the project
2. Developer would design to required specs
3. Developer to invest money and recover during O&M period
    1. Either as User Fee or
    2. As Annuity
4. Developer assumes risk of Cost & Time overrun and operations



Developer's Cash Flow: Annuity/User Fee



NJS

In a Nutshell

	Conventional	PPP with Annuity model
Design Risk	Authority's	Developer's
Cash Flow Risk	Authority's	Developer's
Cost and Time Over run	Authority has no control over it	Developer has inherent incentive to control time & cost
Operations Period	Authority invests substantial time and manpower	Independent Engg-monitoring Developer bears the risk of operations
Performance Standard	The contractor is already paid for, hence no control	Future payments to developer are linked to the performance
Revenue (Demand) Risk	Rests with Authority	PPP (Annuity)- with Authority PPP (User Fee) – with the developer

NJS

Risk/Barriers to Implementation

- **Private Sector**
  - **Presently limited technical and financial resources are involved – L1 becomes a big stumbling block in selecting quality contractors.**
  - **The time taken for completing all the formalities /documentation is too long -**
  - **Lack of Timely Payments**

NJS

Key Issues for Private Sector Participation

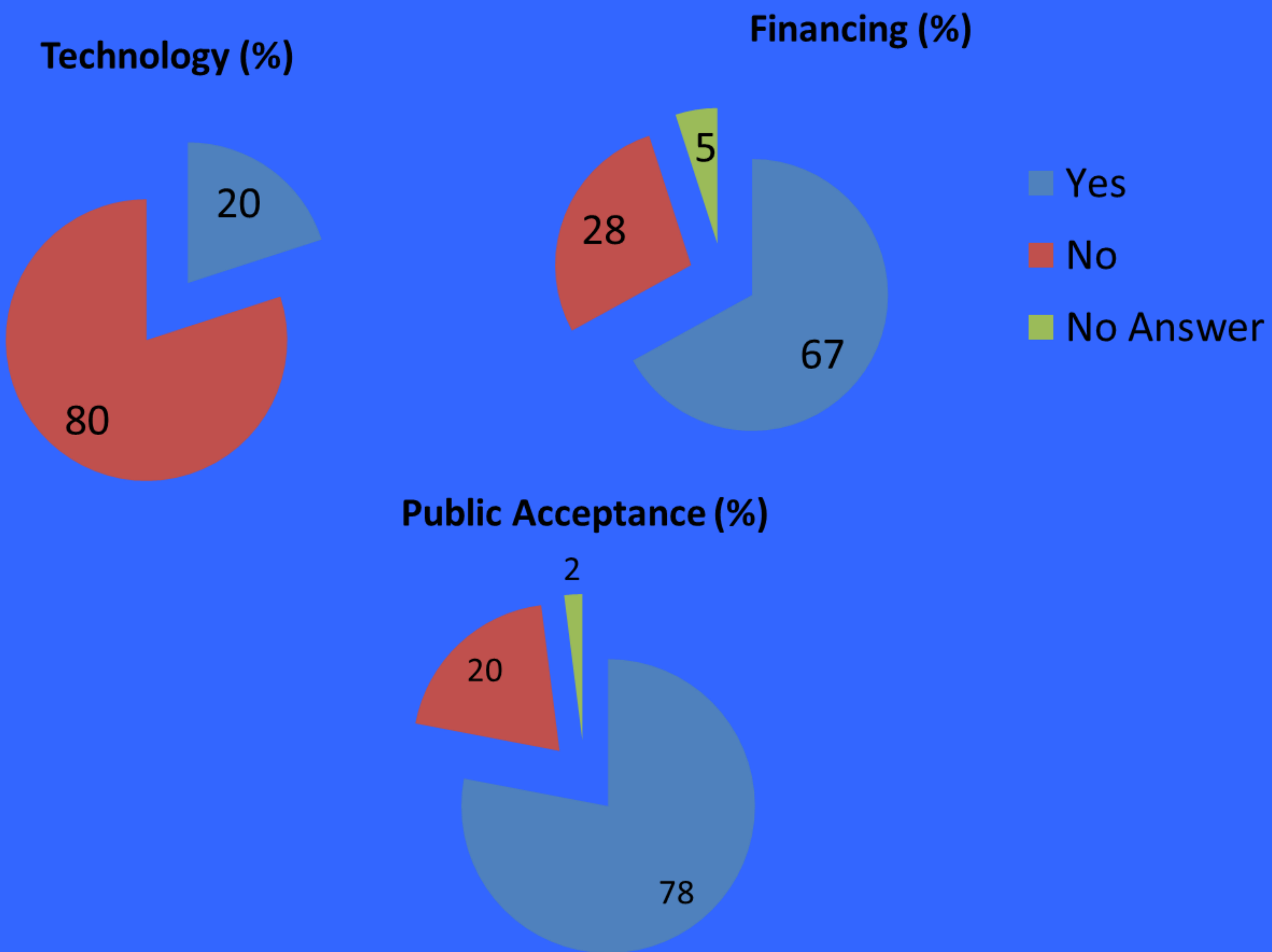
- Risk Assessment and Mitigation
  - Quality and Quantity of Wastewater,
  - Liability due to presence of Hazardous waste,
  - Change in duties and taxes
  - Inadequate Infrastructure

Contd.,

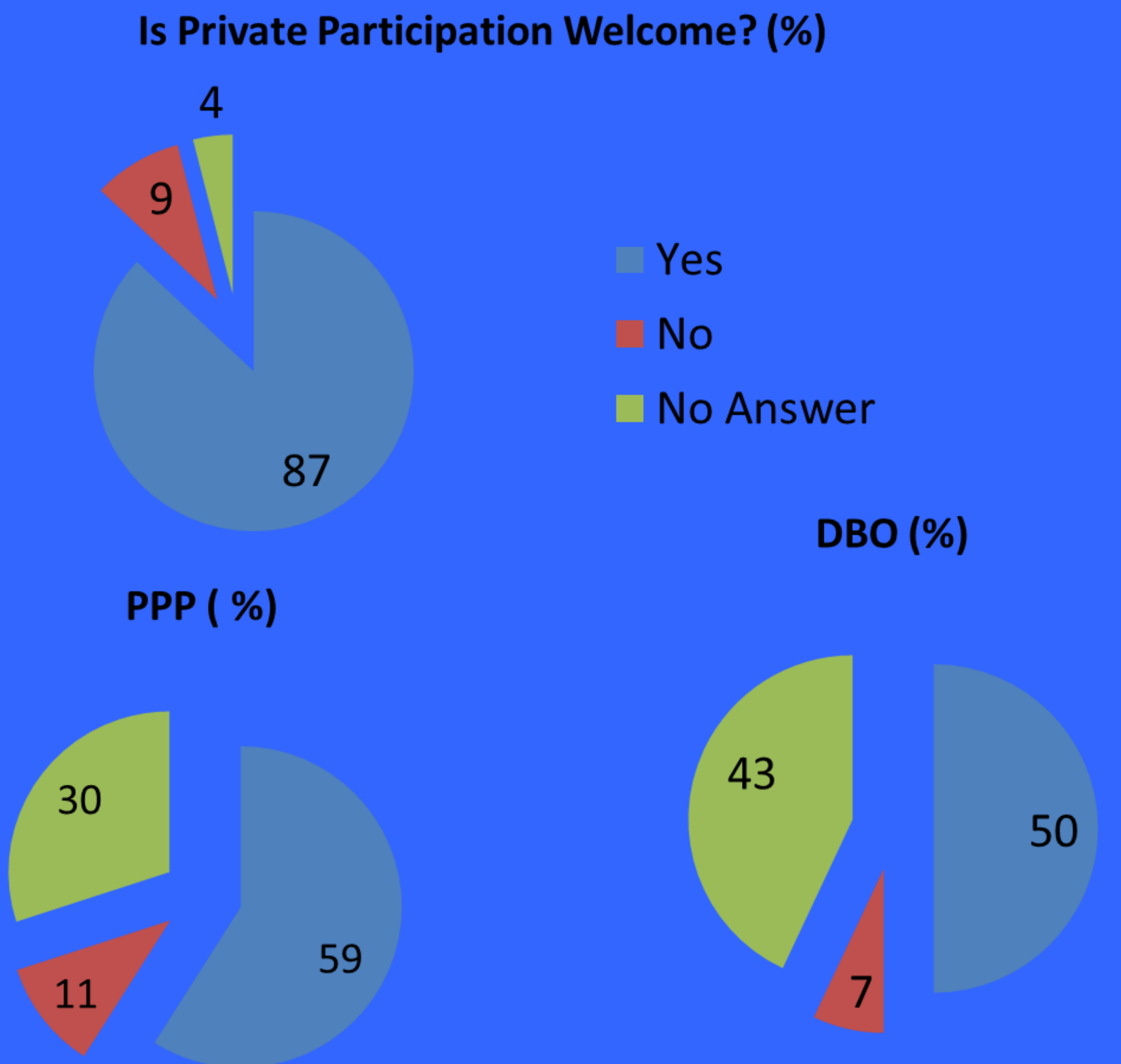
Key Issues for Private Sector Participation

- Commercial Viability
  - Capital Subsidy
  - Interest subsidy
  - Guaranteed Buyback, Taxation, Tariff Revision
- Other Incentives
  - Tax Credits
  - Trust Funds
  - Renewable Energy Production Incentive (REPI)

Survey Analysis-Other Issues



Survey Analysis-Models



Development of Reuse Guidance Document

Promoters of Recycled Water

Central Govt. or any State Govt.

- Policy Development for R&R
  - Guidance Document with legal & Institutional drivers
  - Commercial/Fiscal incentives
  - Water Quality Regulation and monitoring
  - Arbitrations
  - Risk Management Framework

SPV or any Water Board

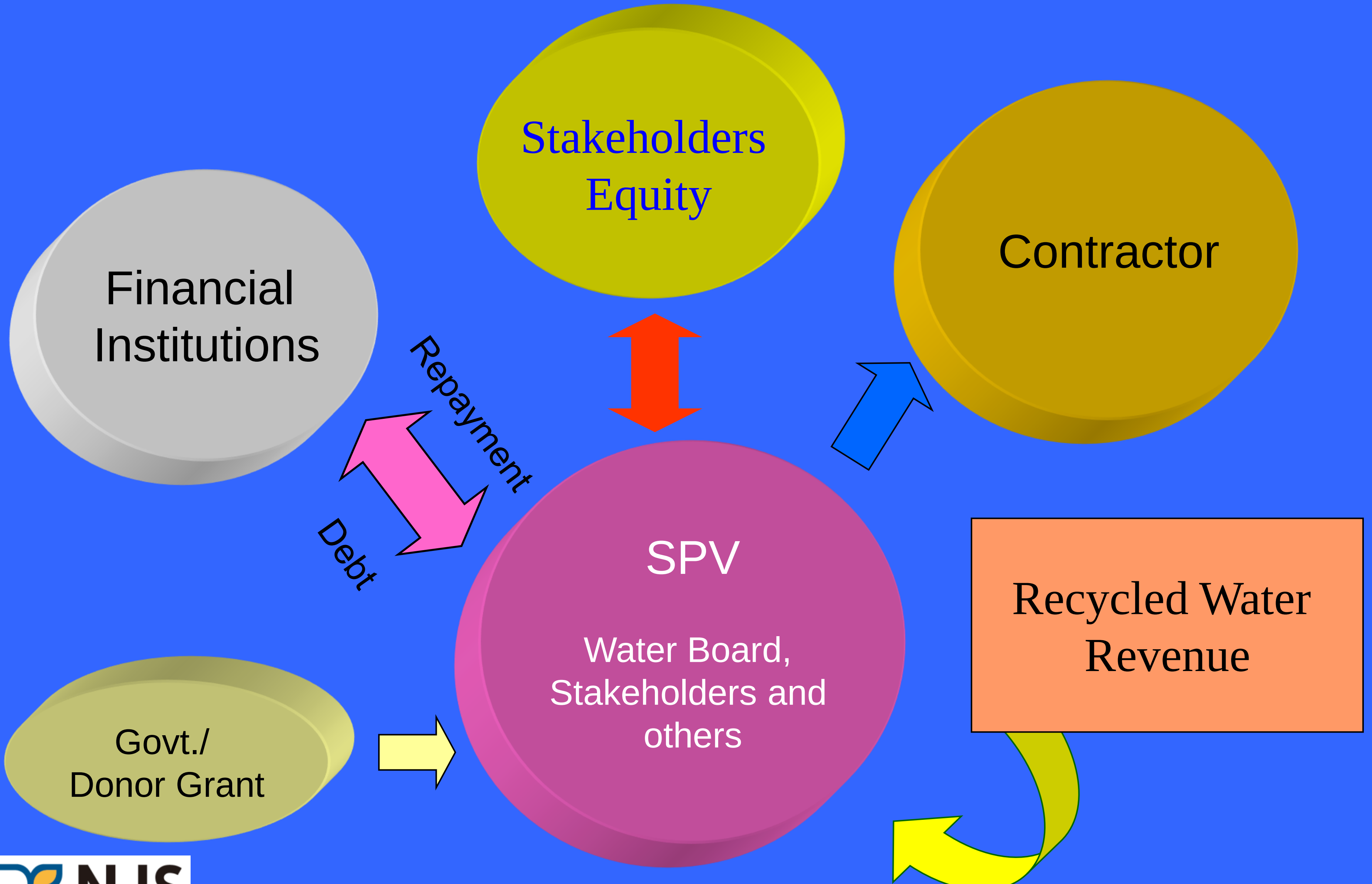
- Implementation of R&R
  - Demand Assessment and Marketing
  - Financial and Institutional framework
  - Public Awareness Campaign
  - Water Purchase and Sale agreements
  - Water Quality Monitoring
  - Customer Service

Prospective Buyers

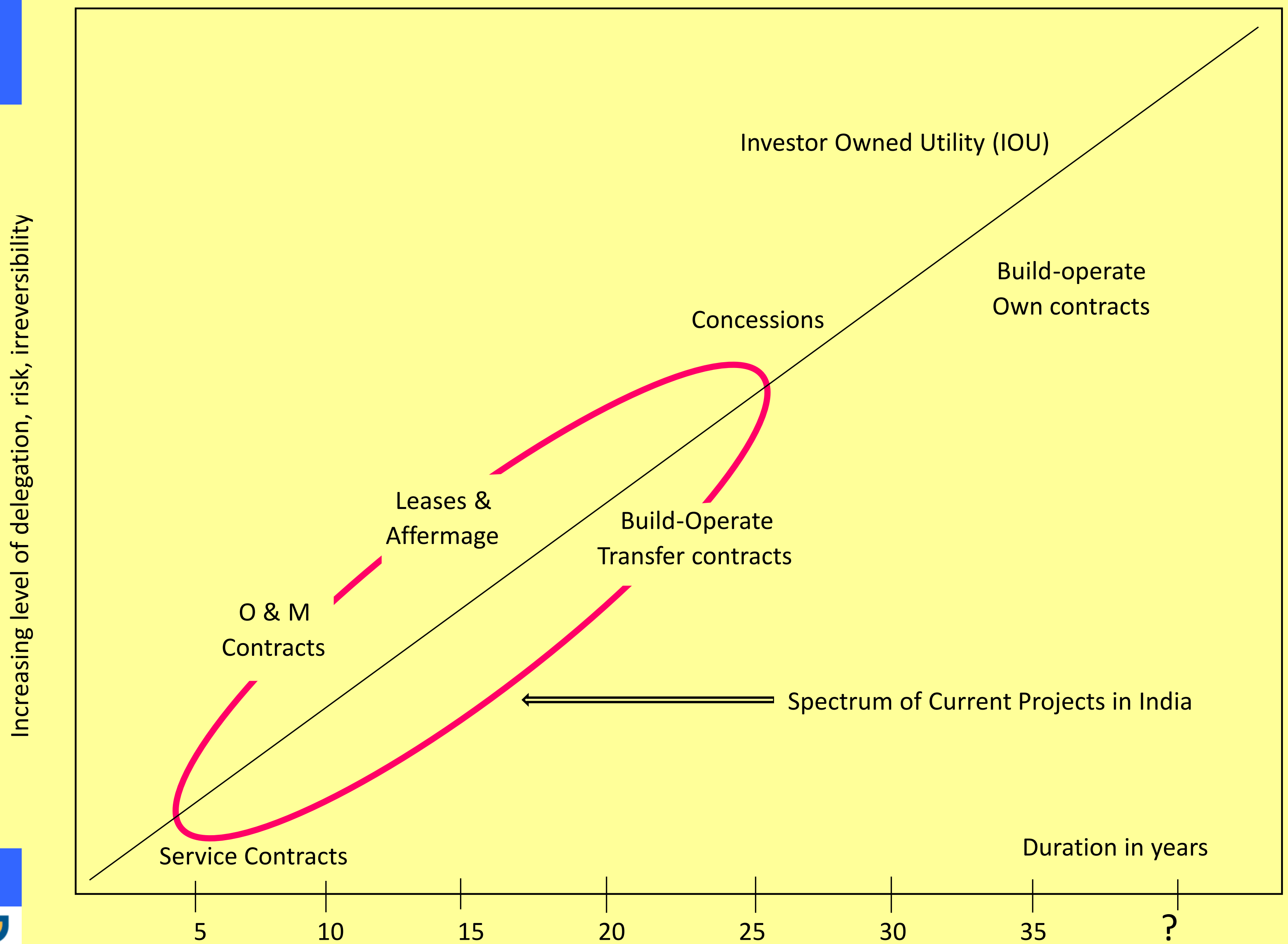
- Commitment to use Recycled Water
  - Infrastructure for use of Recycle water within their premises.
  - Water Quality and Quantity Bench-marks.
  - Point of use treatment if required.
  - Promotion of Recycled water

NJS

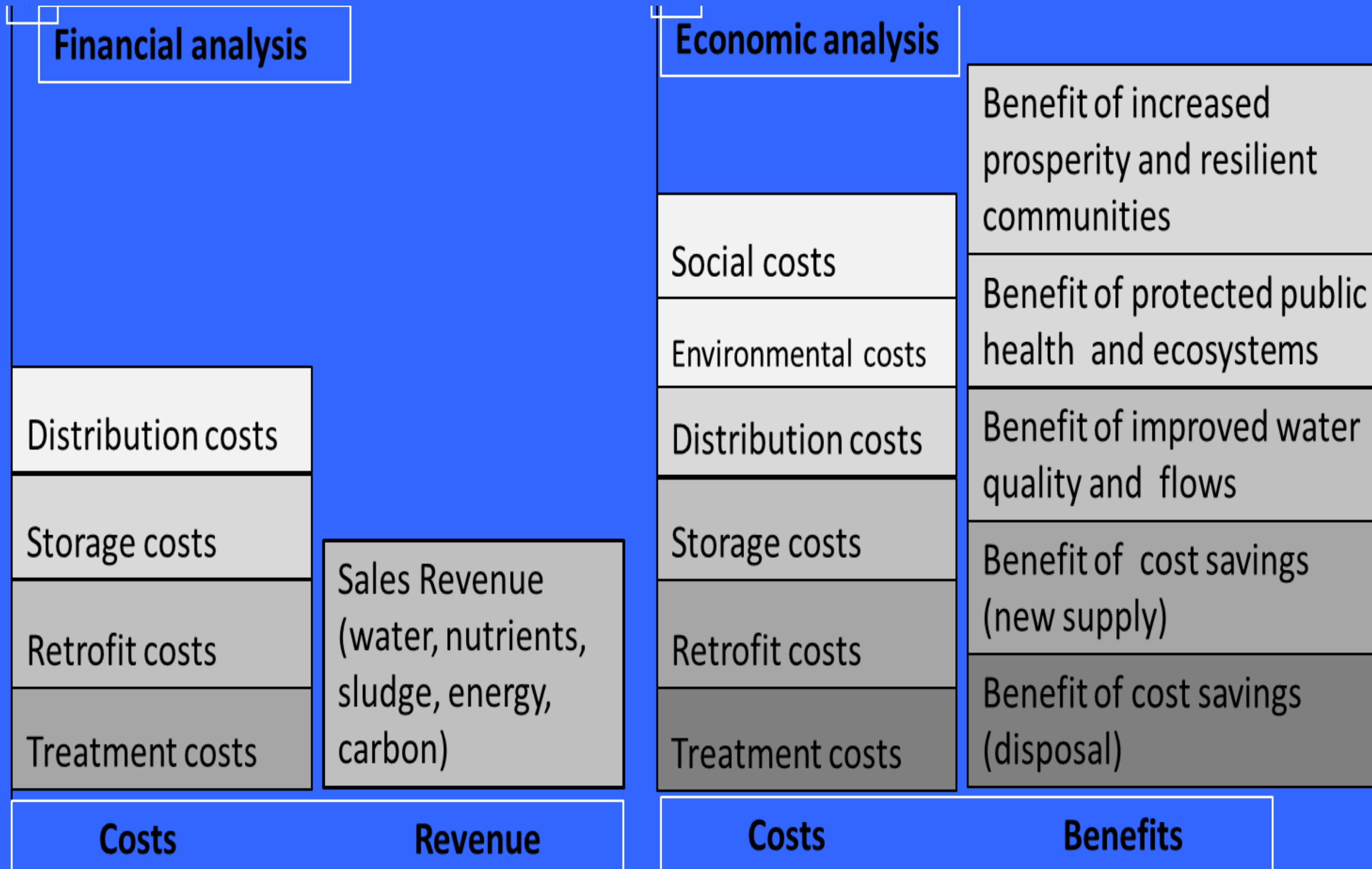
Suggested Financial Model for Project Implementation



Typical Business Models



Economic & Financial Analysis



Institutional Reforms to Promote Recycle and Reuse*

- Develop policy and guidance on recycled wastewater standards based on intended use

- Prioritize development of recycled wastewater schemes through an appropriate incentives structure within the Central Government sponsored schemes (such as the Atal Yojana).

- Develop guidance on cost recovery for utilities, encourage (and incentivize) utilities to invest in power generation at STPs.

- Develop an incentives framework for Cities to promote wastewater recycle and reuse, aligned with SDG targets for wastewater reuse.

***Adapted from WSP Advisory on Recycling & Reuse of Wastewater**

NJS

Reforms for WW Recycle and Reuse* Central Level

- **To Promote Collection & Treatment**
  - Policy guidance on universal sanitation access
  - Sewage management rules
  - Mandatory collection of all wastewater
    - All households to connect to network when available
    - All ULBs to provide access to such network & Treatment infrastructure
    - Utilities to develop sanitation master plan
    - ULBs to treat wastewater to predefined standards

- **To Promote Recycle and Reuse**
  - Inter Ministerial coordination for guidance on:
    - Regulatory framework for IWRM
    - Recycled wastewater standards
    - Development of reuse schemes through national programs
    - Incentive schemes
      - Additional funds for achieving pre-defined targets
      - Reuse of wastewater plans a pre-requisite for any assistance from central funds
      - Awards etc.
      - Incentives for Users

***Adapted from WSP Advisory on Recycling & Reuse of Wastewater**

Potential Contract Structure

- Private sector operator will provide technology, construction and maintenance support
- Financing construction will be the purview of the ULB through loans / grants from Govt.
- The same contractor will be responsible for maintaining the STP for the next 5-6 years based on a management contract for which he will be paid a management fee;
- A single contract document shall be developed, where the Net Present Value (NPV) of the Capital cost and the O&M cost for the next 15 years will be calculated and the operator with the ‘least’ NPV need to be chosen for implementation.
- The operator will be responsible for the technology he provides and for maintenance based on specific output targets

NJS

Structuring WW recycle projects

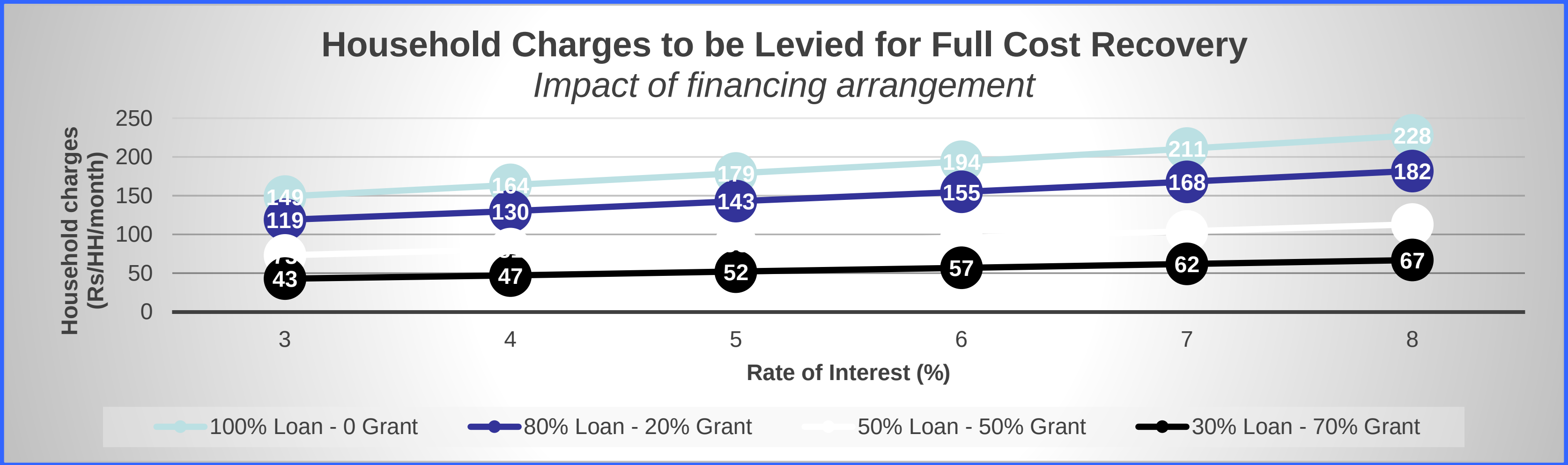
Financing and Implementation arrangements

NJS

Cost Recovery – User charges

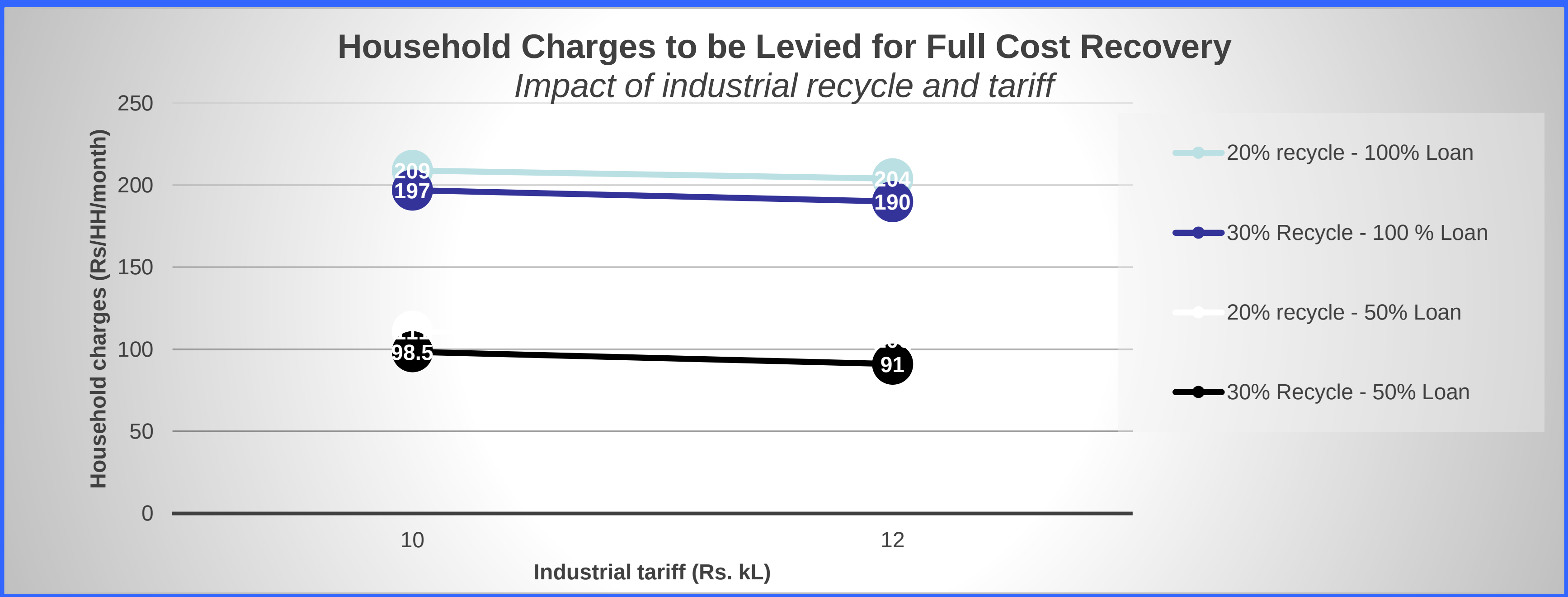
Impact of financing arrangements

Rate of Interest (%)	Average household user charge (Rs/month/hh)			
	100% Loan - 0 Grant	80% Loan - 20% Grant	50% Loan - 50% Grant	30% Loan - 70% Grant
3	159	129	83	53
4	173	140	90	57
5	188	152	98	62
6	204	165	106	66
7	220	178	114	71
8	237	191	122	76



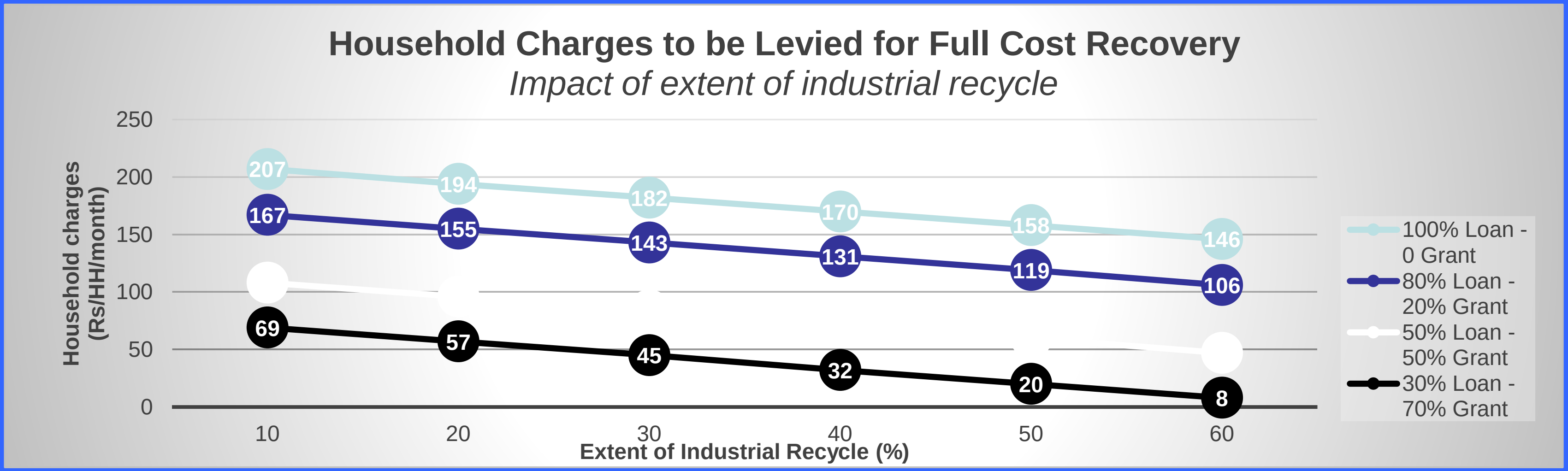
Cost Recovery – User charges
Impact of industrial recycle

Tariff for industries (Rs./kL)	Average household user charge (Rs/month/hh)			
	20% recycle - 100% Loan	30% Recycle - 100 % Loan	20% recycle - 50% Loan	30% Recycle - 50% Loan
10	209	197	111	98.5
12	204	190	106	91

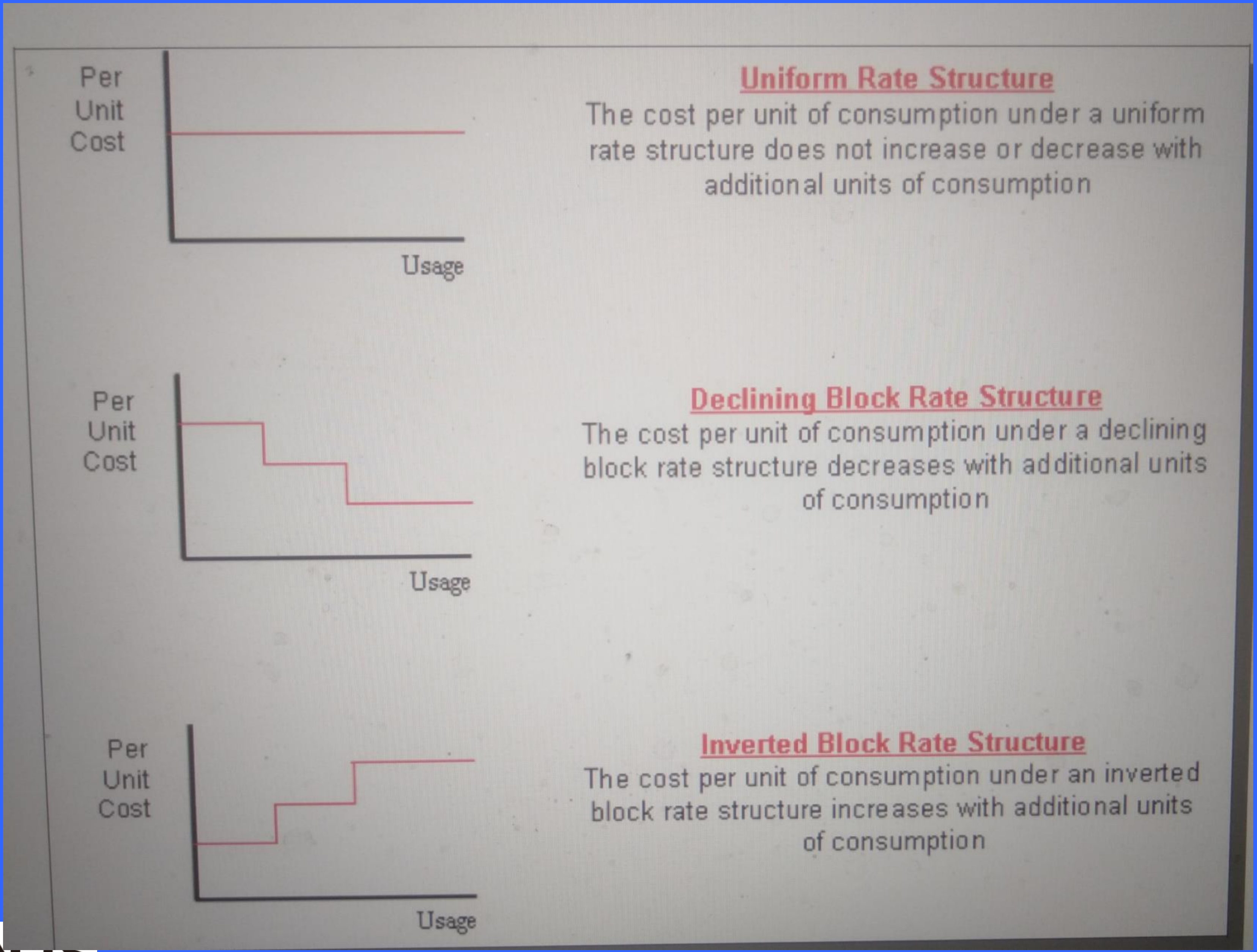


Cost Recovery – User charges
Impact of extent of industrial recycle

Extent of Industrial Recycle (% of total recycle)	Average household user charge (Rs/month/hh)			
	100% Loan - 0 Grant	80% Loan - 20% Grant	50% Loan - 50% Grant	30% Loan - 70% Grant
10	221	182	123	83
20	209	170	111	71
30	197	158	98	59
40	185	145	86	47
50	173	133	74	35
60	160	121	62	23



Overview of variable charge rate structures



Present Indian Examples

Reuse Projects – Presently in India – Ongoing or completed

- Industrial Usages - in large Cities – Mumbai, Chennai, Surat, Delhi, Gandhi-Dham-Anjar
- Indirect Potable – Pilots (study) Bangalore., Hyderabad, Delhi, Pune, Chennai
- Urban non-potable application in buildings – Govt./Semi-Govt./Private
- Agricultural and Horticultural – Many large Cities
- Lake Restoration – Hyderabad, Bhopal, Delhi, Bangalore, Jaipur
- Thermal Plant Cooling Water – Nagpur, CPCL, IOCL-Mathura, and other Refineries

Water Reuse Policies at National Level

2008

National Urban Sanitation Policy – Endorses reuse of Wastewater , min 20% in a City

2010

Service Level Bench marking frame work

encourages reuse in Cities

2012

JNNURM
63 Cities – ULBs, Corporations with Central Funding, 100% Wastewater treatment + development of reuse bylaws and promote National Water Policy – recognizes water reuse

2013 & 2016

CPHEEO – MoHUA – Sewerage Manual with Reuse Plans and Designs. CH7.
In 2016 Reuse Guidelines as amendment to Ch. 7 – JICA Assisted.
Niti Aayog – promoted Reuse of WW for self sustainability

2015

AMRUT & Smart City Mission
Encourages Cities to provide all basic needs in sanitation and water supply – encourages reuse of WW for sustainability
Some states like TN, AP, RJ, MH, GJ, MP, developed state wide reuse guidelines.

2014 to 2029

Formation of NMCG – Development of Water Reuse Policies for Power Plants, Railways, Refineries, Agricultural. ZLD for polluting Industries. Development of Reuse Guidelines in partnership with EU – On Going

2019 to 2021…..

National Water Framework – Law – Draft

Gazette Notification for reuse of WW in 50 Km radius for Thermal power and Refineries

Water Secure Cities – Jal Jeevan Mission Urban

Reuse Potential in India

- **By 2030 – collection of 80% of Urban Wastewater could generate 17 BCM of water annually.**

- **With appropriate treatment and reuse could suffice 75% of Industrial water demand and ¼ th of potable water demand**

- **Recycled wastewater from 465 Class I cities (i.e., Cities with 100,000 and above population) and 3894 Class II Cities (population between 50,000 to 99,000) could meet ¼ th of the existing Industrial demand including Energy demand**

NJS

Factors Affecting Market Viability of Reuse water in India

Sanitation in Smart Cities

Aligned to the UN Sustainable Development Goals (SDG)

- Goal 6. Ensure availability and sustainable management of water and sanitation for all
  - Wastewater flows treated to national standards, by municipal and industrial source
  - Total water resources used
  - Focus on Integrated Water Resources Management
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
  - Focus on sustainable development strategy for each urban agglomeration

Source: Indicators and a monitoring framework for Sustainable Development Goals: A report by the Leadership Council of the Sustainable Development Solutions Network; July 2014

NJS

Smart City - Sanitation Financing

- The recurring expenditures (annual expenses) for the project to include the following components:
  - Expense incurred towards **operation and maintenance** of the STP and network
  - **Debt servicing** towards the loan component of the project cost
  - **Management fees** for the service contractor providing operation assistance
- Cost Recovery through:
  - Revenue from sale of wastewater especially to high-end clients
  - User charges to recover balance costs including debt servicing
  - Graded tariff structure based on size of household

NJS

A start

Harmonization:

- Situation analysis and needs assessment
- Establish a mechanism for policy dialogue
- Obtain political endorsement
- Engage in an adequately resourced policy dialogue
- Ensure policy changes are legitimized through Parliament and/or decreed by the Prime Minister's Office

Institutional Arrangements:

- Agreed mechanisms for coordination and resource sharing between sectors
- Identification of roles and responsibilities
- Incentive: partial inputs lead to credit for 100% outcome
- through specific Memoranda of Understanding between sectors
- through existing intersectoral mechanisms
- by operating at lower levels of governance

NJS

How would the WICER assessment tool work?

1. Understand project/ engagement & local context

- Project (City/rural? WSS, WRM, Agriculture? Involves new infrastructure? Centralized/decentralized…)
- Local conditions of the region/country
- Existing PIR Framework
- Key goals

2. Assess if project/system is WICER

- Specific WICER questions (in next slides)
- Could be done by the TTL or in a workshop with stakeholders if needed (with support from the WICER team if needed)

If yes → **3. Include the project in the WICER database & potential to document as a case study**

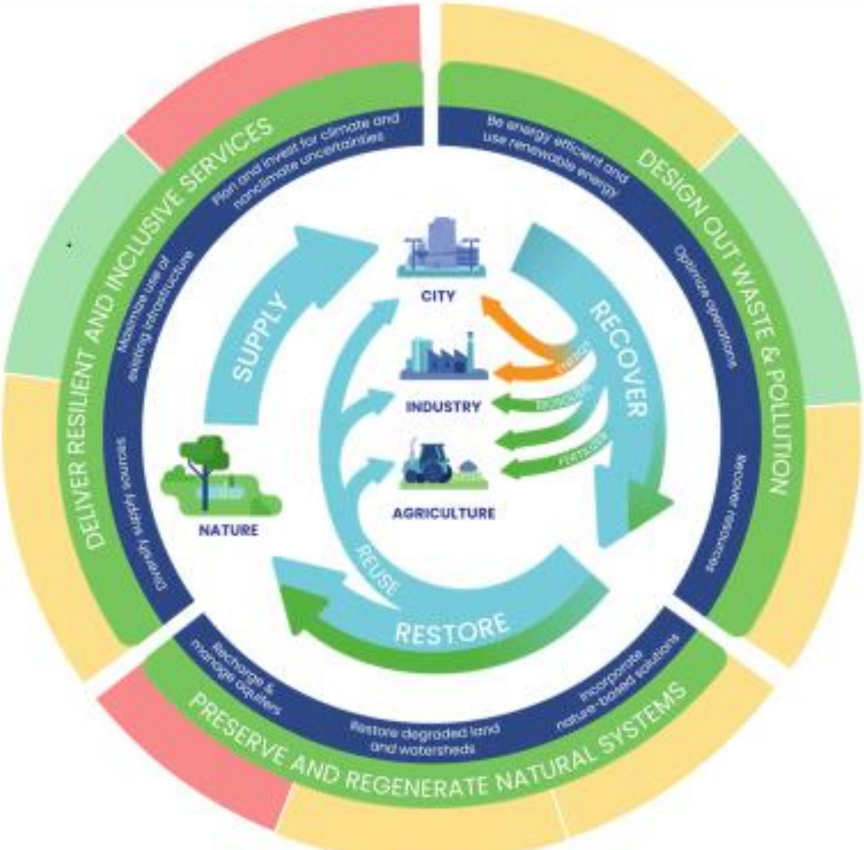
If not → **3. Showcase examples and provide tools**

- Refer to the prepared case studies and the guidelines of the WB as needed
- This could be done by the team case by case, by the TTL, or in a workshop with stakeholders, depending on audience (with support from the WICER team if needed)

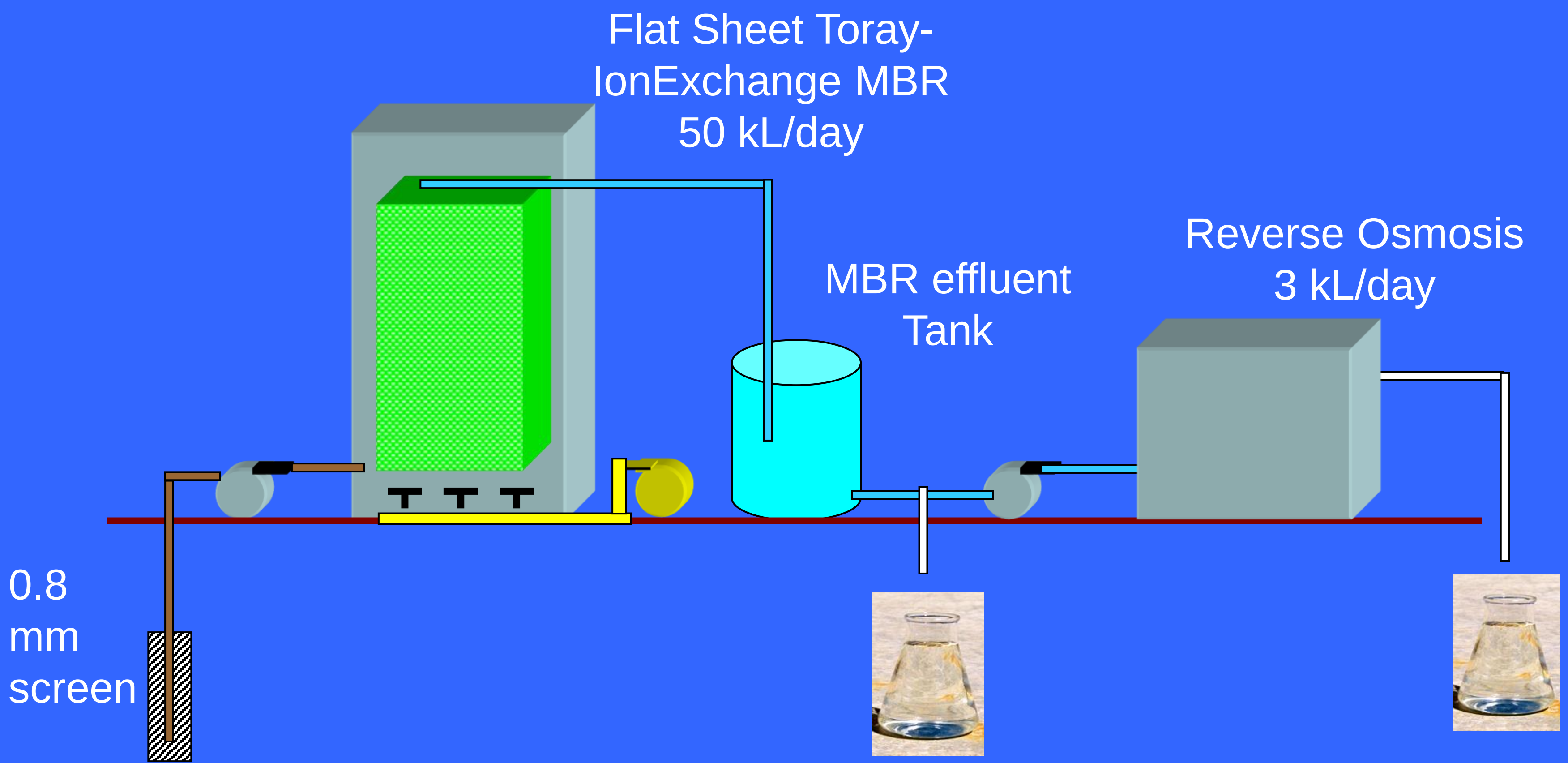
Familiarize the user with WICER concepts and solutions

Color-coded results – is the Project WICER?

- To continue doing
- To be improved
- To start doing/exploring



MBR & RO Pilot Performance



BOD – 180 to 225 mg/L

COD – 360 to 500 mg/L

SS – 450 mg/L

TDS – 600 to 900 mg/L

MPN > 1 million/100 mL

BOD < 2 mg/L

COD – 8 to 20 mg/L

SS < 2 mg/L

TDS – 600 to 900 mg/L

MPN < 10/ 100 mL

BOD – non detect

COD < 10 mg/L

SS < 1 mg/L

TDS < 20 mg/L

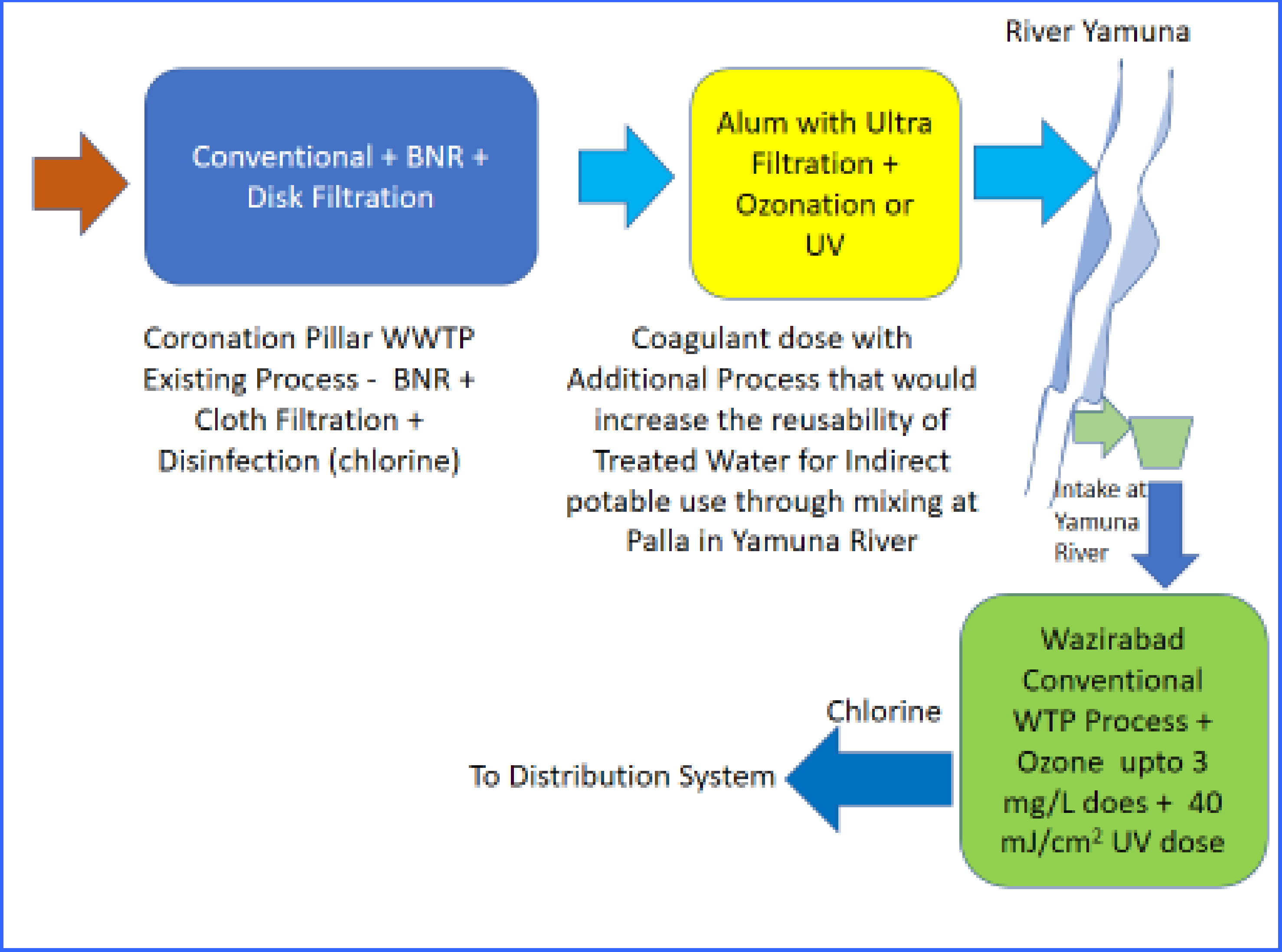
MPN < 2 / 100 mL

SAFE ENOUGH

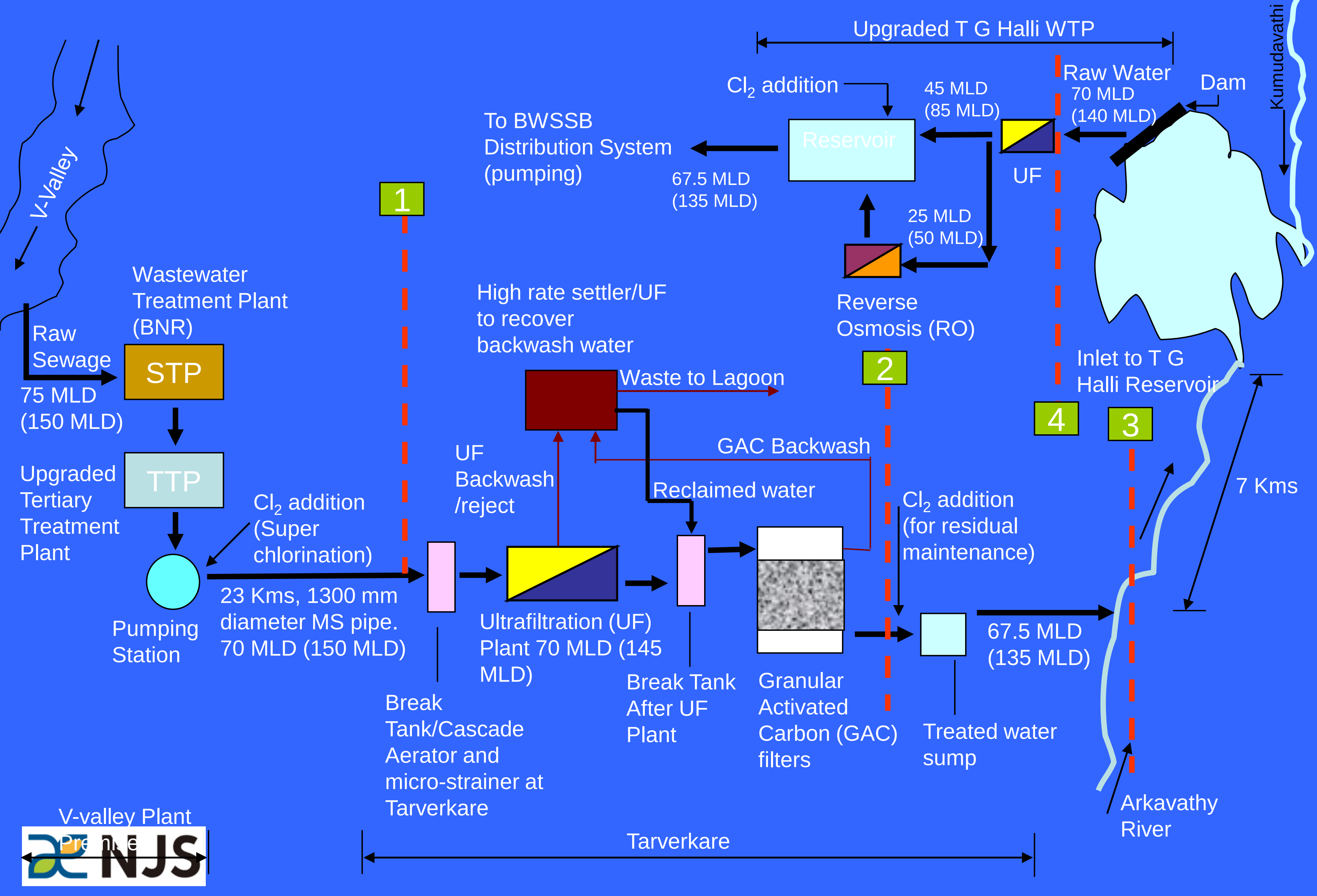
CM Sheila Dikshit takes a sip of treated water during a visit to a treatment plant on Thursday.

NJS

Current Thinking of Delhi Jal Board for Augmentation of its source water – Yamuna River, through High Quality treated wastewater from Coronation plant and other WWTPs



135 MLD Reuse Process Scheme



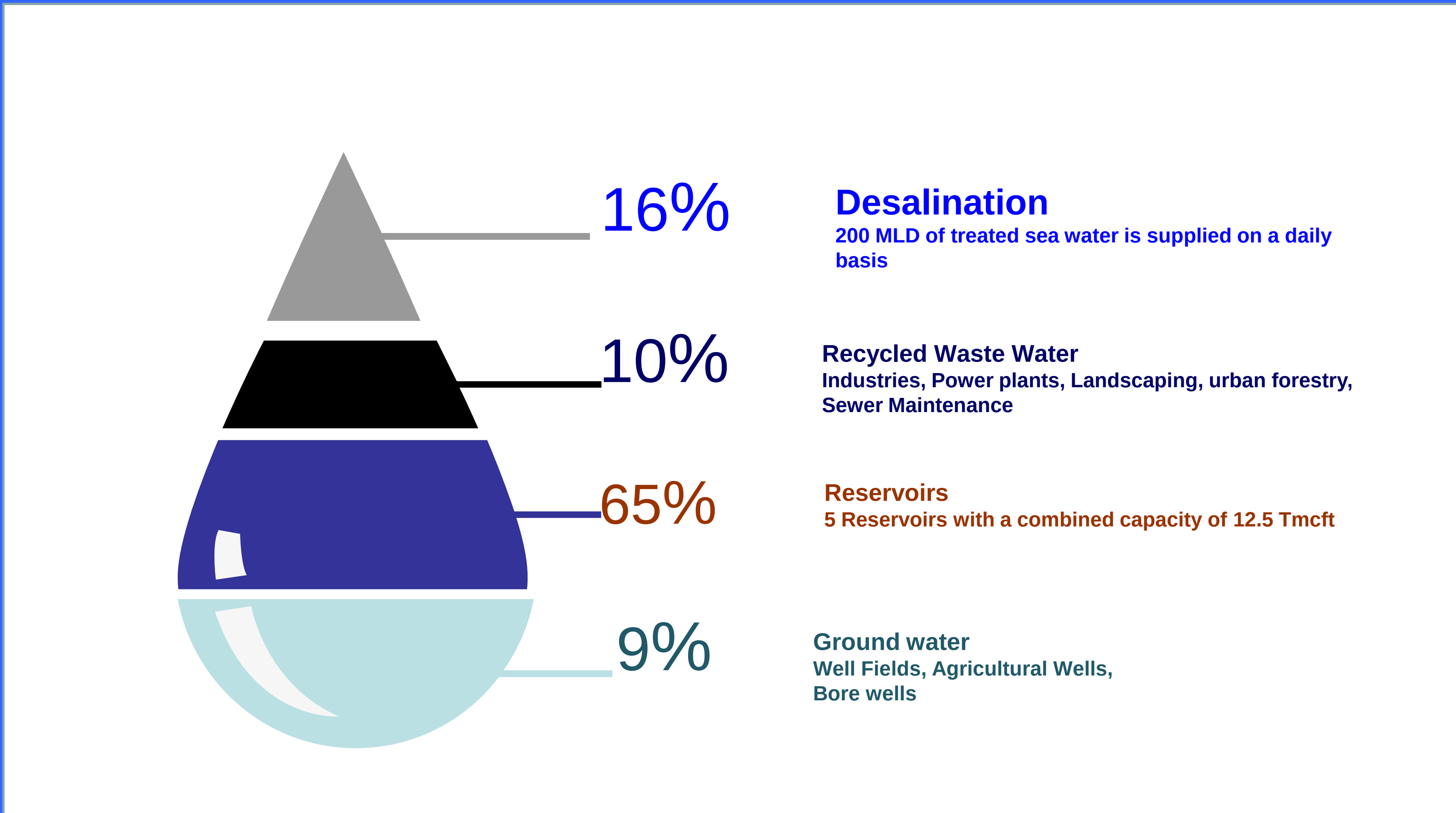
Bangalore Pilot Experience

NJS

Average values over a 12 month period Pilot works at V-valley Plant in Bangalore

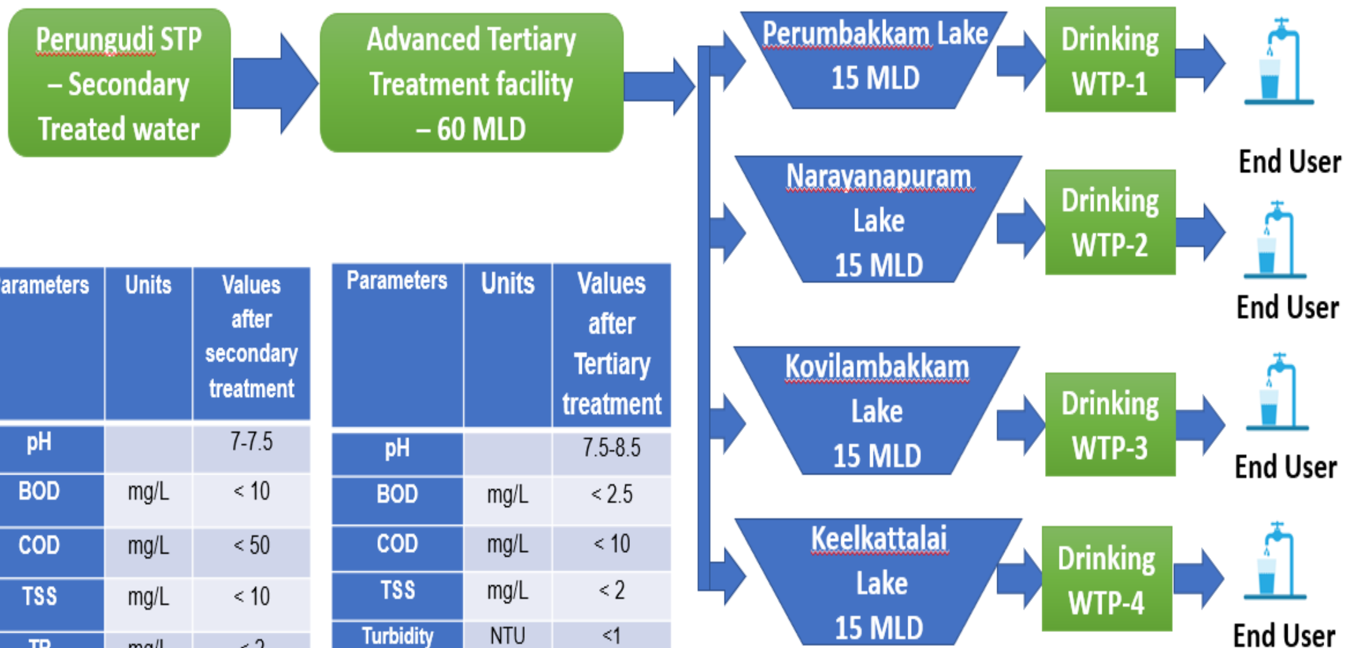
Parameter	effluent from V-Valley Plant	Tertiary Treatment Plant output		Arkavathy River 7 Kms before meeting T.G. Halli Reservoir
BOD mg/L	22	2		12
COD mg/L	65	12		27
Sulfate mg/L	24.7	8		86.18
Magnessium	28	19		62.5
Phosphaste mg/L	1.8	0.4		2.8
Ammonia mg/L	25	2		12
TDS mg/L	450	228		320
Fecal Coliforms/ 100 mL	> 1600	ND		> 1600
Ecoli/100 mL	>400	ND		>600

Chennai Water Supply Sources



NJS

Source: CMWSSB – 2020 & Dr. Joseph Ravikumar, WB



Parameters	Units	Values after secondary treatment
pH		7-7.5
BOD	mg/L	< 10
COD	mg/L	< 50
TSS	mg/L	< 10
TP	mg/L	< 2
TN	mg/L	< 10
Ammonia N	mg/L	< 5
Fecal coliform	MPN/100 ml	< 100

Parameters	Units	Values after Tertiary treatment
pH		7.5-8.5
BOD	mg/L	< 2.5
COD	mg/L	< 10
TSS	mg/L	< 2
Turbidity	NTU	<1
Total Organic Carbon	Mg/L	<1
Nitrates as NO3-N	Mg/L	<0.9
Fecal coliform	MPN/100 ml	Nil

* Based on the adsorption capacity WTP will be designed

Parameters	Units	Drinking water
pH		6.5-8.5
Turbidity	NTU	<1
TDS	mg/L	500
Free residual chlorine	mg/L	0.2

IS 10500 : 2012

- Learning and improving on indirect potable reuse plant operational at IIT, Chennai
- Pilot two plants of direct of 10 MLD capacity designed with assistance of IIT, Chennai under construction and thereafter scale to 260 MLD

NJS

Source: CMWSSB – 2020 & Dr. Joseph Ravikumar, WB

Direct Potable Reuse

Public Acceptance

- Have to Create Credibility & Trust
- Analysis of Wastewater Effluent.
  Compared to Drinking Water Standards
- Total Transparency with the Public
- Engaged Medical & Academic Communities
- Engage Business Leaders

CMWSSB – 45,000 m3/day

Adapted from Wabag, Chennai.

ENVIRO™

Enviro Control Associates (I) Pvt. Ltd.

Solutions for a Cleaner Environment

NJS

Enviro Control Associates (I) Pvt. Ltd.
Solutions for a Cleaner Environment

NJS

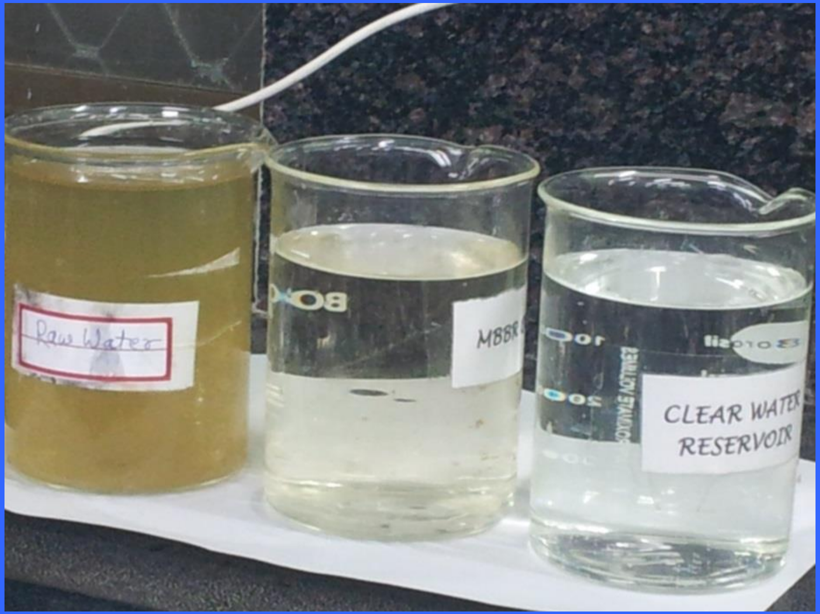
130MLD Sewage Treatment Plant at Bhandewadi

NJS

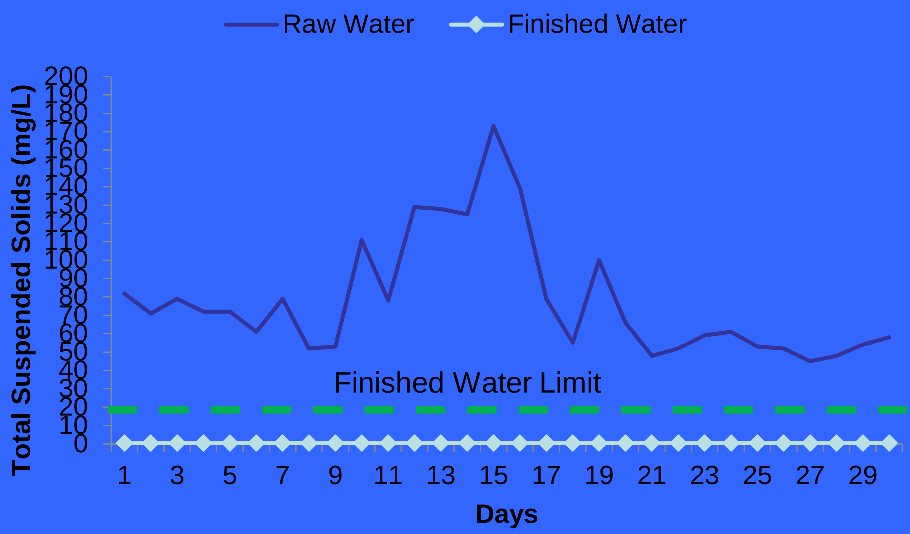
Sewage Treatment Plant at RCF, Chembur

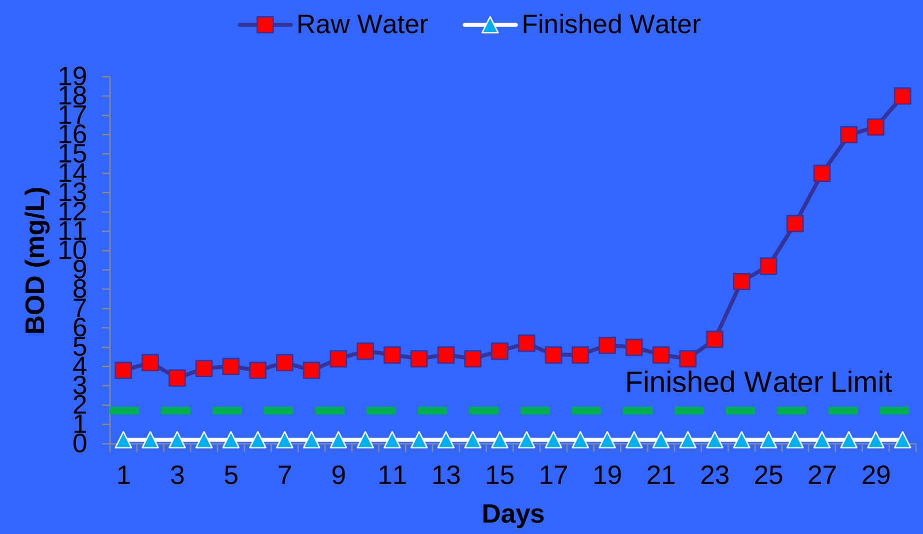
30MLD STP at Welspun, Anjar

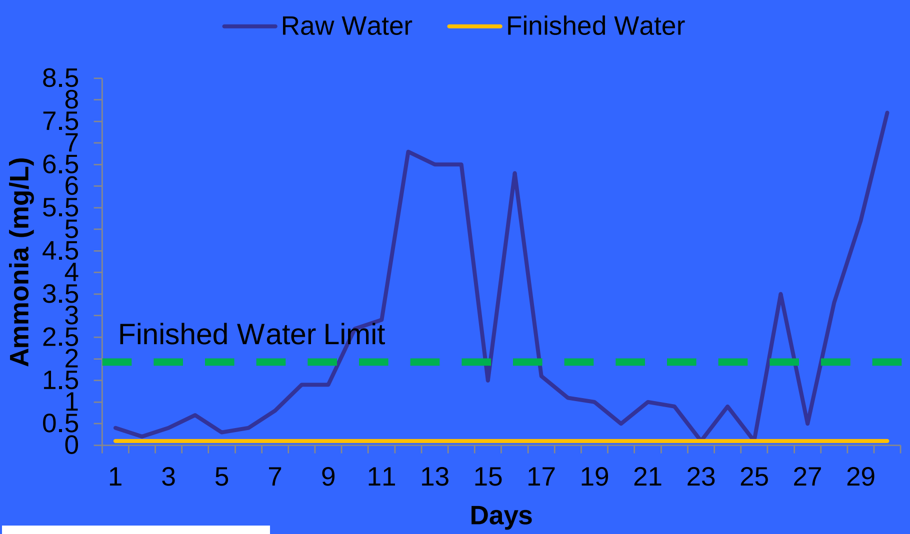
NJS

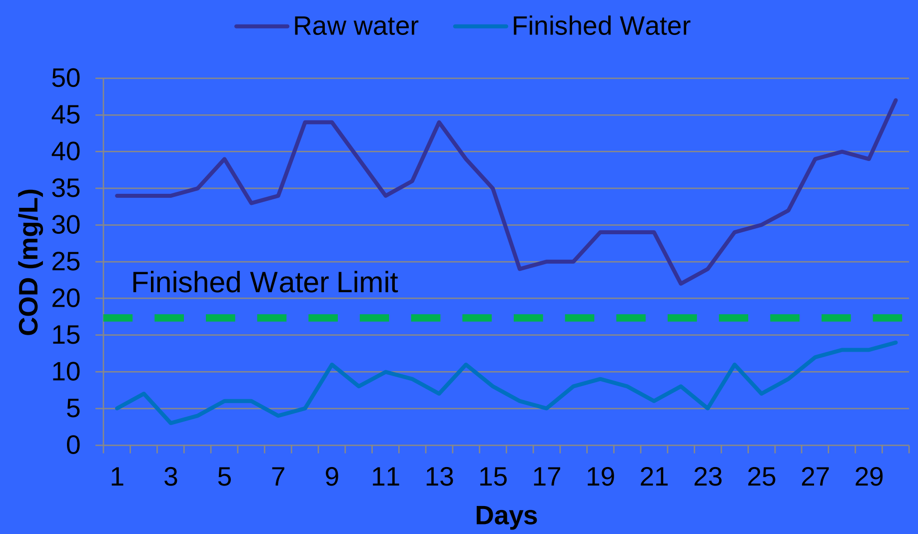


Secondary Sewage quality is treated to potable grade – 144 MLD – Agra

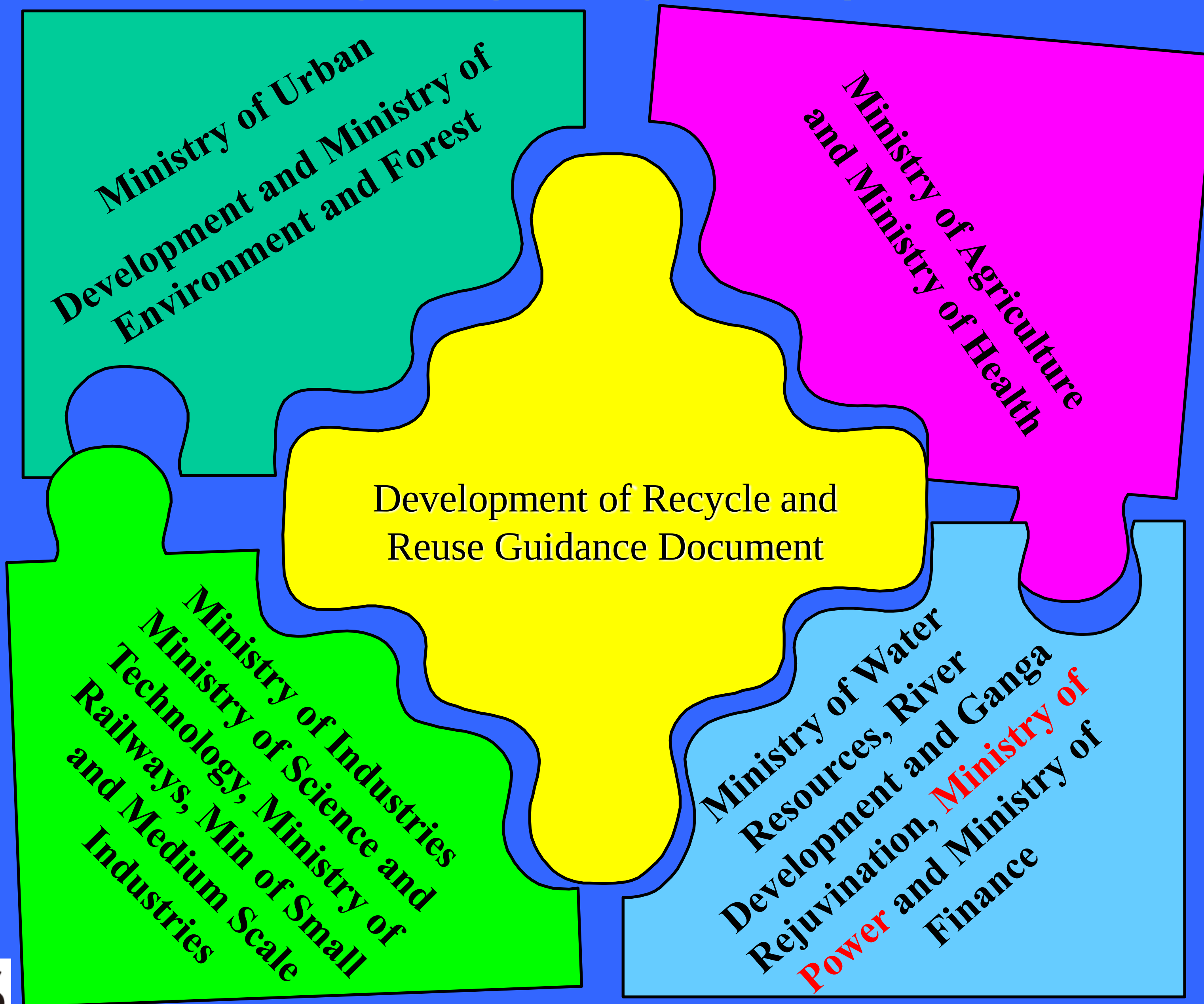

Raw Water
Finished Water
Total Suspended Solids (mg/L)
Finished Water Limit
Days


Raw Water
Finished Water
BOD (mg/L)
Finished Water Limit
Days


Raw Water
Finished Water
Ammonia (mg/L)
Finished Water Limit
Days


Raw water
Finished Water
COD (mg/L)
Finished Water Limit
Days

Inter-Ministry, Agency Cooperation



Statement of Support for Water Reclamation
(NAGPUR REGION)

Nagpur Municipal Corporation (NMC), Urban Development Department, Water Supply & Sanitation Department, Environment Department, Water Resources Department, Government of Maharashtra (GoM) adopt the following joint statement of support for water reclamation

Whereas, water reuse is defined as the beneficial use of treated wastewater for non-potable use as power plants. Industrial Cooling, Washing, Irrigation, Landscaping, Gardening, Recreation, Construction and other uses

Whereas, the NMC to make water reuse an important element of Master Plan for Nagpur Water Supply

Whereas, NMC & GoM discourage to use potable water for non-potable application by institutions, wherever the reclaimed water is available for reuse

Whereas, amount of wastewater generation in Nagpur to increase from 380 Mld per year in 2005 to over 747 Mld in 2031

Whereas, the demand assessment survey 2005 reported that water reuse potential in greater Nagpur region is appx. 245 Mld by 2011 and that the major constraints to achieving these levels of reuse appear to be funding, institutional and regulatory disincentives, the permitting process, and public acceptance; and

Whereas, a world wide extensive experience with water reclamation provides reasonable assurance that the potential public health risk associated with water reclamation in Nagpur are minimal, provided all regulations pertaining to water quality, monitoring, reporting and reliability are adhere to; and

Whereas, NMC & GoM agencies to frame the water reuse law and regulations to be fully protective of human health and require a specific level of water quality and treatment corresponding to each beneficial use of reclaimed water; and

Whereas, NMC & GoM agencies to setup the mechanism for monitoring and reliability requirements to further assure that use of reclaimed water is safe; and

Now therefore, be it resolved on Wednesday the 14th day of December, 2005, the undersigned agencies support the pursuit and development of State and local water reclamation policies that will reduce constraints and promote water reclamation. Specifically, the agencies will work to overcome and reduce institutional and regulatory disincentives and funding constraints and to promote public acceptance of water reclamation. The agencies will co-operate to develop specific policies and resource commitments that will enable the Nagpur Municipal Corporation to meet the water reclamation goals and to help satisfy the greater Nagpur region overall water need.

Principal Secretary Urban Development Dept. Govt. of Maharashtra	Principal Secretary Water Supply & Sanitation Dept. Govt. of Maharashtra	Principal Secretary Environment Dept. Govt. of Maharashtra	Principal Secretary Water Resources Dept. Govt. of Maharashtra

Municipal Commissioner
Nagpur Municipal Corporation, Nagpur

नीरजा

NMC

Water Reuse Guidelines and Policy Recommendations for Nagpur Region

Draft Version 1.0 (2/08/06)

February 8, 2006

Prepared Under:

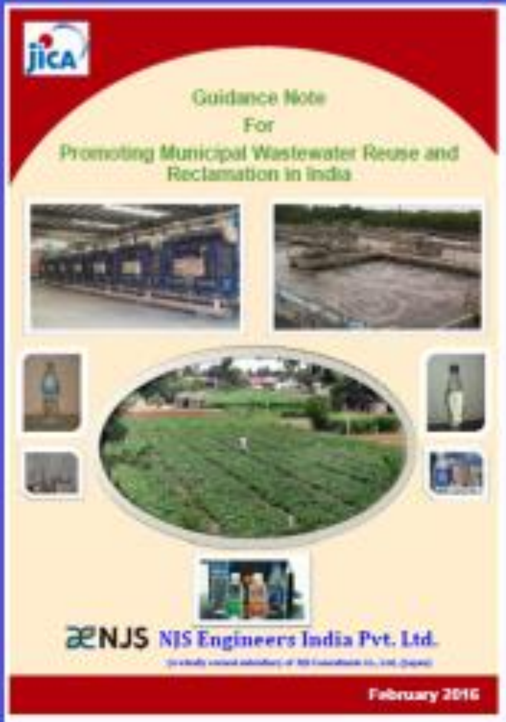
Task 6. Site Based Support To Improve Urban Energy/Water Accessibility, Delivery Efficient Use, and Waste Management

Prepared By:

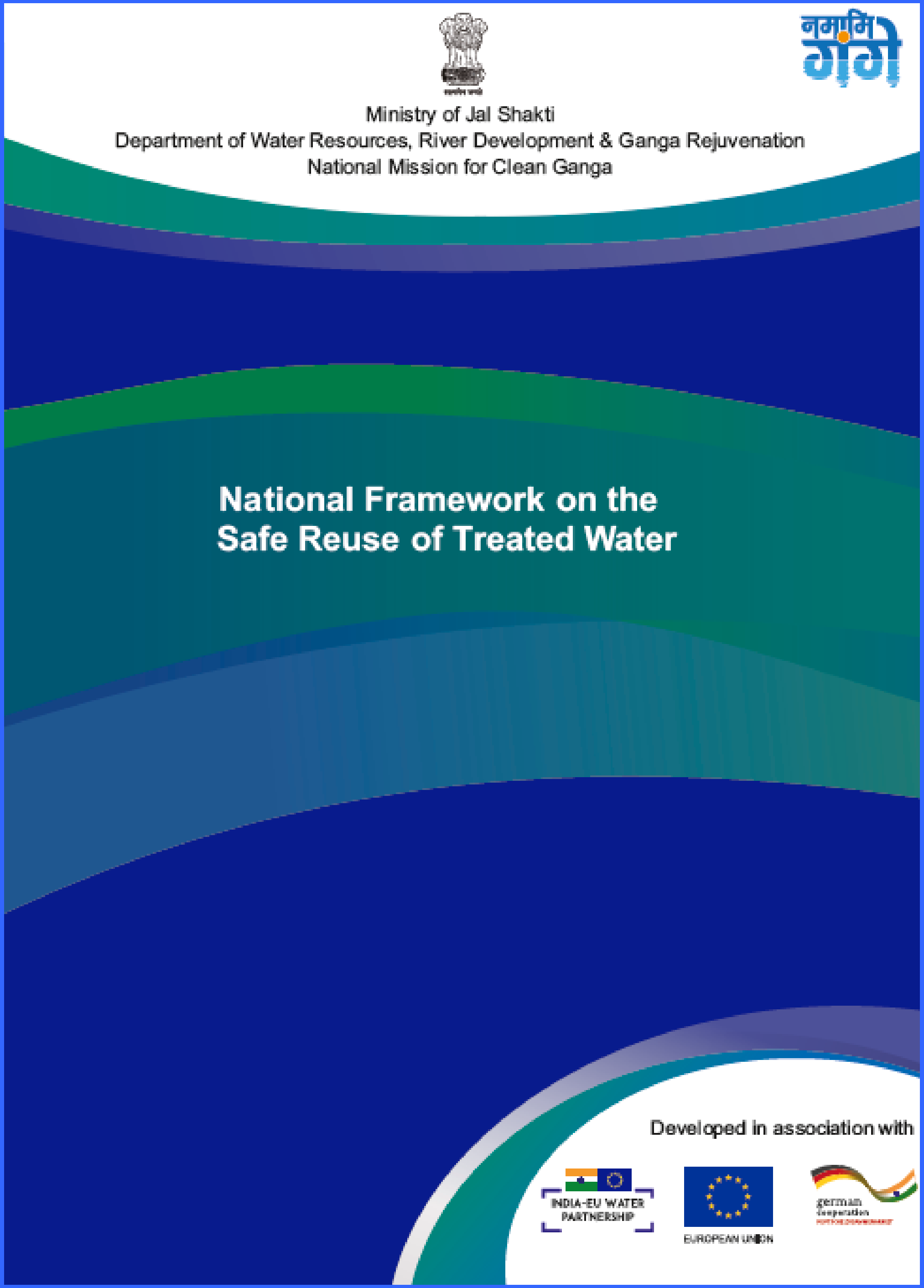
USAID/India Water and Energy Nexus Project Task 6 Team

NJS

Development of Reuse Guidance Document

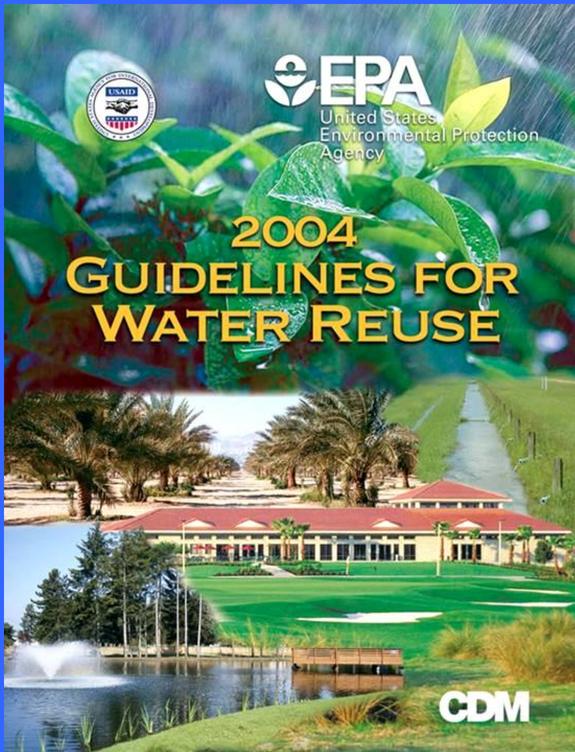


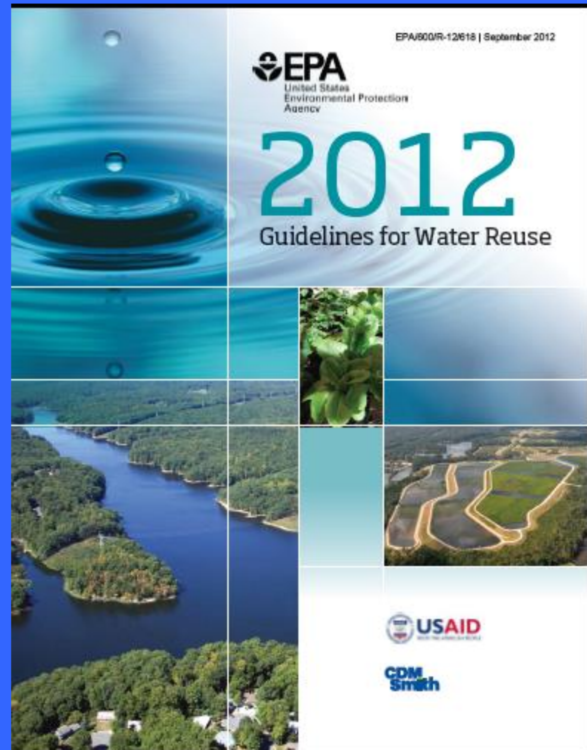
NJS

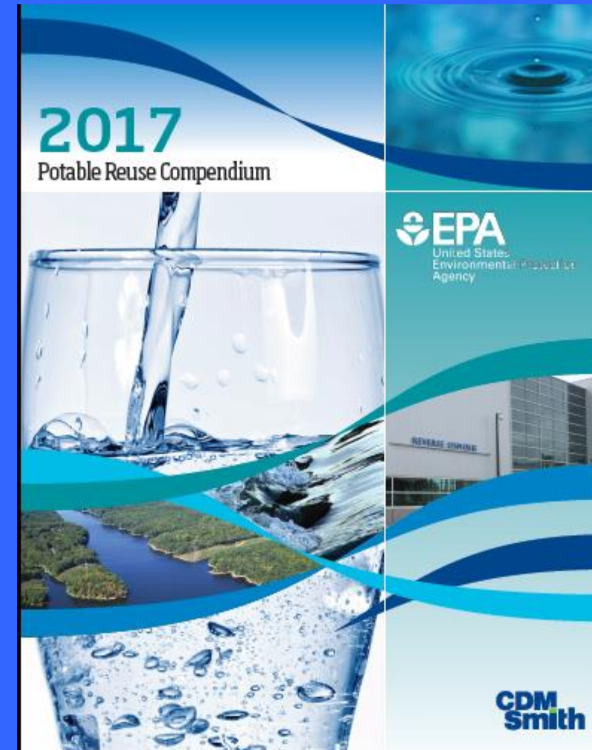


Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation
National Mission for Clean Ganga
National Framework on the Safe Reuse of Treated Water
Developed in association with
INDIA-EU WATER PARTNERSHIP
EUROPEAN UNION
german cooperation

NJS







Appendix E – International case Studies

E-47	India-Bangalore	V Valley Integrated Water Resource Management: the Bangalore Experience of Indirect Potable Reuse	Uday G. Kelkar, PhD, P.E., BCEE and Milind Wable, PhD, P.E. (NJS Consultants Co. Ltd.); and Arun Shukla (NJS Engineers India Pvt. Ltd.)
E-51	India-Nagpur	City of Nagpur and MSPGCL Reuse Project	Uday G. Kelkar, PhD, P.E., BCEE (NJS Consultants Co. Ltd) and Kalyanaraman Balakrishnan (United Tech Corporation)

NJS

Thank You

Contact Information
Dr. Uday G. Kelkar, P.E., BCEE
Cell: +91-9822401962

Ajit Savadi
Cell:+91-9727764800

uday@njsei.com
Ajit.Savadi@njsei.com

NJS

FIT FOR PURPOSE TECHNOLOGIES FOR
RECYCLE & REUSE OF WASTEWATER

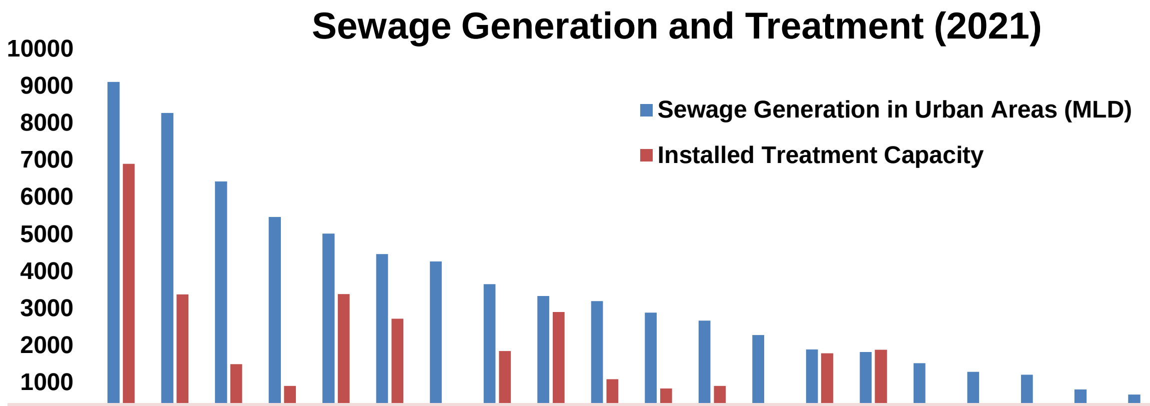
Nature-Based or Mechanized Wastewater Treatment Technologies: Selection for 'Fit for Purpose' Application

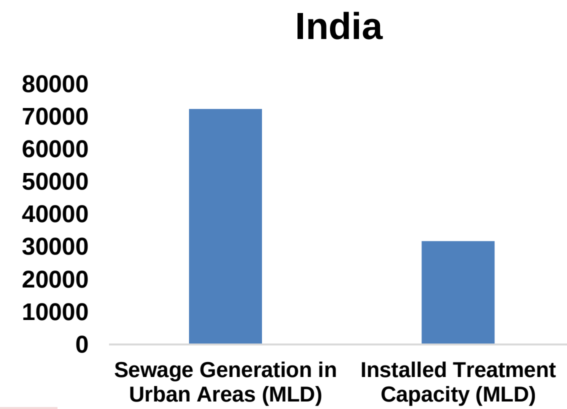
Dr. Pradip Kalbar
Associate Professor
Centre for Urban Science and Engineering (CUSE)
Indian Institute of Technology Bombay
Email: kalbar@iitb.ac.in
Tel. No. 022 2576 9330

11th Jan 2023

Centre for Urban Science and Engineering
Improving Quality of Urban Life
Indian Institute of Technology Bombay

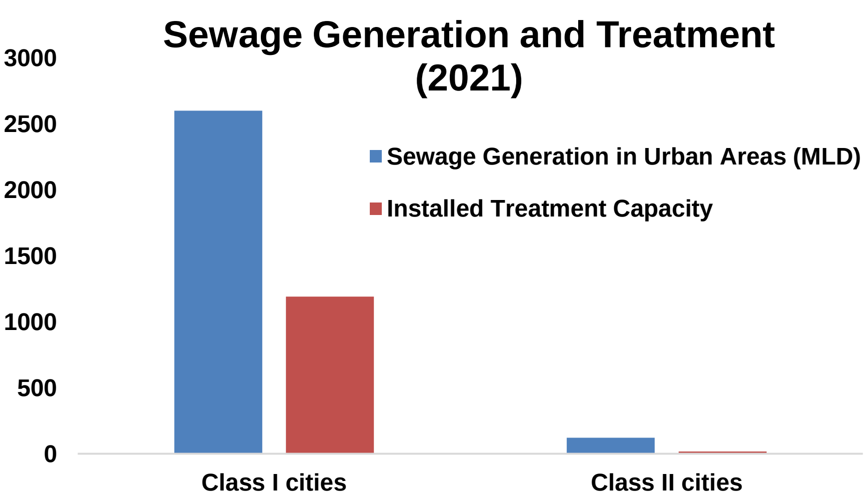
Background

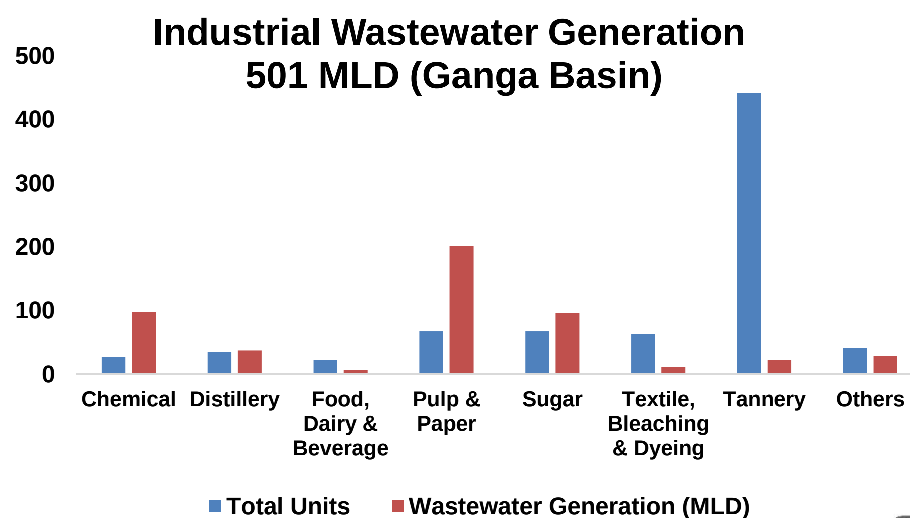




Water is important resource and wastewater generated is more important resource!

In India on average about 44% Sewage treatment capacity





http://www.sulabhenvis.nic.in/database/stst_wastewater_2090.aspx

Urban Water Management (UWM)

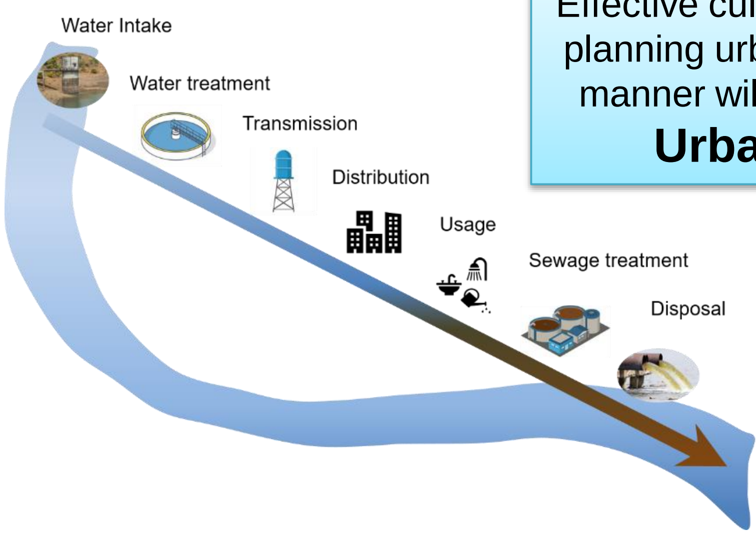
Urban Water Infrastructure:

- Source
- Intake
- Water treatment
- Transmission and distribution
- Water consumption
- Sewage conveyance
- Sewage treatment
- Disposal

Stakeholders:

- Planners
- Consultants
- Research organizations
- Pollution Control Boards
- Public utilities
- Politicians
- Users
- Operators

Effective culmination of relevant stakeholders in planning urban water infrastructure in a holistic manner will result in sustainable and resilient
Urban Water Management

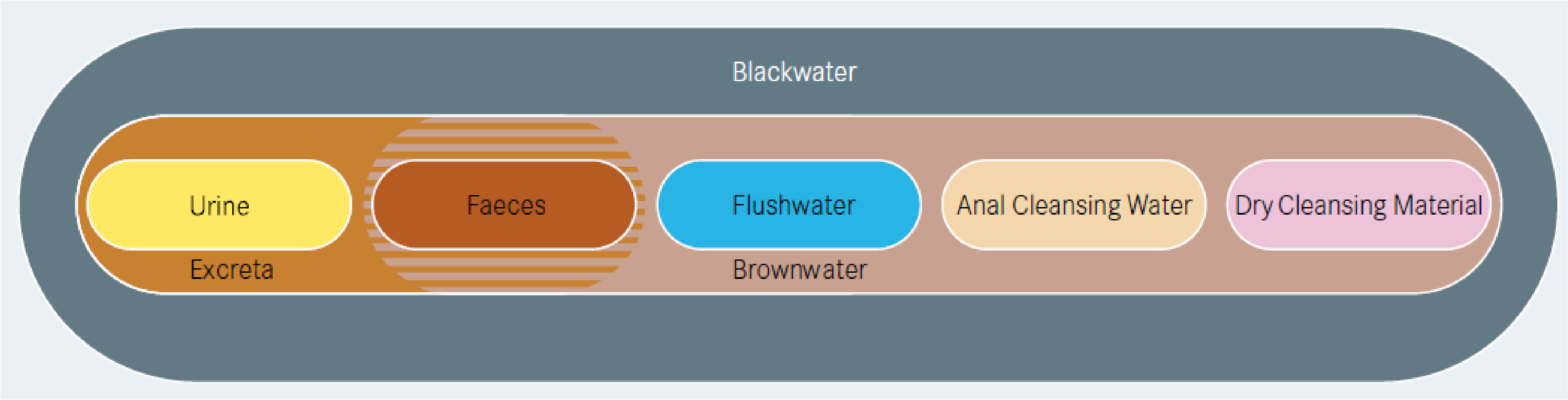


Terminologies

- ***Blackwater*** is the mixture of Urine, Faeces and Flushwater along with Anal Cleansing Water (if water is used for cleansing) and/or Dry Cleansing Materials Blackwater contains the pathogens of Faeces and the nutrients of Urine that are diluted in the Flushwater.

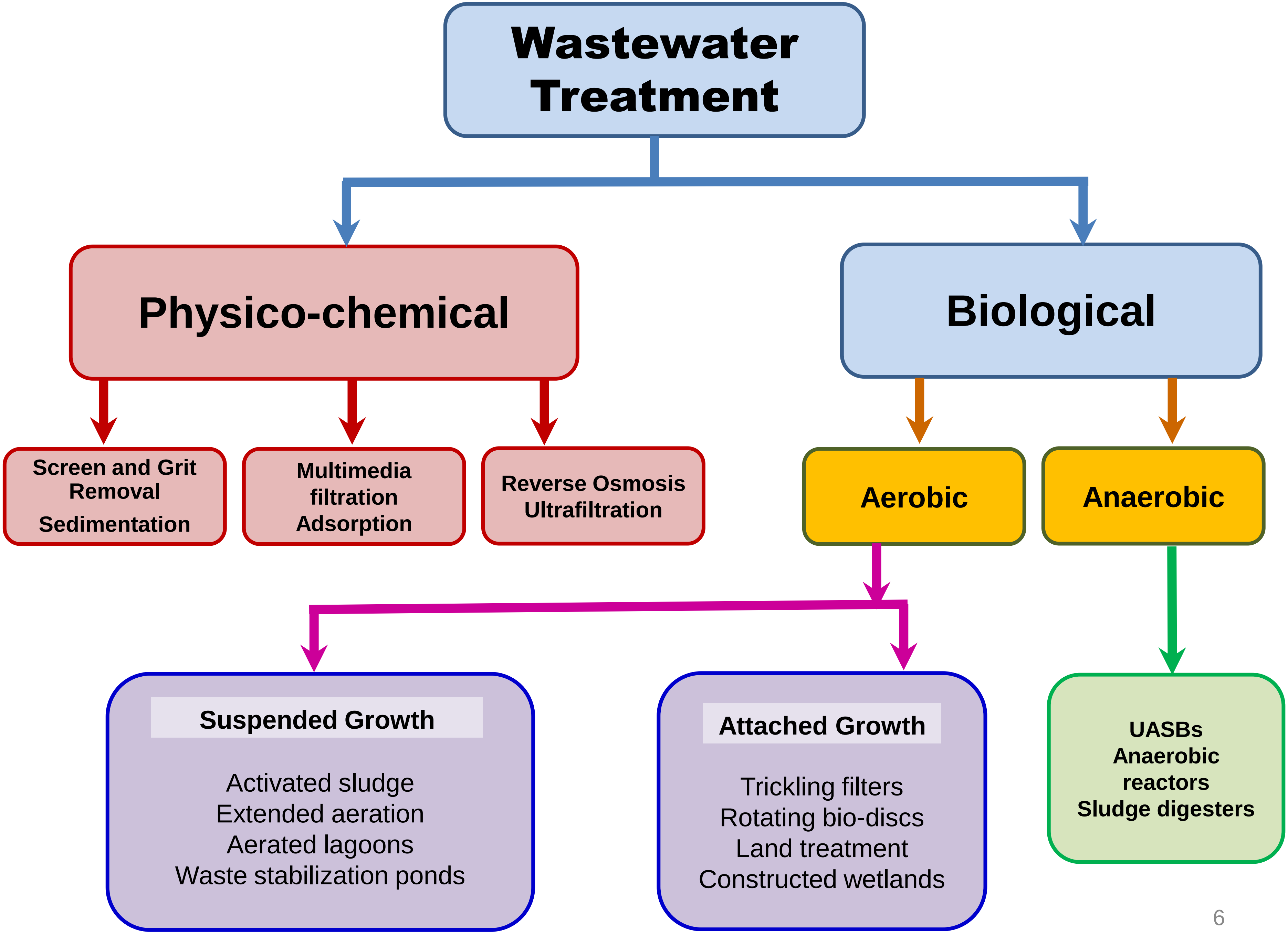
- ***Brownwater*** is the mixture of Faeces and Flushwater, and does not contain Urine. It is generated by Urine-Diverting Flush Toilets

- ***Greywater*** is the total volume of water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets.

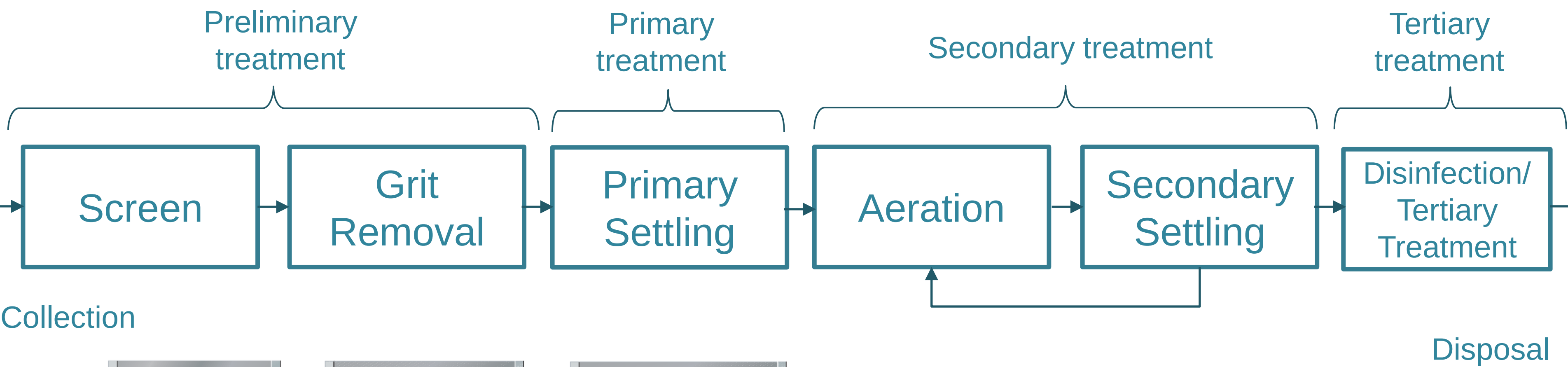


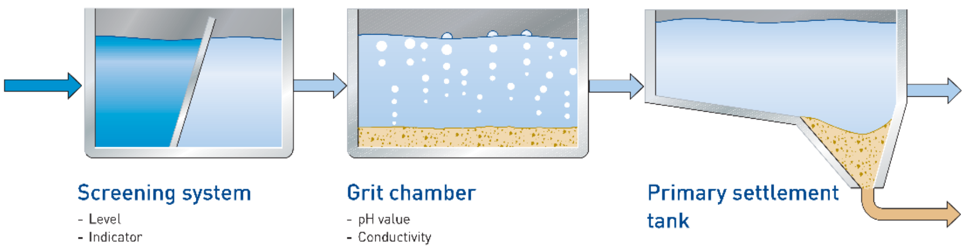
(Source: TILLEY, E.; ULRICH, L.; LUETHI, C.; REYMOND, P.; ZURBRUEGG, C. (2014): Compendium of Sanitation Systems and Technologies)


Approaches for Wastewater Management
Preventive/Conservation
Treatment/Recycling/Recovery
Reduce consumption
Efficient Devices
Household/ Building level
Decentralized treatment scheme
Centralized treatment scheme

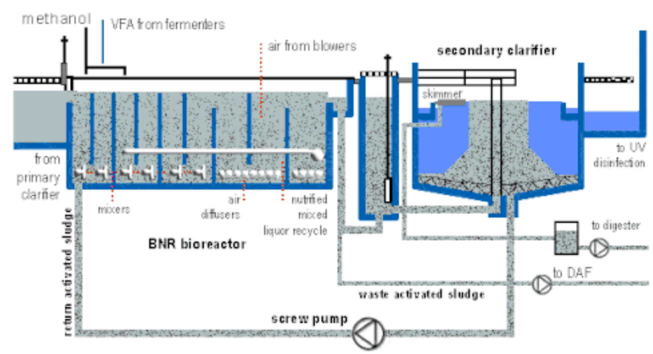

Wastewater Treatment
Physico-chemical
Biological
Screen and Grit Removal
Sedimentation
Multimedia filtration
Adsorption
Reverse Osmosis
Ultrafiltration
Aerobic
Anaerobic
Suspended Growth
Activated sludge
Extended aeration
Aerated lagoons
Waste stabilization ponds
Attached Growth
Trickling filters
Rotating bio-discs
Land treatment
Constructed wetlands
UASBs
Anaerobic reactors
Sludge digesters

Conventional Wastewater Treatment Flowsheet



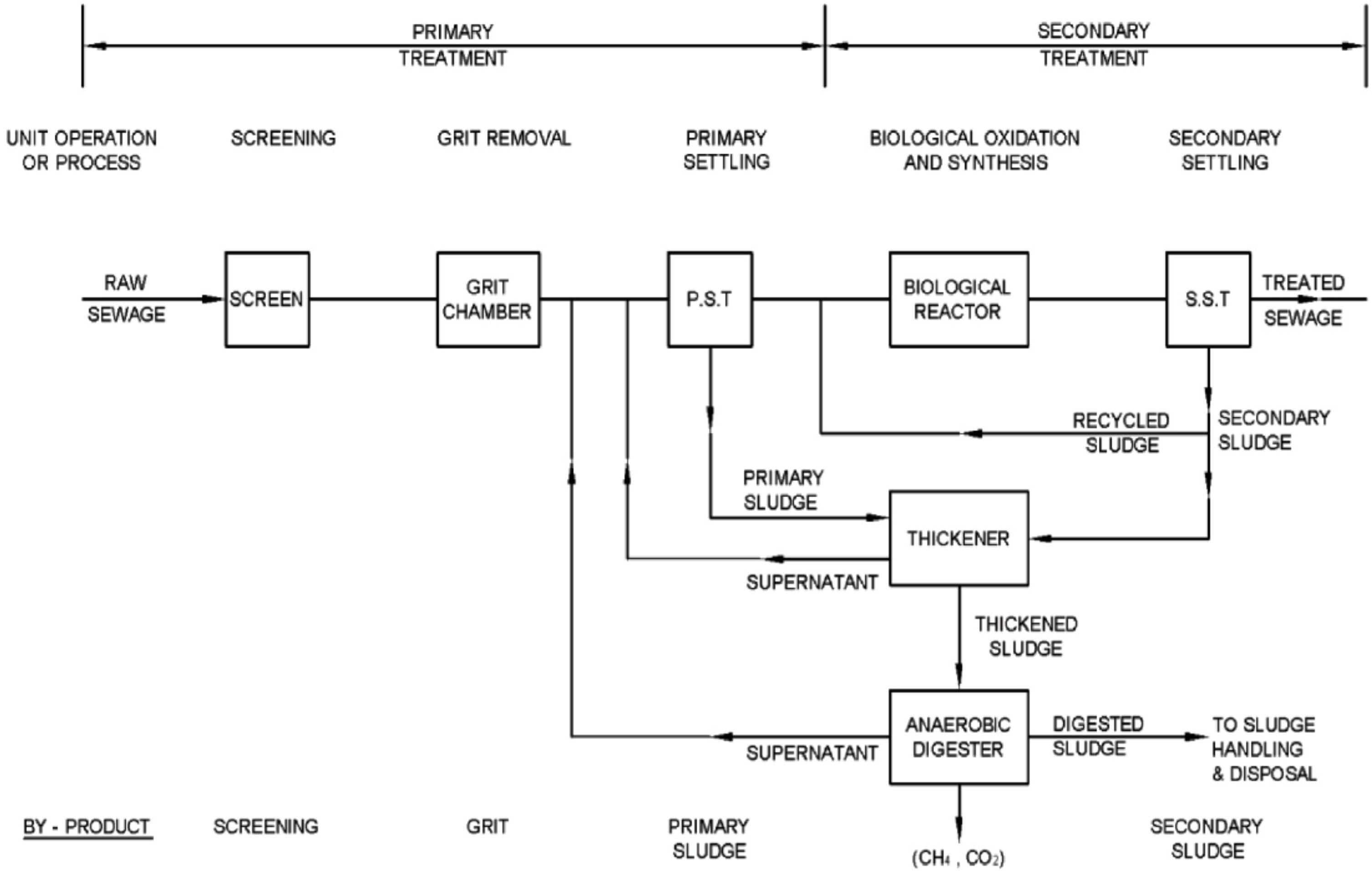


Source: https://amvco.at/industrial-wastewater/



Source: https://i.gifer.com/9CGO.gif

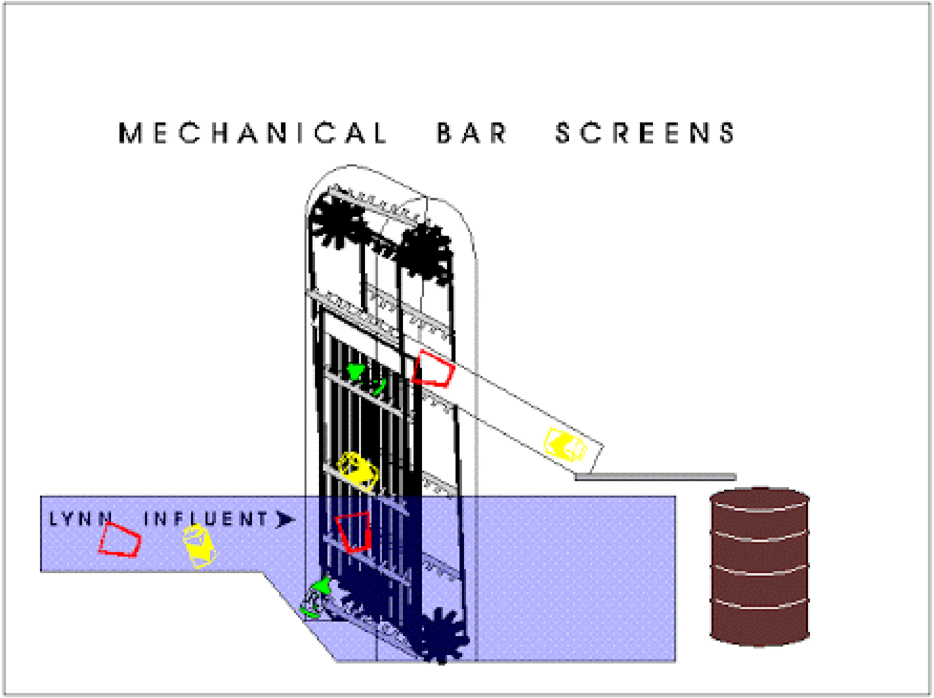
Conventional Sewage Treatment Plant



(Source: CPHEEO Manual on Sewerage and Sewage Treatment Systems Part A Engineering, 2013)

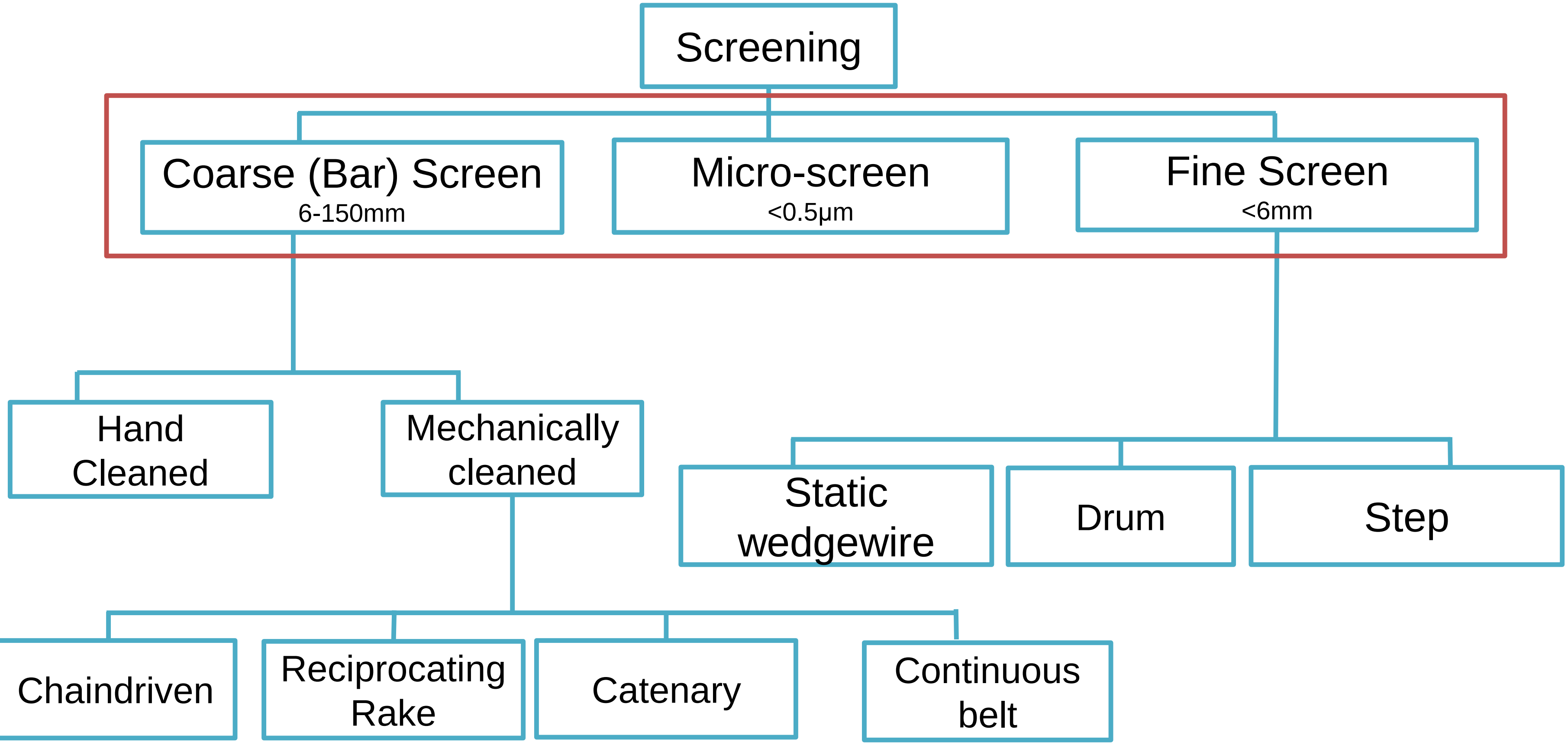
Screen

- The first unit operation
- Used to screen solids/large size material present in wastewater
- Generally uniform in size
- Provided to avoid damage to further units



Source: https://eec.oregonstate.edu/screening

Classification of Screen



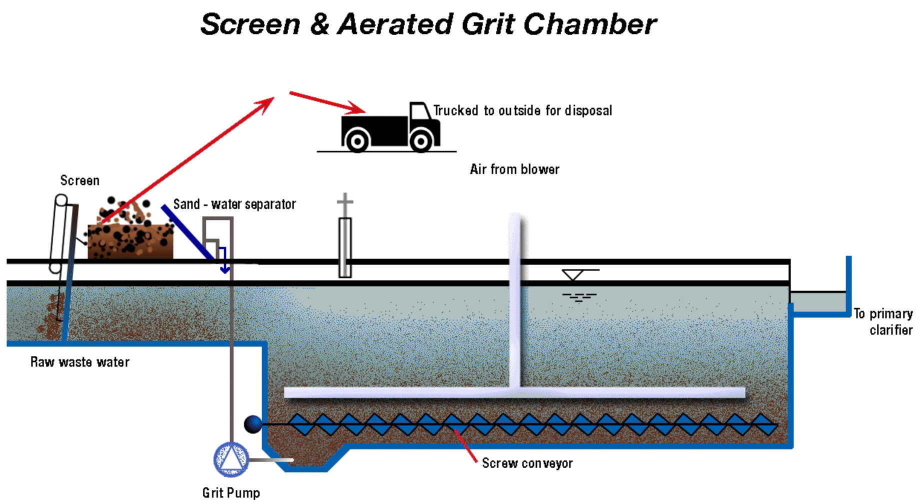
Source: Metcalf & Eddy, Burton, F. L., Stensel, H. D., & Tchobanoglous, G. (2003). Wastewater engineering: treatment and reuse. McGraw Hill.

Screen

Source1 : https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.slideshare.net%2Fjshrikant%2Fl-11-screen-chamber&psig=AOvVaw3PUWpWK9b7TBYBGOOudJLb&ust=1616393082593000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCIDR0dHbwO8CFQAAAAAdAAAAABAD
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fmechanical-bar-screen-19121127033.html&psig=AOvVaw3PUWpWK9b7TBYBGOOudJLb&ust=1616393082593000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCIDR0dHbwO8CFQAAAAAdAAAAABAp

Grit Chamber

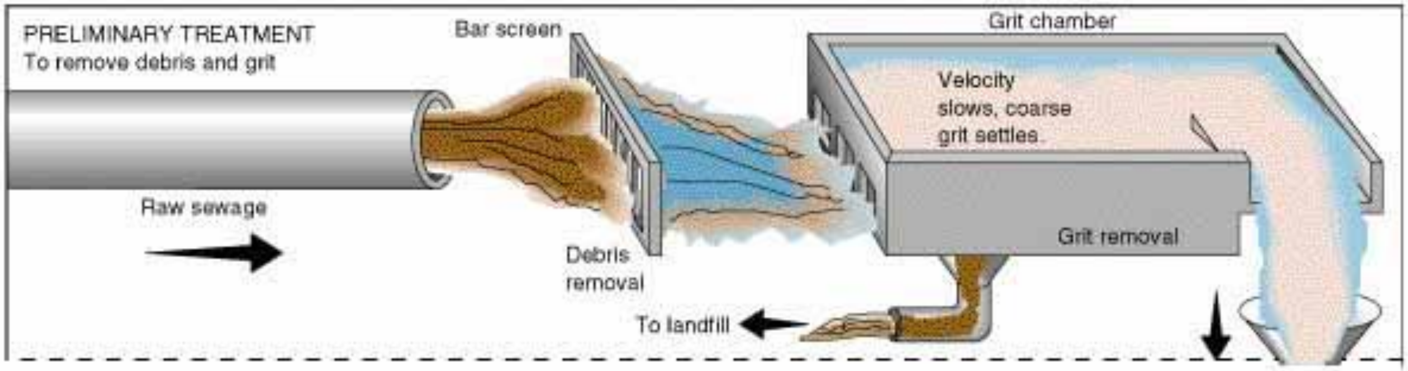
- Removal of inorganic particles silt, sand, etc.
- Having high specific gravity
- Settling under gravitational force
- Particles which do not decompose readily
- Average size of grit is 0.2mm dia and specific gravity 2.3-2.65



Source: https://civilengineerfriend.blogspot.com/2018/12/primary-treatment-primary-treatment.html

Grit Chamber

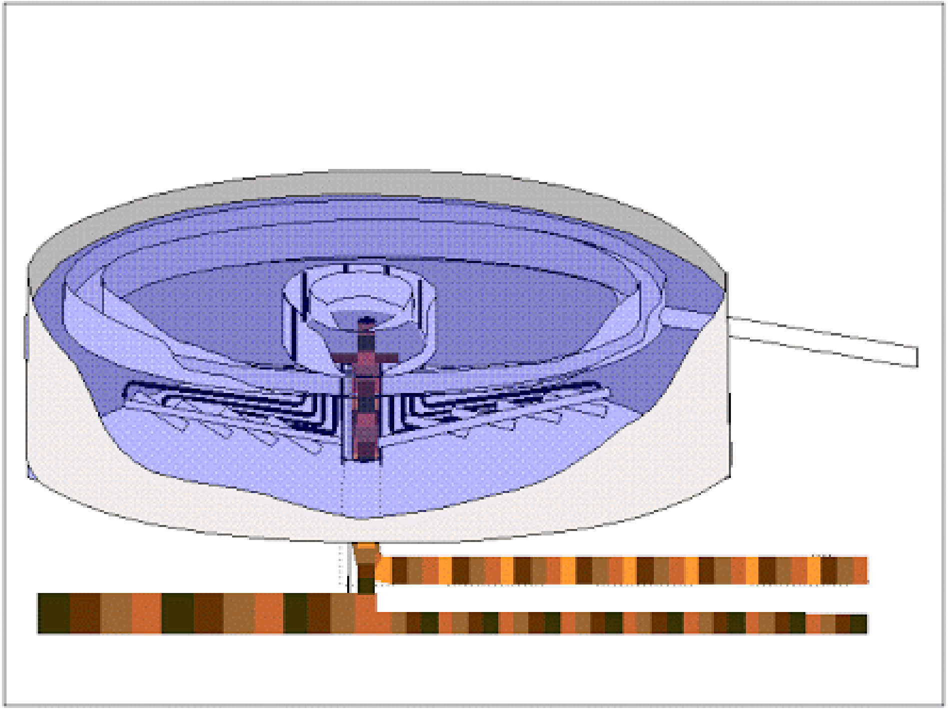
- It is provided to
  - Protect other mechanical units
  - Prevent clogging of pipes
- Disposal of sludge – landfill



Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.slideshare.net%2FErYaserSaleemSiddiqu%2Funit-4-70546952&psig=AOvVaw3IT4LBlD6O3iDrFob_UeaR&ust=1614876452297000&source=images&cd=vfe&ved=2ahUKEwj6-9DbyZTvAhUiJLcAHZSsCK8Qr4kDegUIARCRAg

Primary Clarifier

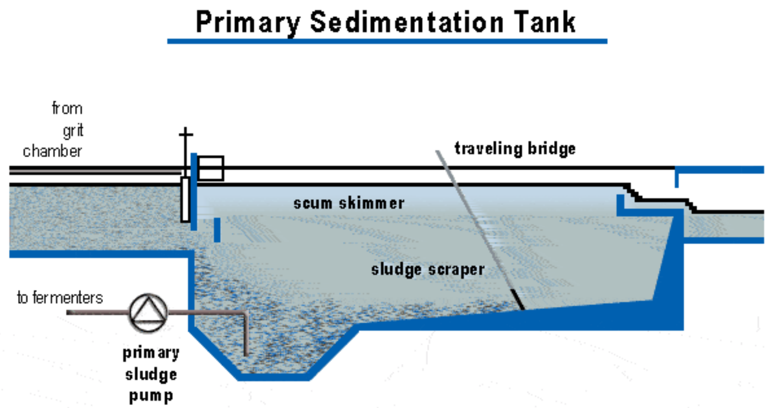
- The objective of primary sedimentation is to remove readily settleable solids and floating organic material (called scum) to reduce the suspended solids load for subsequent treatment processes
- Detention period - 90 to 150 min
- Organic suspended solids - above 0.1 mm



Source: https://i.gifer.com/E7lg.gif

Primary Clarifier

- An efficiently designed primary sedimentation tank can remove
  - 50-70% solids
  - 25-40% BOD
- Can be rectangular or circular in shape



Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fcivilengineerfriend.blogspot.com%2F2018%2F12%2Fprimary-treatment-primary-treatment.html&psig=AOvVaw072WQ_Wf42HcpacYhmUM1I&ust=1616334183810000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCLi15J2Av-8CFQAAAAAdAAAAABAD

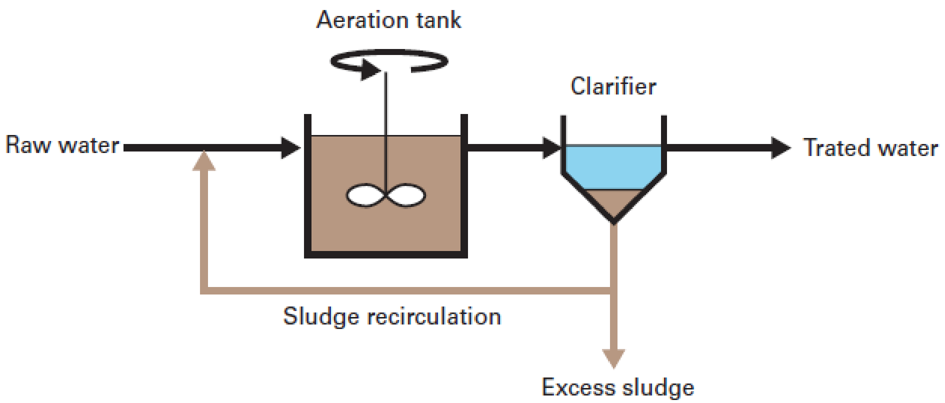
Primary Clarifier

Source:
https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.paramountlimited.com%2FPrimary_Clarifier.html&psig=AOvVaw3VJ5vehhEnAK8aqD6lNGGm&ust=161639392659
39000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCMiYh47fwO8CFQAAAAAdAAAAABAK

Overview of Mechanized Treatment Technologies

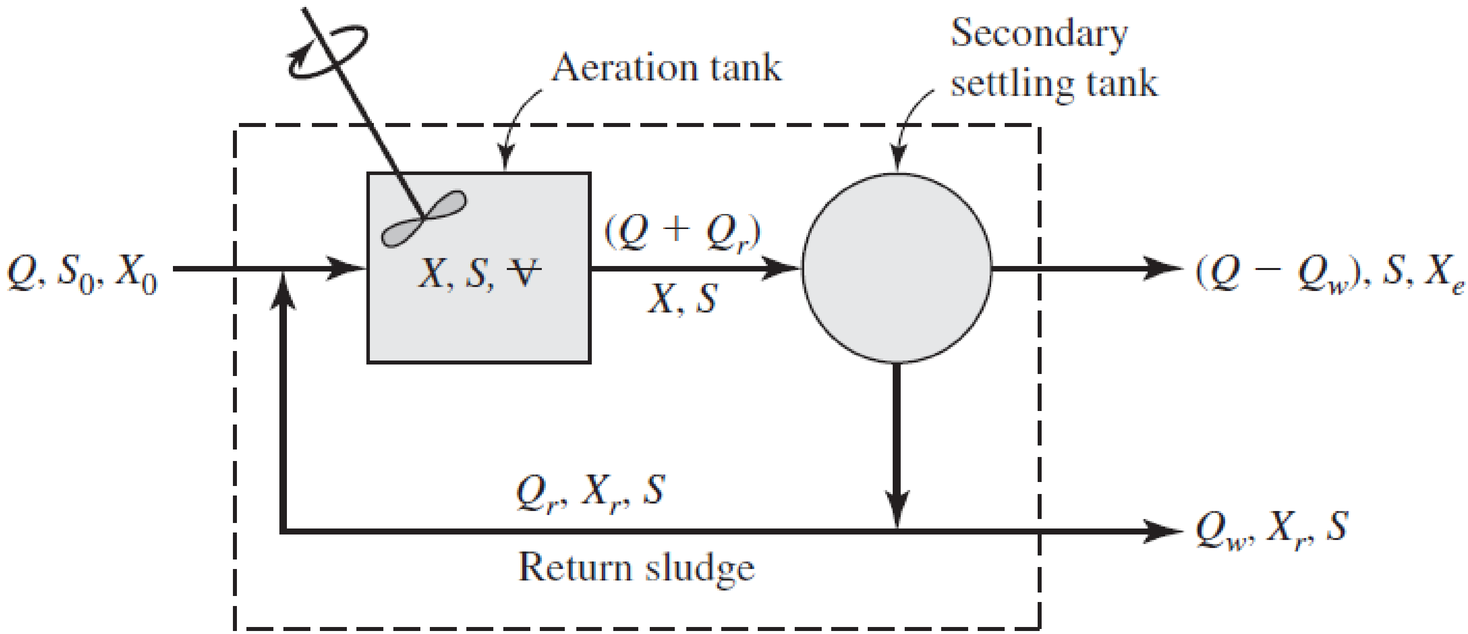
Activated Sludge Process (ASP)

- An aerobic biological suspended growth process
- Wastewater and biological sludge are mixed and aerated
- Abundance of oxygen
- The mixed liquor obtained in aerator is allowed to settle in secondary aerator
- The settled sludge is called as Activated Sludge
- A part of activated sludge is returned back to aeration process



Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.suezwaterhandbook.com%2Fprocesses-and-technologies%2Fbiological-processes%2Fsuspended-growth-cultures%2Factivated-sludge-reactor-type-and-configurations&psig=AOvVaw0CBlbxDzFasUTv7QdIhYYc&ust=1616335434112000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCNDx4-uEv-8CFQAAAAAdAAAAABAD

Design Principles for ASP



Biomass in influent	+	Net biomass growth	=	Biomass in effluent	+	Biomass wasted

(Source: Davis, M. L. (2010). *Water and wastewater engineering*. McGraw-Hill.)

Sludge Return

- If it is assumed that sedimentation of suspended solids in the laboratory is similar to that in sedimentation tank, then $X_R = 10^6/\text{SVI}$ (mg/L)
- Values of SVI between 100 and 150 ml/g indicate good settling of suspended solids
- X_R value may not be taken more than 10,000 g/cum (1%) unless separate thickeners are provided to concentrate the settled solids or secondary sedimentation tank is designed to yield a higher value

Food-to-Microorganism Ratio (F/M)

- Very useful parameter for monitoring WWTPs

$$F/M = \frac{QS_o}{\cancel{V}X}$$

$$F/M = \frac{[\text{BOD of wastewater (g m}^{-3})][\text{Influent flow rate (m}^3\text{ d}^{-1})]}{[\text{Reactor volume (m}^3)][\text{Reactor biomass (g m}^{-3})]}$$

where Q = wastewater flow rate into the aeration tank, m^3/d

S_o = influent readily biodegradable soluble COD (rbsCOD), mg/L

$\cancel{V}$ = volume of aeration tank, m^3

X = microorganism concentration (mixed-liquor volatile suspended solids or MLVSS) in the aeration tank, mg/L

The units of F/M are

$$\frac{\text{mg BOD}_5\text{/d}}{\text{mg MLVSS}} = \frac{\text{mg}}{\text{mg} \cdot \text{d}}$$

Oxygen Demand

- Oxygen is used in reactions where substrate is degraded to produce the high-energy compounds required for cell synthesis and respiration.
- Oxygen used = bCOD removed – COD of waste sludge

$$C_5H_7NO_2 + 5O_2 \rightleftharpoons 5CO_2 + 2H_2O + NH_3 + \text{energy} \qquad \frac{5(32)}{113} = 1.42$$

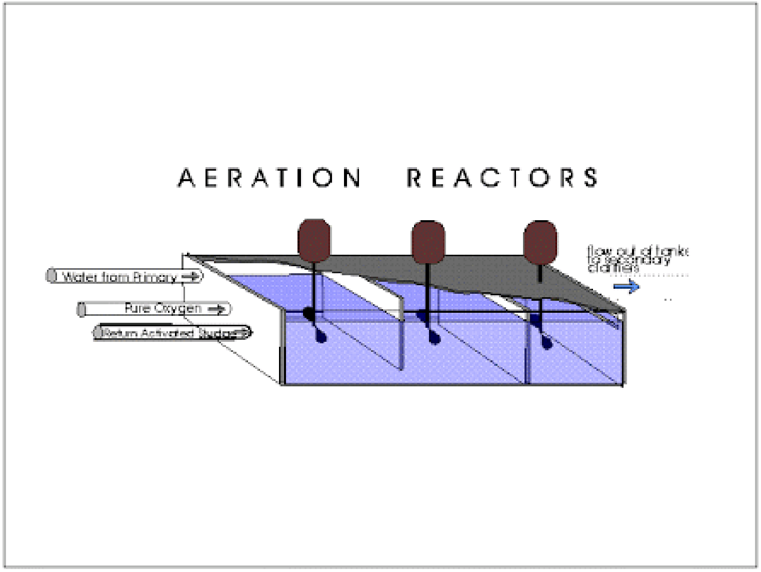
- Mass of oxygen:

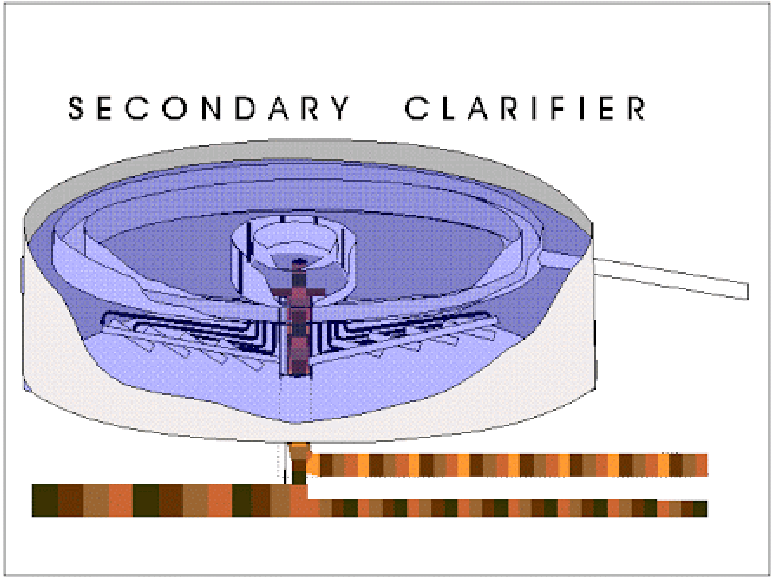
$$M_{O_2} = Q(S_o - S)(10^{-3}\ \text{kg/g}) - 1.42\ (P_x)$$

where M_{O_2} = mass of oxygen, kg/d
Q = wastewater flow rate into the aeration tank, m^3/d
S_o = influent bCOD, g/m^3
S = effluent bCOD, g/m^3
P_x = waste activated sludge produced, kg/d

Aerator and Secondary Clarifier

- ASP is one of the most commonly used technology for sewage treatment
- Modifications to conventional ASP are
  - Oxidation ditch
  - SBR



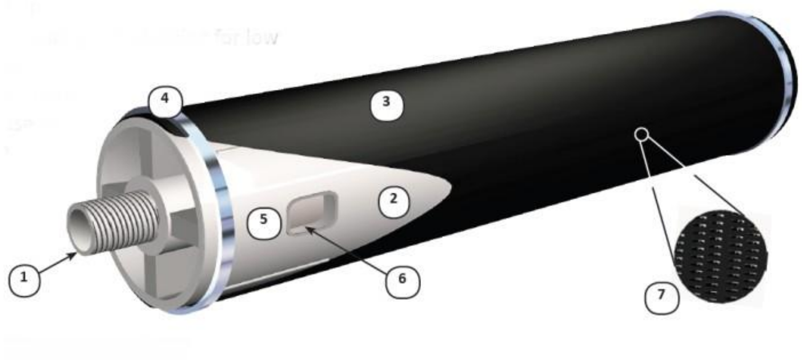


Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.thewatertreatments.com%2Fwastewater-sewage-treatment%2Fadvantages-disadvantage-aeration-system%2F&psig=AOvVaw3m4DFKmYYVksIEqx-uMo7Y&ust=1614876931222000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCICExsHLlO8CFQAAAAAdAAAAABAD
Source 2: https://i.gifer.com/E7lg.gif

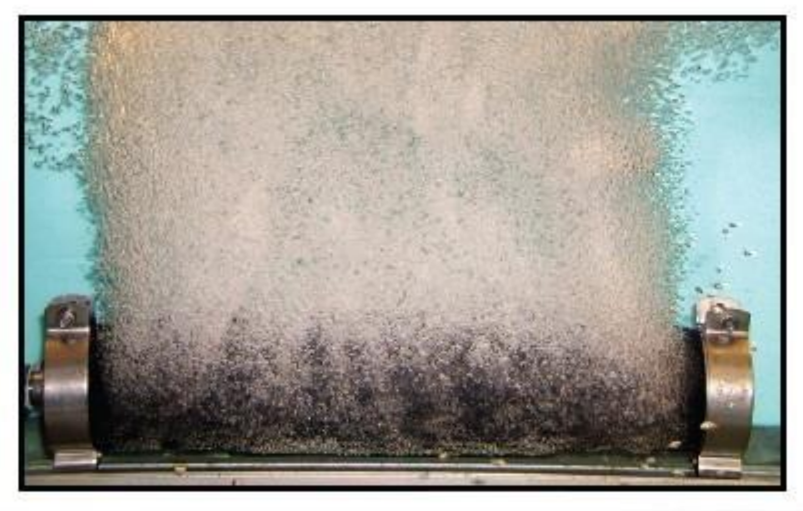
Aerator and Secondary Clarifier

Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.watertechonline.com%2Fwastewater%2Farticle%2F15550311%2Faerated-activated-sludge-basics&psig=AOvVaw2_ecmHdJUa_WBU-JY0NYJV&ust=1616394193883000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCNCN7OHfwO8CFQAAAAAdAAAAABAD
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.simivalley.org%2Fdepartments%2Fpublic-works%2Fsanitation-services%2Fsecondary-clarifiers&psig=AOvVaw06OeB9Ph08mwVBbTECIt2Q&ust=1616393979190000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJiyh__ewO8CFQAAAAAdAAAAABAD

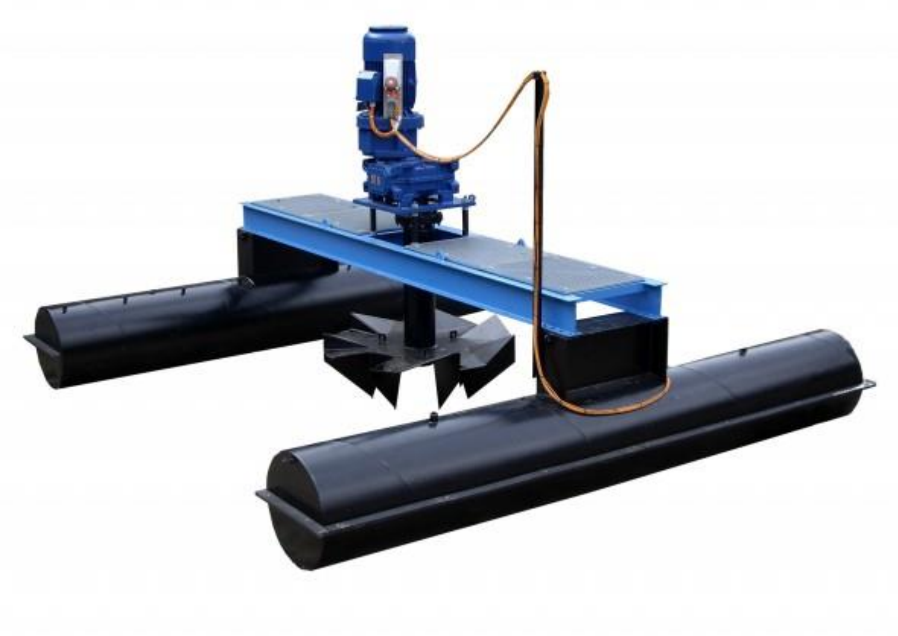
Diffuse Aerator



Flexair® Fine Bubble EPDM Tube Diffusers from EDI®



Mechanical aerators

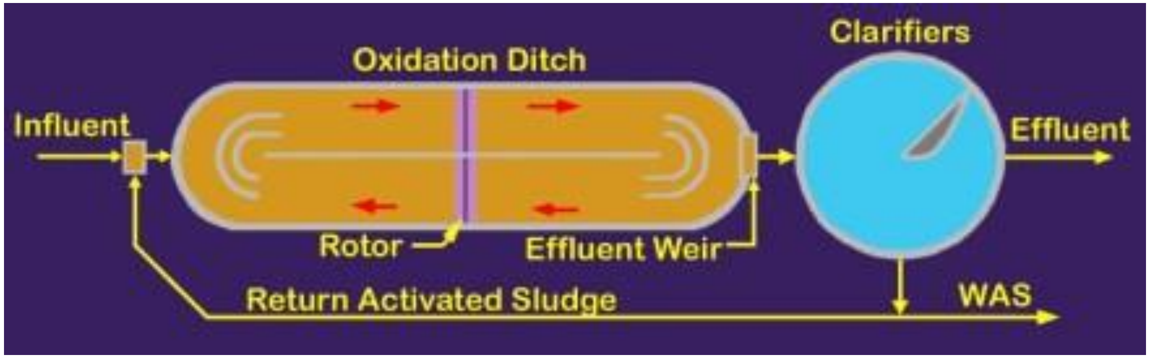


(Source: https://www.corgin.co.uk/aeration-mixing/aerators/vertex-surface-aerator)



Oxidation Ditch

- The oxidation ditch is a modified form of activated sludge process
- Also known as “extended aeration process”
- The ditch consists of a long continuous channel oval in shape
- Longer solid retention time helps in removal of organic matter



Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.slideshare.net%2FHaddies%2Fwater-pollution-and-its-control-through-biotechnology&psig=AOvVaw2QDKJHSZAzs-VlNr-TbAJ4&ust=1615025616082000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCICq8cH1mO8CFQAAAAAdAAAAABAJ

Oxidation Ditch

Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.environmental-expert.com%2Fproducts%2Ftri-oval-oxidation-ditch-system-309481&psig=AOvVaw2QDKJHSZAzs-VlNr-TbAJ4&ust=1615025616082000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCICq8cH1mO8CFQAAAAAdAAAAABAO
Source 2: https://www.slideshare.net/ashishaligarh2010/waste-water-treatment-processes
Source 3:
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DAKvRu88YhZ8&psig=AOvVaw1iK4lncw7S_FSTYFz9ITzo&ust=1616395589899000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCPiv_frkwO8CFQAAAAAdAAAAABAD

Oxidation Ditch

Advantages

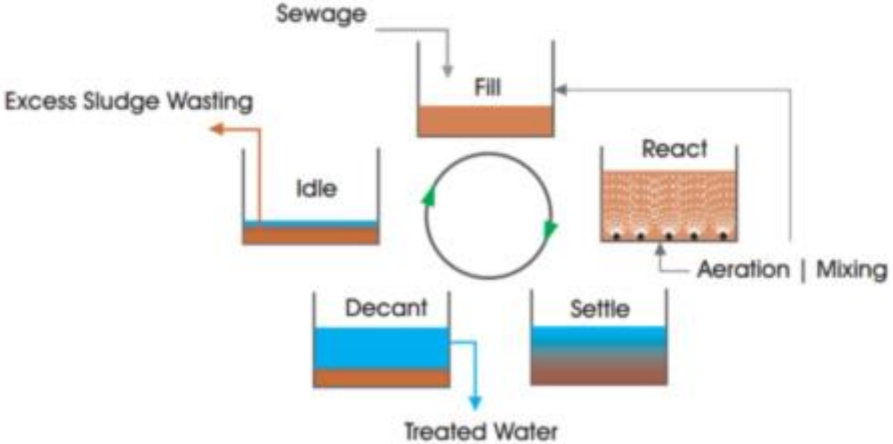
- Highly reliable and simple process
- Adaptable to nutrient removal
- High quality effluent possible
- Well stabilized sludge, low bio-solids production

Disadvantages

- Large structure greater space requirement
- Requires comparatively more aeration energy
- Plant capacity expansion is more difficult

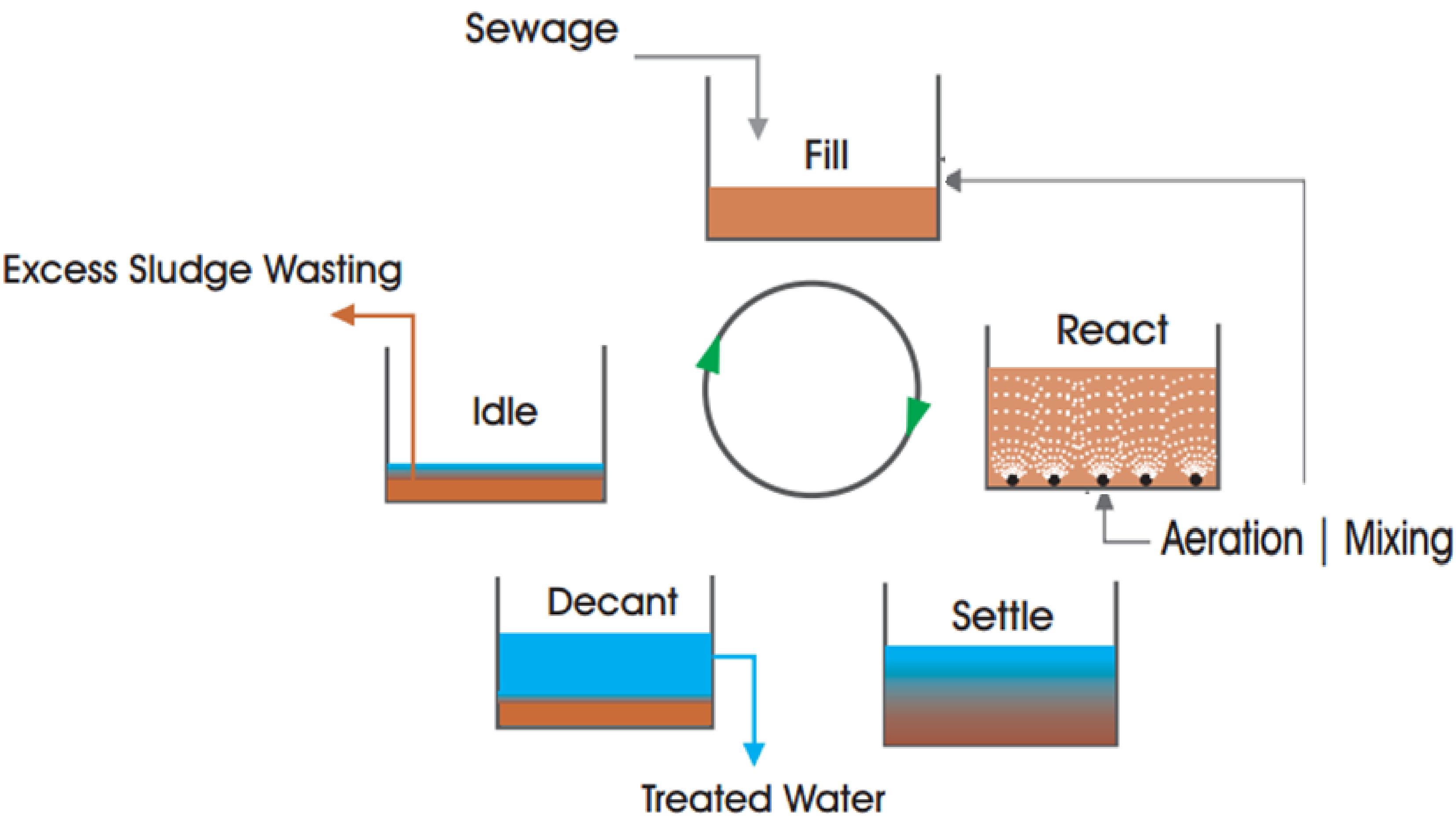
Sequencing Batch Reactor (SBR)

- Sequencing Batch Reactor (SBR) is the fill-and-draw type Activated sludge process
- It is the process in which, wastewater is filled in a batch reactor, treated to remove pollutants, and then discharged
- According to a 1999 U.S. EPA report, an SBR is no more than an activated-sludge plant that operates in time rather than space.



Source: https://knowhowtogmo.wordpress.com/2011/02/01/biological-phosphorus-removal-from-waste-water/

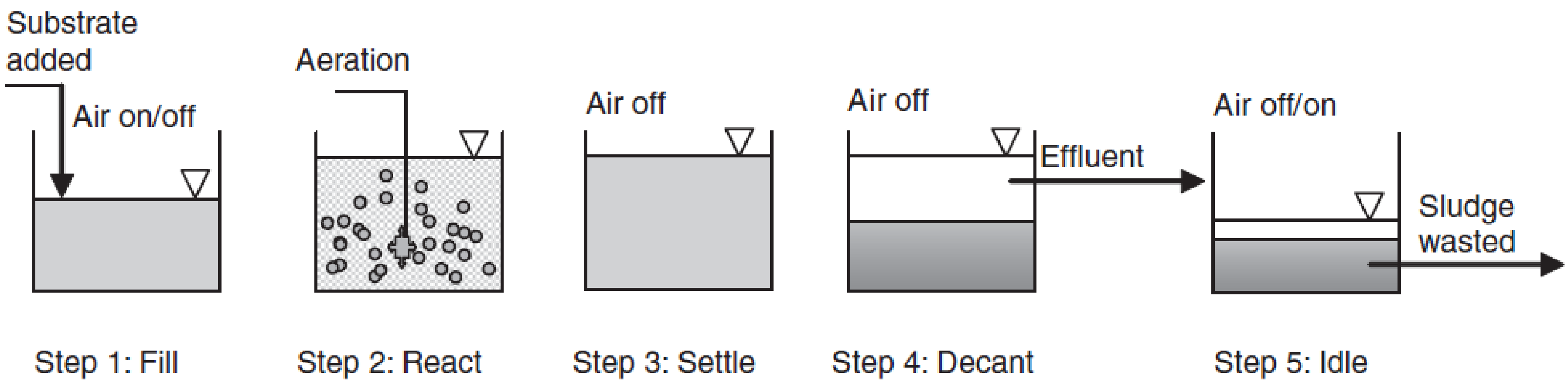
Sequencing Batch Reactor (SBR)



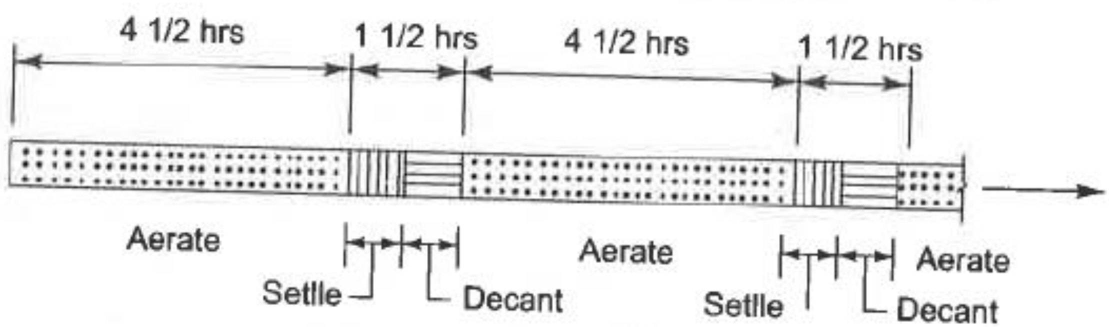
Source: https://knowhowtogmo.wordpress.com/2011/02/01/biological-phosphorus-removal-from-waste-water/

Sequencing Batch Reactor (SBR)

Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.xylem.com%2Fen-us%2Fproducts-services%2Ftreatment-products-systems%2Fbiological-treatment-processes%2Fsequential-batch-reactor-sbr%2Ficeas-advanced-sbr-d3f8bba3%2F&psig=AOvVaw2tGsSV8ULc2dfJfmPznVBX&ust=1616395547487000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCPD74-jkwO8CFQAAAAAdAAAAABAJ
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Ftranscendcleantec.com%2Fsequencing-batch-reactor%2F&psig=AOvVaw0GFpsD3m8JWudJ7XMJ6x-N&ust=1616395459005000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCMCa6bvkwO8CFQAAAAAdAAAAABAJ

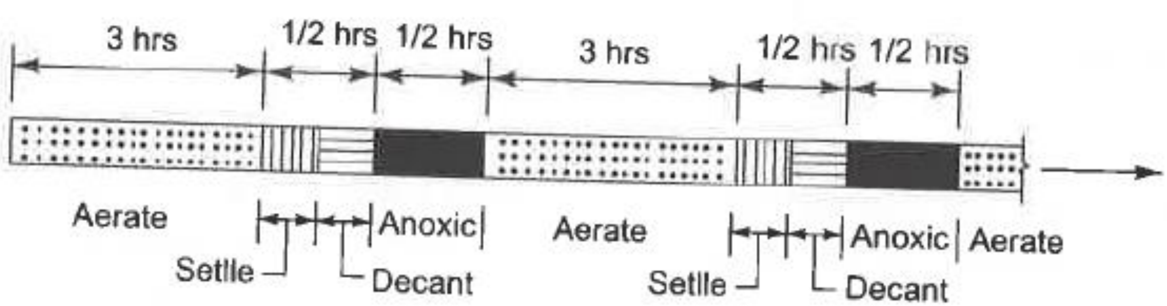


(Source: Ghangrekar, M. M., & Behera, M. 3.5 (2013) Suspended Growth Treatment Processes.)



(a) Operating Schedule Required for Discharge or Reuse without nitrogen removal

SBR Cycle



(b) Modified Operating Schedule Where Denitrification is Desired

(Source: Arceivala, S. J., & Asolekar, S. R. (2006). *Wastewater treatment for pollution control and reuse*. Tata McGraw-Hill Education.)

Sequencing Batch Reactor (SBR)

Advantages

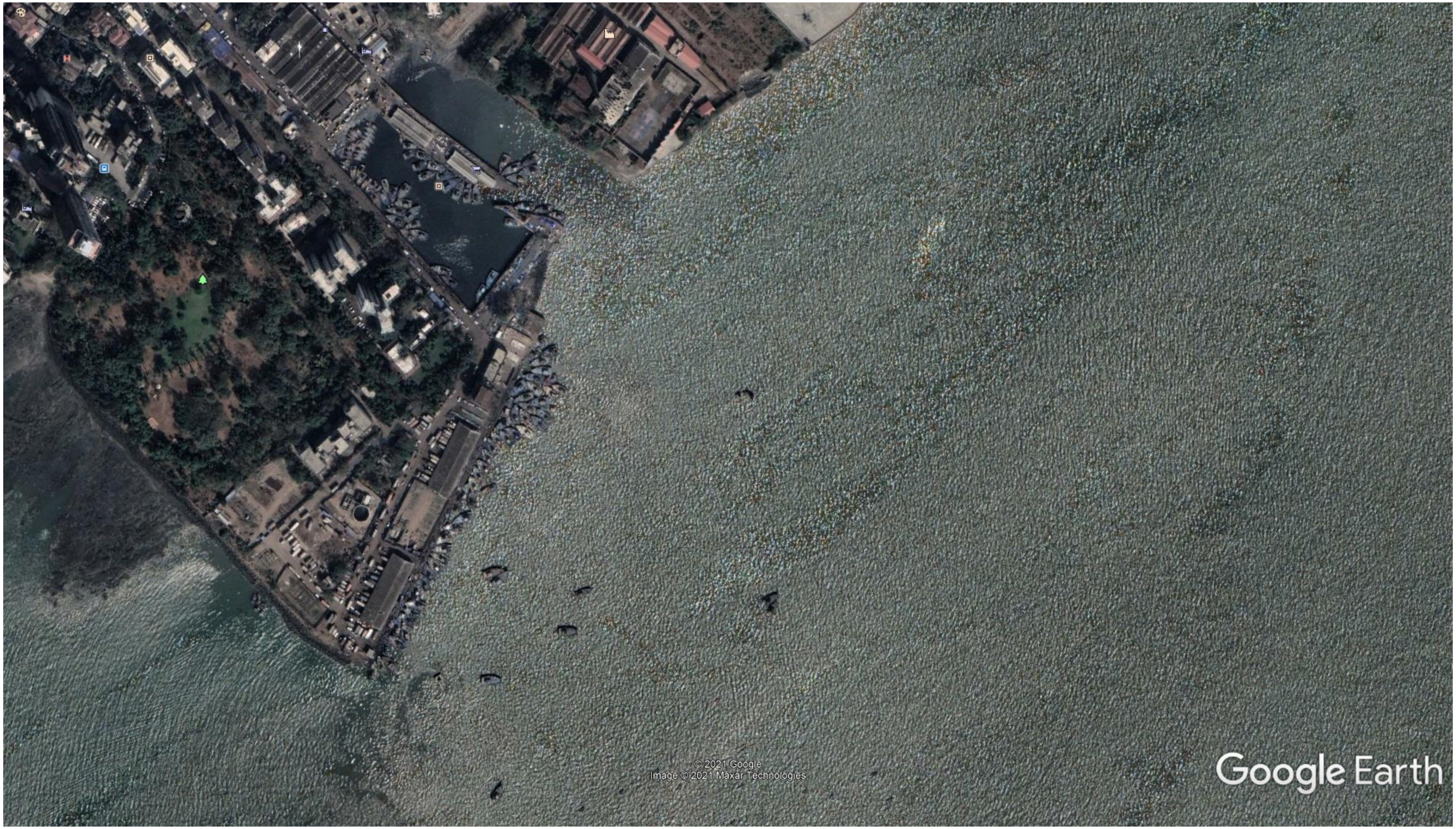
- Minimum Footprint
- Flexible and easy to operate
- Equalization, Aeration and Clarification in same tank
- Cost savings
- Separate tanks for clarification not required

Disadvantages

- Higher level of Sophistication
- Higher level of Maintenance
- Chances of withdrawal of sludge during decant phase

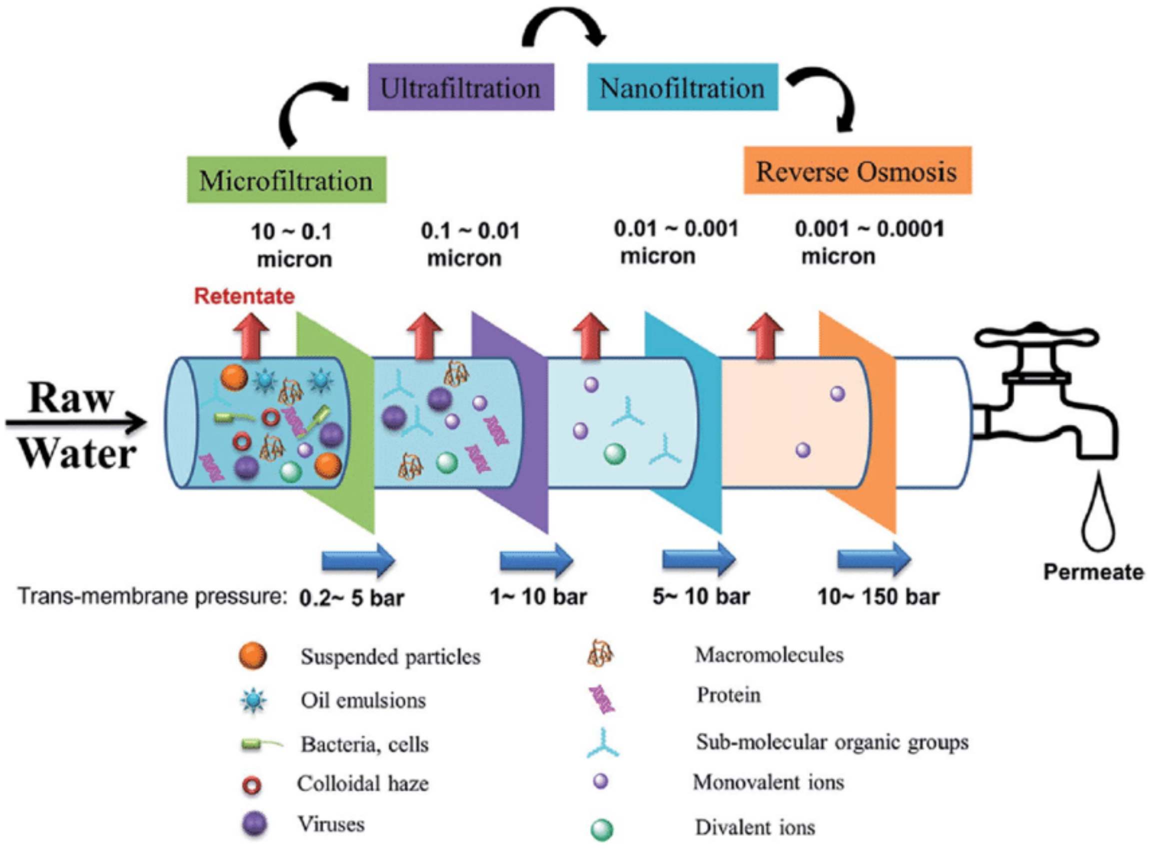
Nagpur (STP)

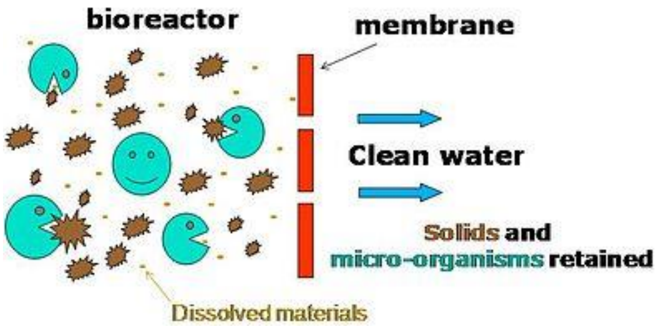
Colaba WWTF



Colaba WWTF

Membrane Treatment



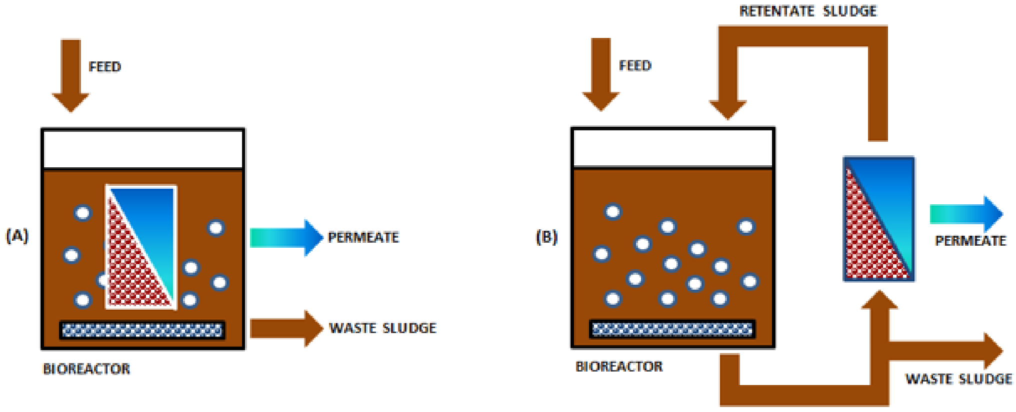


Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FPressure-driven-membrane-processes-for-water-treatment-technologies-showing-the_fig2_328882399&psig=AOvVaw1OhQveYDdb44kgcEyEOCzQ&ust=1616391408145000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCOjq57DVwO8CFQAAAAAdAAAAABAW

Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FMembrane_bioreactor&psig=AOvVaw0zV680M5akHfRzAowuIVue&ust=1616340398911000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCOiw_6-Xv-8CFQAAAAAdAAAAABAD

Membrane Bioreactor (MBR)

- MBR technology is the combination of a membrane filtration process with a suspended growth bioreactor
- Can be operated in two configurations
  - Submerged and
  - Side stream
- Introduced in late 1960s
- Original process was introduced by Dorr-Olivier Inc.

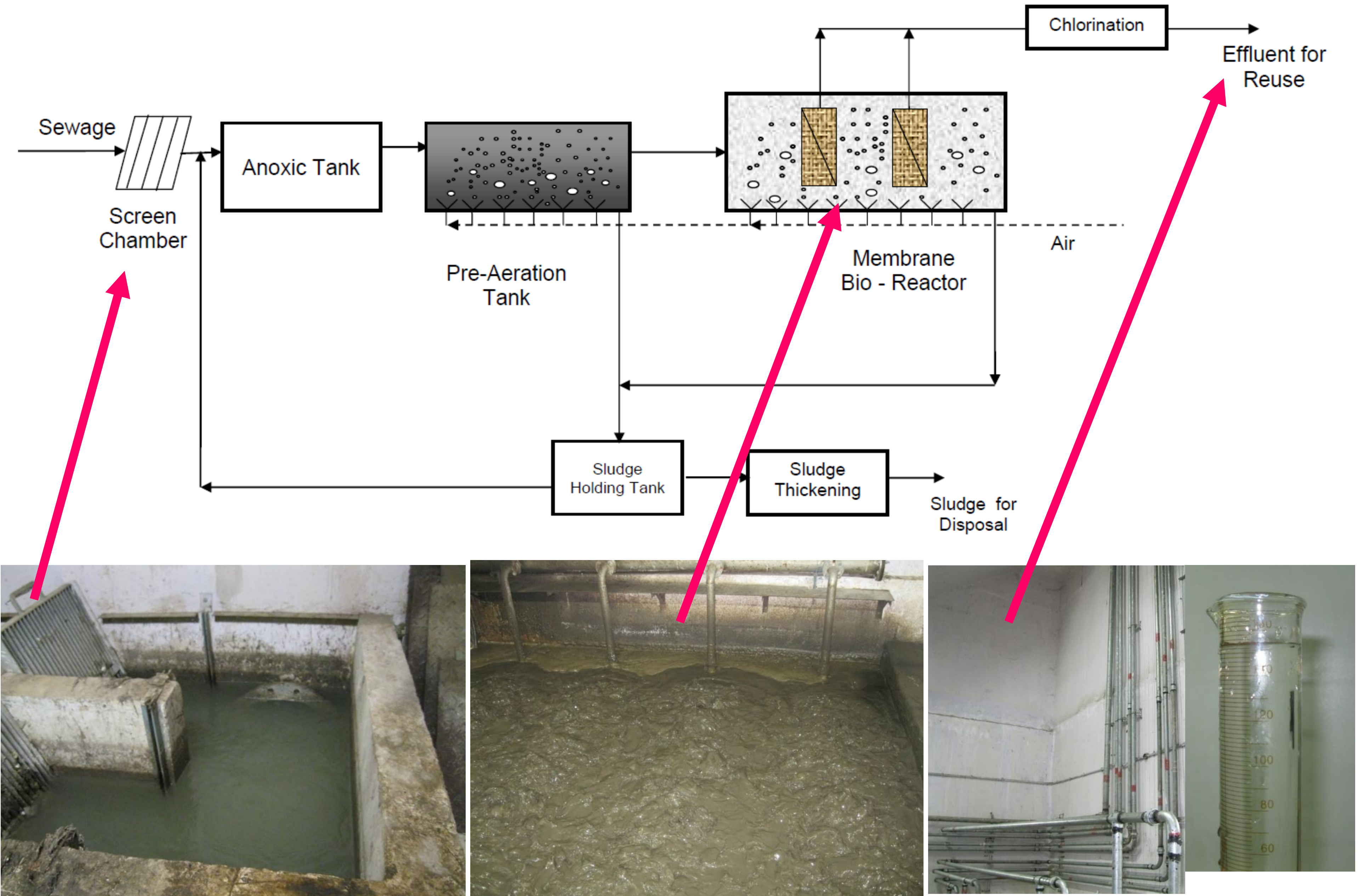


Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.lenntech.com%2Fprocesses%2Fmbr-introduction.htm&psig=AOvVaw3vL5zk7HESeR7NUFvqzKNy&ust=1616340582419000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCKCM_4mYv-8CFQAAAAAdAAAAABAD

Membrane Bioreactor

Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.hydrobluemem.com%2Fproduct%2Fmbr-bio-reactor-for-wastewater-treatment%2F&psig=AOvVaw0n1m6wtWy7cxygr7rb7fr-&ust=1616395626497000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCPDv-IzlwO8CFQAAAAAdAAAAABAK
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fmbr-sewage-treatment-plant-14395367962.html&psig=AOvVaw0n1m6wtWy7cxygr7rb7fr-&ust=1616395626497000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCPDv-IzlwO8CFQAAAAAdAAAAABAf

Process Flow Diagram of Building Scale STP based on MBR



Membrane Bioreactor

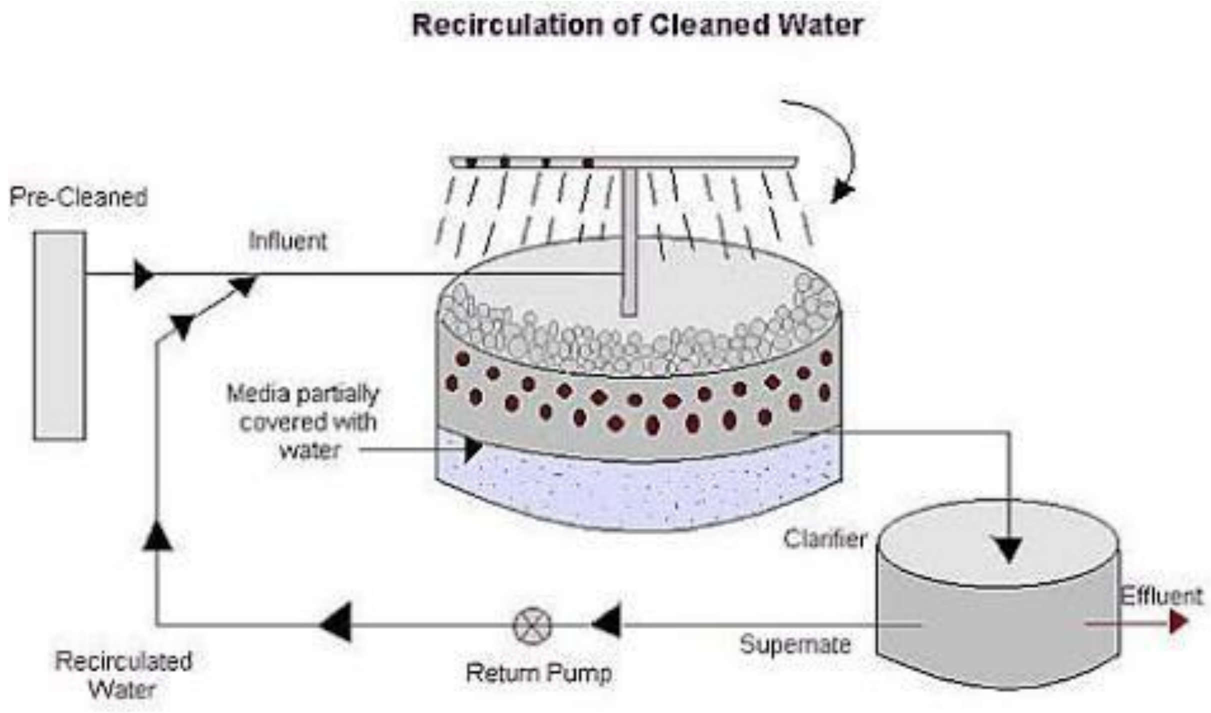
Advantages

- High quality effluent
- Potential for N removal
- Compact in size, less space required
- Lesser sludge because of longer solid retention time
- Higher volumetric loading rates and thus shorter hydraulic retention time

Disadvantages

- Higher capital and operation cost
- Membrane fouling
- Membrane costs
- Technical knowledge and care required during construction

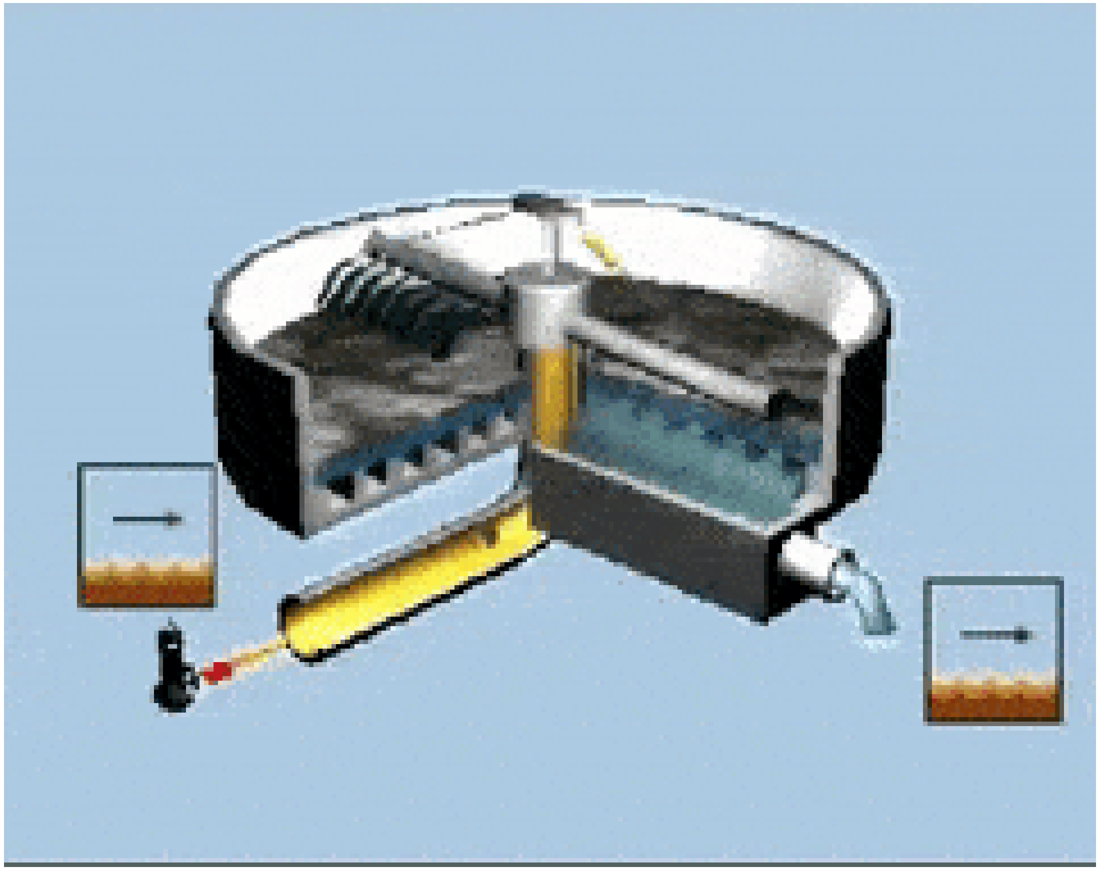
Trickling Filter



- It is an attached growth treatment process
- The wastewater is distributed over media
- Upon media, biological film is formed
- The film is made up of living organisms that help in breaking down the organic matter

Source: https://www.google.com/url?sa=i&url=http%3A%2F%2Fweb.deu.edu.tr%2Fatiksu%2Fana52%2Fani4041.html&psig=AOvVaw11Y4-Yfhrz9oTBemqtO-B0&ust=1614877031584000&source=images&cd=vfe&ved=2ahUKEwjO4e3vy5TvAhXCDLcAHQeaD30Qr4kDegUIARCTAQ

Trickling Filter



Source: https://www.youtube.com/watch?v=R2-w4cvi_bM

Trickling Filter

Source 1: https://www.google.com/url?sa=i&url=https%3A%2F%2Fhydroflux.com.fj%2Ftrickling-filter-package-sewage-treatment-plant-wastewater-hydroflux-epco-australia-gallery-8%2F&psig=AOvVaw0FMAe6TG4djq441H64f9m1&ust=1616395822021000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJCNs-nlwO8CFQAAAAAdAAAAABAD
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.hewitech.de%2Fen%2Fproducts%2Fwater-purification%2Ftricklingfilter%2F&psig=AOvVaw0FMAe6TG4djq441H64f9m1&ust=1616395822021000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJCNs-nlwO8CFQAAAAAdAAAAABA-

Advantages and Disadvantages Trickling Filter

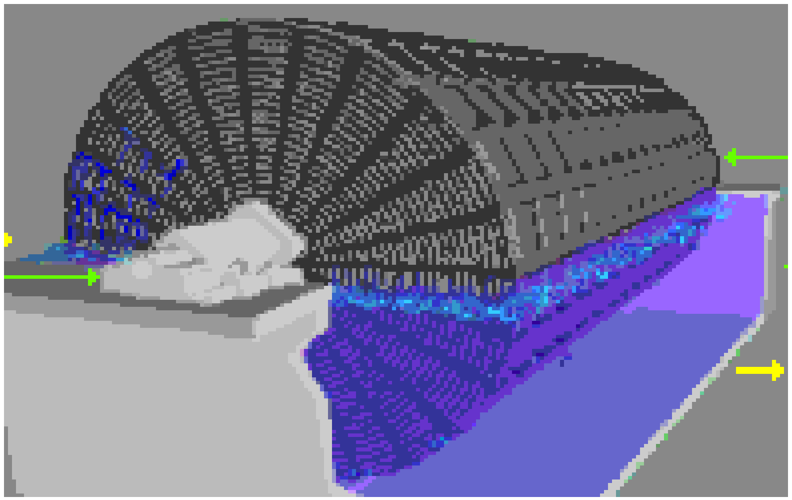
Advantages

- Simple, reliable, biological process
- Effective in treating high concentrations of organics depending on the type of medium used
- Appropriate for small- to medium-sized communities.
- Durable process elements
- Low power requirements
- Moderate level of skill and technical expertise needed

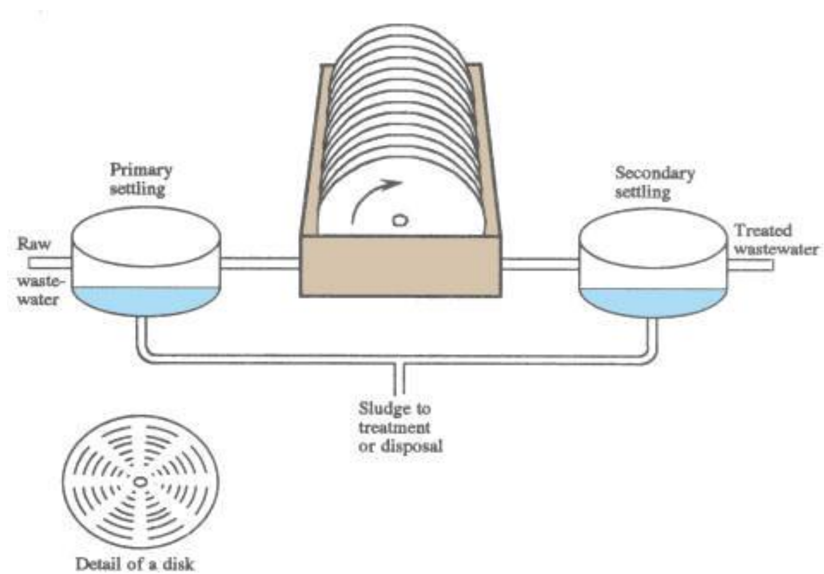
Disadvantages

- Additional treatment may be needed to meet more stringent discharge standards
- Requires regular operator attention
- Incidence of clogging is relatively high
- Flexibility and control are limited in comparison with ASP
- Odor problems

Rotating Biological Contactors (RBC)



Rotating biological contactors is a simple attached growth process which removes the soluble organic matter by its conversion to insoluble microbial cells which are easily settable



Purpose of RBCs

- Treatment of both industrial and domestic wastewaters
- For carbonaceous BOD removal
- For Nitrification

Source: https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.aesarabia.com%2Frotating-biological-contactor%2F&psig=AOvVaw0LrcYFgAZisjBYdCdTeDE6&ust=1614877128229000&source=images&cd=vfe&ved=2ahUKEwihz_idzJTvAhUAIrcAHVSKA48Qr4kDegUIARDMAQ

Rotating Biological Contactors (RBC)

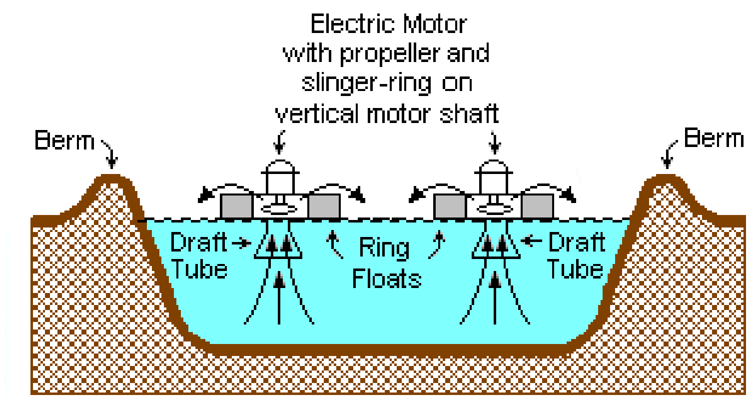
Source 1: STP at MNIT Jaipur
Source 2: https://www.google.com/url?sa=i&url=http%3A%2F%2Fm.yhenviro.com%2Fenviromental-machinery%2Fsewage-wastewater-treatment-machinery%2Fthree-dimensional-structure-rotating.html&psig=AOvVaw3QZ7GZIt4JmbOGjpHfSDo5&ust=1616395936409000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJirkZ_mwO8CFQAAAAAdAAAAABAJ

Lagoons

- Lagoons: Earthen basin with sloping side walls
- Based on the type of metabolism:
  - **Aerobic lagoons** are generally shallow, have adequate mixing to prevent stratification; may be aerated by phototrophs in day time or may be mechanically aerated
  - **Facultative lagoons** tend to be deeper than aerobic and have an upper aerobic zone, where phototrophs are active and a lower zone where anaerobic heterotrophic activity dominates.
  - **Anaerobic Lagoons** are generally deeper and depend upon anaerobic heterotrophic activity as primary treatment, with upper phototrophic zone that minimizes odour emissions

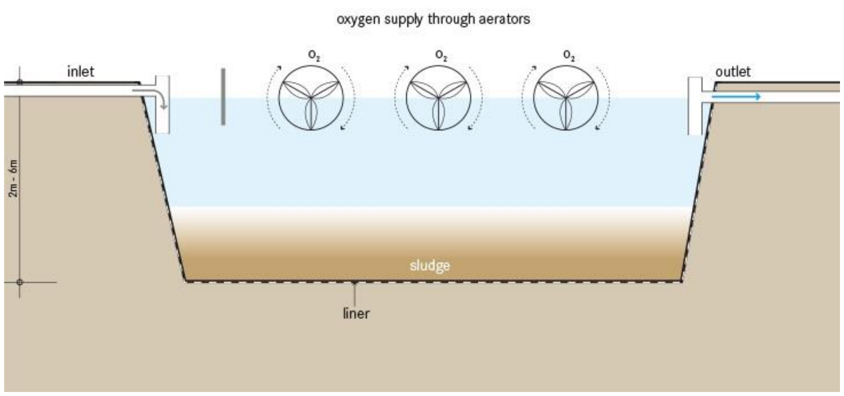
Aerated Lagoons

- Consists of a large earthen basin equipped with mechanical aerators
- Aerated lagoons are of two types depending on the microbial biomass
  - Suspended growth aerated lagoon
  - Facultative aerated lagoons



A TYPICAL SURFACE – AERATED BASIN

Note: The ring floats are tethered to posts on the berms.



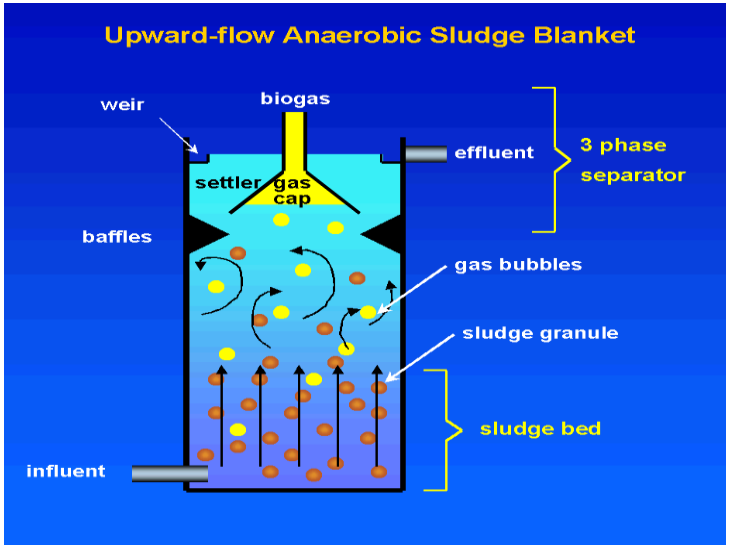
Source: https://en.wikipedia.org/wiki/Secondary_treatment#/media/File:Surface-Aerated_Basin.png
Source: Source: http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments/w

Aerated Lagoons

Source 1:
https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.lagoonsonline.com%2Fsitemap.htm&psig=AOvVaw3ZWvsDrLdVJ_cPAQcQapKf&ust=1616397272110000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCKDiuJ3rwO8CFQAAAAAdAAAAABA0
Source 2: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.wabcointernational.com%2Fproducts-services%2Fwaste-water-treatment%2Faeration-systems%2F&psig=AOvVaw3ZWvsDrLdVJ_cPAQcQapKf&ust=1616397272110000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCKDiuJ3rwO8CFQAAAAAdAAAAABAv

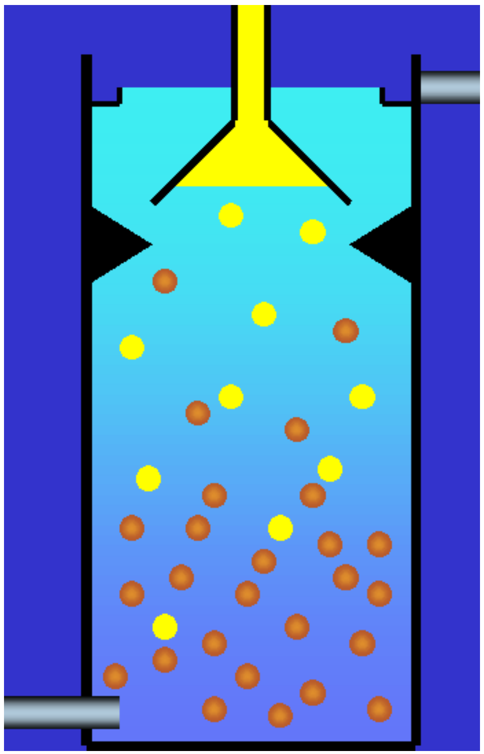
Upflow Anaerobic Sludge Blanket (UASB)

- It is one of the most notable developments in anaerobic treatment process technology
- A special kind of reactor for the "high rate" anaerobic treatment of wastewater
- Also known as methanogenic (methane-producing) digester

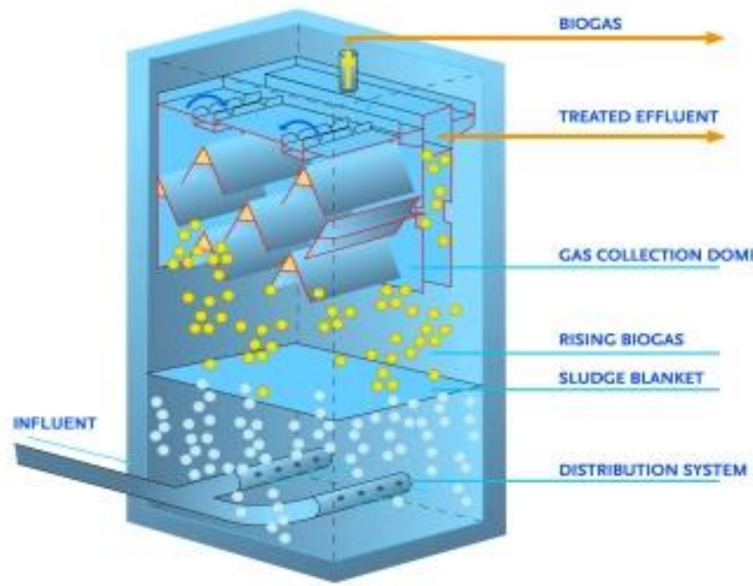


Source: https://microbewiki.kenyon.edu/index.php/Upflow_Ananerobic_Sludge_Blanket

Upflow Anaerobic Sludge Blanket (UASB)

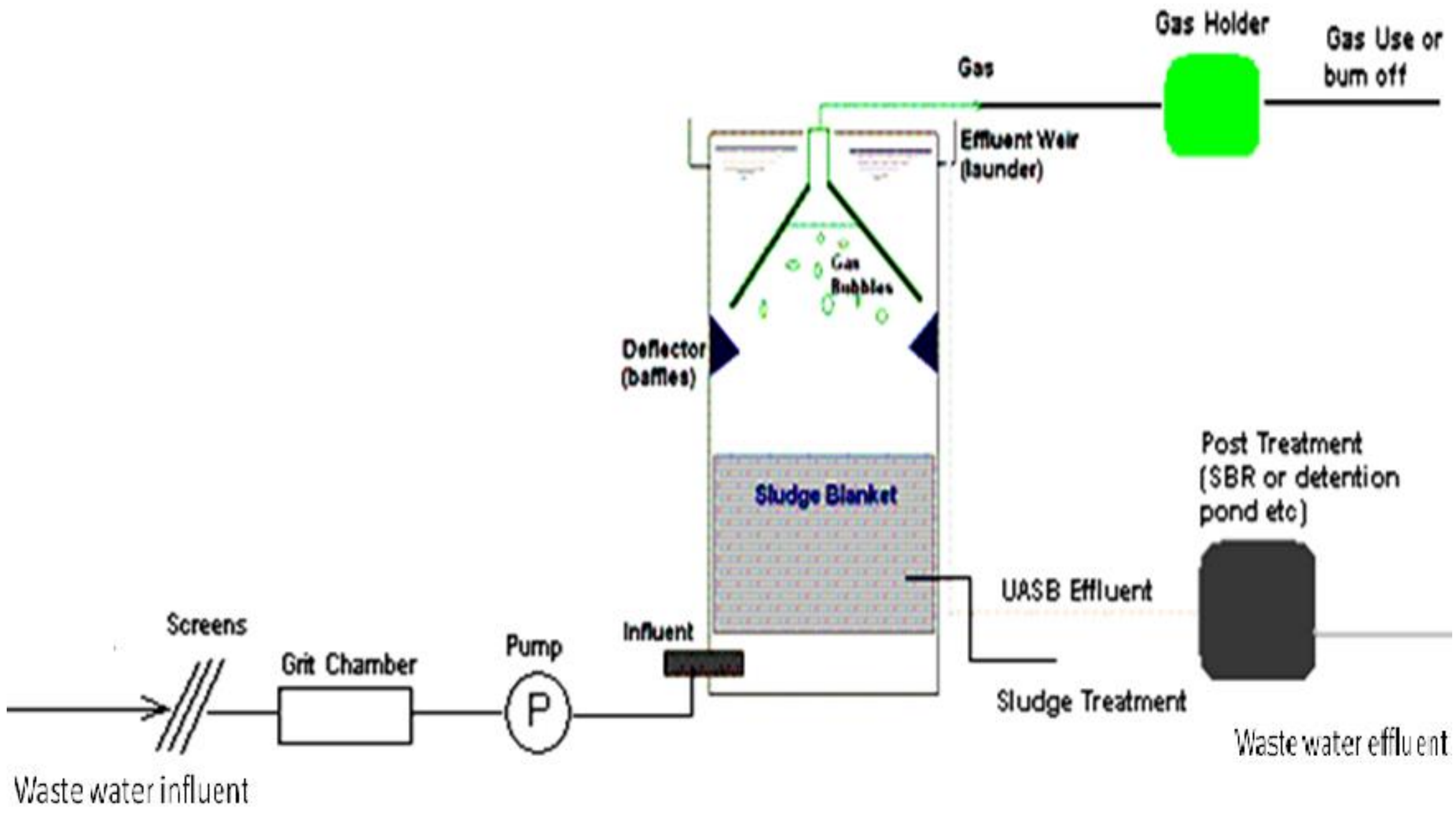


Source: http://enveng.blogspot.com/2005/11/upflow-anaerobic-sludge-blanket-uasb.html



Source: https://www.iwapublishing.com/news/flow-anaerobic-sludge-blanket-reactor-uasb

Upflow Anaerobic Sludge Blanket (UASB)



Source: https://www.google.com/url?sa=i&url=http%3A%2F%2Fwastewater-engineering.com%2Fuasb_upflow_anaerobic_sludge_blanket.htm&psig=AOvVaw04bOh7uj3TV7tk1n74rRlY&ust=1615026198232000&source=images&cd=vfe&ved=2ahUKEwjauofI95jvAhWx0nMBHdDHCWoQjRx6BAgAEAc

UASB tank

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fup-flow-anaerobic-sludge-blanket-reactor-uasb-anaerobic-digester-22578092333.html&psig=AOvVaw0ieFlJg9mCDGc_R33W-mhU&ust=1616401033869000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCNiV_J_5wO8CFQAAAAAdAAAAABBH

Upflow Anaerobic Sludge Blanket (UASB)

Advantages

- Low energy requirement
- Less operation and maintenance cost
- Lower skill requirement for operation and supervision
- Less sludge production
- Potential for resource recovery through generation of electricity from bio gas

Disadvantages

- The efficiency of the BOD and suspended solid removal is low as compared to the ASP
- Performance of UASB based plant is adversely affected by mixing industrial effluent that contain some toxic material or high level of sulphate
- Corrosion of structures in & around a UASB based plant is found to be higher compared to other technology based STPs

Overview of Natural Treatment Systems

Natural Treatment Systems

- Mimic the processes taking place in nature
- Use pathways of natural ecosystems
- Affordable and sustainable solutions and are recommended for developing countries
- Occur naturally, hence slowly, at their own pace

European Commission defined Nature-Based Solutions as:

Living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits

Boano, F., Caruso, A., Costamagna, E., Ridolfi, L., Fiore, S., Demichelis, F., Galvão, A., Pisoeiro, J., Rizzo, A., & Masi, F. (2020). A review of nature based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits. *Science of The Total Environment, 711*, 134731. https://doi.org/10.1016/j.scitotenv.2019.134731

East Kolkata Wetlands

- ‘Ramsar Wetlands Convention’ designated as wetlands having international importance
- Free sewage treatment plants for decades spread over 12500 hectares
- Comprises of 2000+ water bodies or ponds
- Out of 1400 MLD sewage generated in Kolkata, almost 910 MLD is treated in East Kolkata Wetlands (EKW)
- Source of livelihood for 74% population in the adjoining area

Aerial view of East Kolkata Wetlands and typical ponds

Natural Treatment Systems

➢ **Assimilative capacity of water bodies**

Engineered Natural Treatment Systems

Systems using Phytoremediation

1] Constructed wetlands

2] Duckweed ponds

3] Floating wetlands

Systems using Bioremediation

1] Waste stabilization ponds/ algal ponds

Systems using Zoo-remediation

1] Sewage-fed aquaculture

2] Vermifiltration

Natural Hybrid Systems

1] Phyto + Bio

2] Bio + Zoo

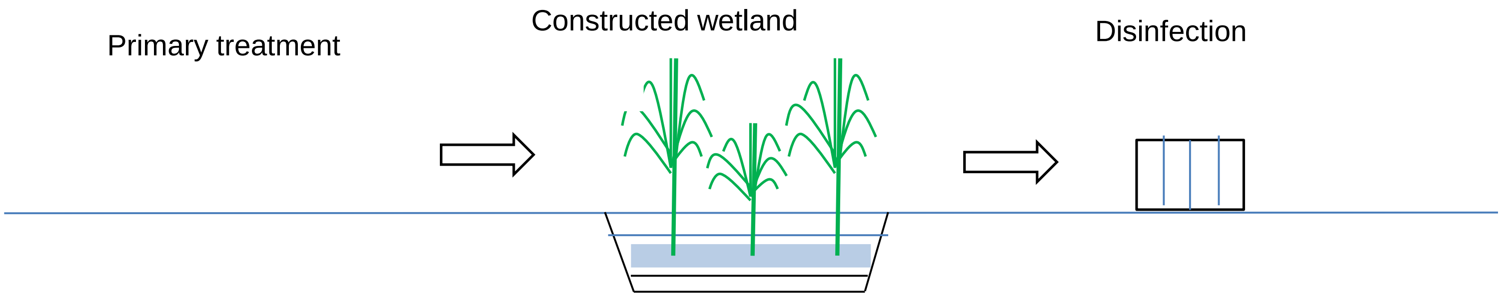
Constructed Wetlands

Other names:

Planted soil filters, reed bed treatment systems, artificial wetlands or vegetated submerged beds

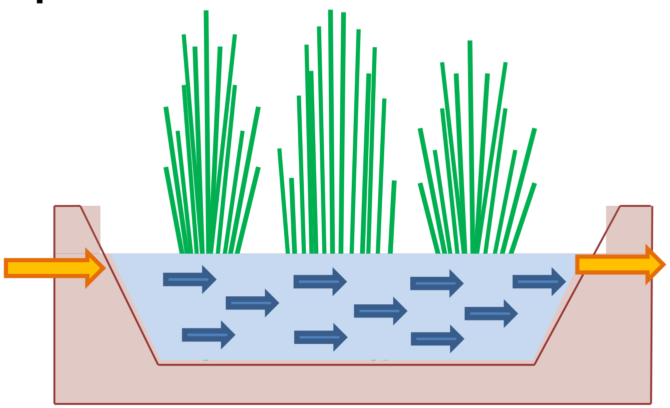
Characteristics:

- Engineered systems artificially developed to function natural processes along with coexisting microorganisms to aid wastewater treatment
- ***Wetland vegetation*** and the ***microbial population*** present in media are the key functional units
- Natural mechanisms assist in the removal of the contaminants present in groundwater or surface water

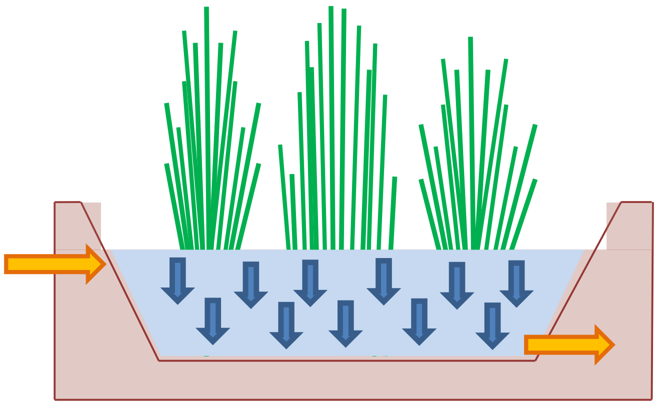


Configurations of Constructed Wetlands

Flow patterns:

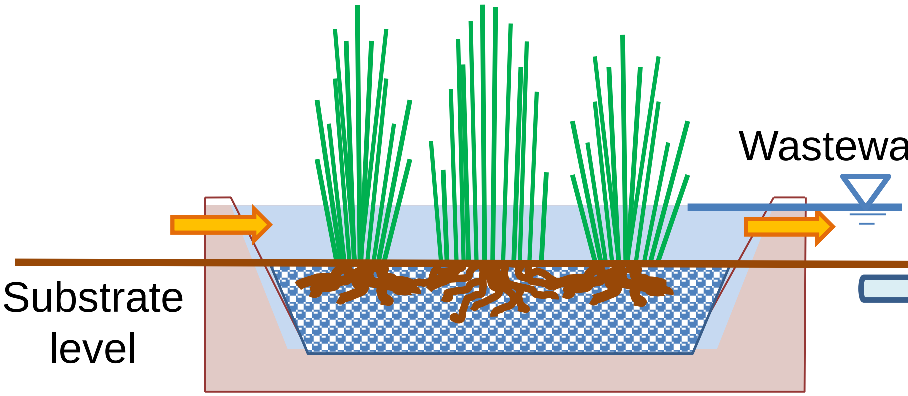


Horizontal flow CW

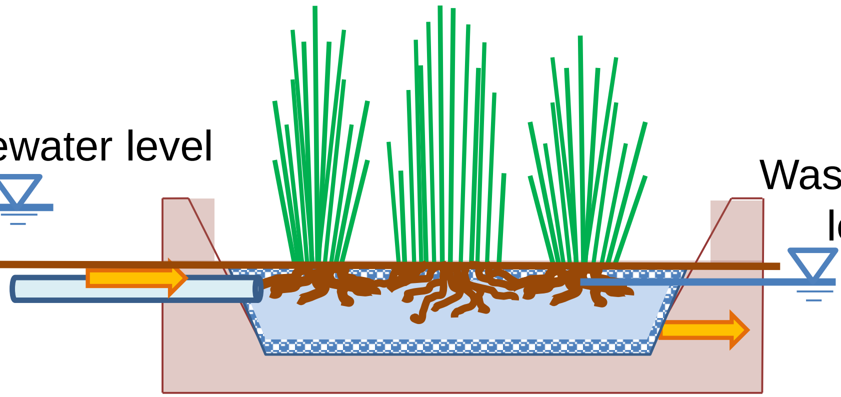


Vertical flow CW

Level of Wastewater:



Free surface flow CW



Subsurface flow CW

Constructed Wetland Design

Land requirement:

$$A_s = \frac{Q * (\ln C_o - \ln C_e)}{K_T * y * n}$$

Where

A_s = wetland surface area (m^2)

Q = average design flow (m^3/d)

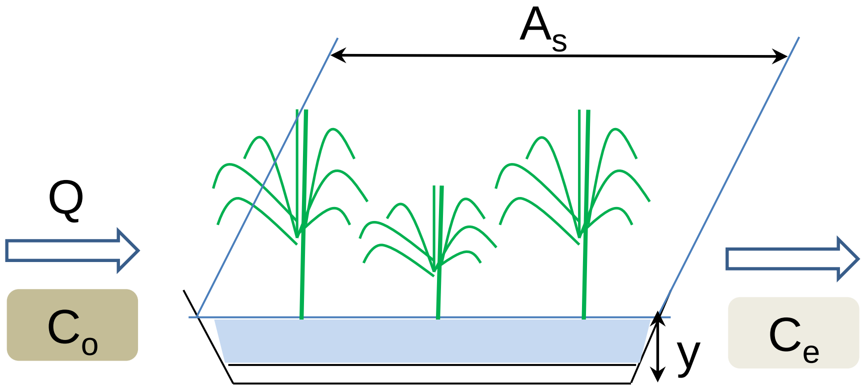
C_0 = influent BOD concentration (mg/L)

C_e = effluent BOD concentration (mg/L)

K_T = rate constant = 1.1 d^{-1} at 20℃

y = design depth (m)

n = porosity of media



A satisfactory performance of constructed wetland is possible with the help of basic design guidelines!

Crites RW, Middlebrooks EJ, Bastian RK, Reed SC (2014) Natural wastewater treatment systems, 2nd edn. CRC Press, the Taylor & Francis Group, Boca Raton

Design Guidelines

Sr. No	Parameters	Typical values	
		European literature	Recommended for India
1	Area required, m^2/person	2.0 – 5.0	1.0 – 2.0
2	BOD_5 loading rate, g/m^2-day	7.5 – 12.0	17.5 – 35.0
3	Detention time, days	2-7	2 – 3
4	Hydraulic loading rate, mm/day	< Hydraulic conductivity of bed	-
5	Depth of bed, m	-	0.6 – 0.9
6	Porosity of bed, % (typical)	-	30 – 40
7	1st order reaction constant, K_T/day	-	0.17 – 0.18
8	Evapotranspiration losses, mm/day	10 - 15	>15

Arceivala, S. J., & Asolekar, S. R. (2017). *Wastewater Treatment for Pollution Control and Reuse* (Third). McGraw Hill Education.

Species Used

Name of species	Properties	Reference
Phragmites australis	• Increased residence time leads to sedimentation of suspended particles • Plants provide a physical site for bioremediation • Suspended solids, nutrients, heavy metals, bacteria efficiently removed	Reenu et al., 2015
T. latifolia	• Intensive gas transfer through convection make it suitable for CW • Found in all water bodies including brackish, freshwater, flowing and stagnant • Found in a variety of climates	Rana and Maiti, 2018
C. esculenta	• Metal uptake ability makes it common choice for bioremediation	Rana and Maiti, 2018

Phragmites australis

Typha latifolia

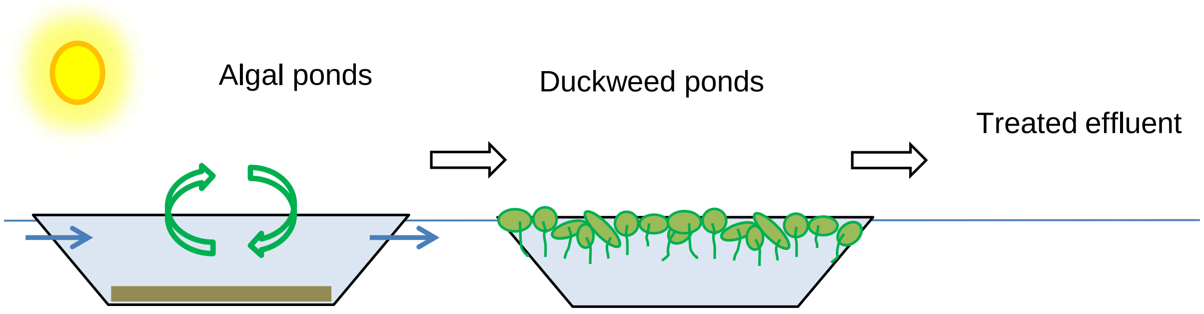
Colocasia Esculenta

Phragmites Karka

Duckweed Ponds

Features of duckweed plants are as follows:

- Freshwater plants growing at a rate 30% faster than water hyacinth
- Surface area of biomass doubles in 2-4 days
- More cold tolerant than water hyacinth; Indian climate suitable for duckweeds
- More responsive to wide range of pH ranging from 5-9
- Ability to control mosquito breeding and bad odor problems
- Better nutrient accumulation and easy harvesting
- Harvested duckweed protein-rich; used as fish or poultry feed provided treated wastewater does not contain heavy metals
- Potential for community based job creation and revenue generation when coupled with fish ponds



Duckweed Species

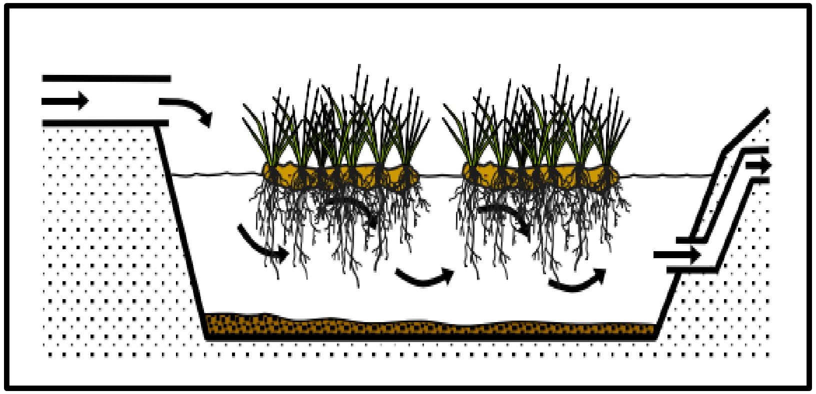
Scientific name	Common name	Uses
Lemna minor	Common duckweed	• Important food source for fish and birds, hence grown in dams • Valuable indicator of nutrient levels • Fish enthusiasts grow it as live food for native and goldfish
Spirodela	Giant/ big duckweed	• High protein food source (ducks, geese, certain fish) • Harvested as feed for cattle and pigs in Asia and Africa
Wolffia	Common water meal	• Variety of duck and geese including mallard can consume it • The dense canopy controls mosquito larvae

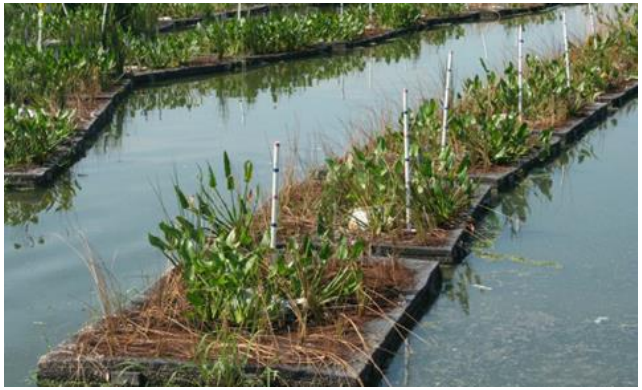
Lemna minor

Spirodela

Wolffia

Floating Wetlands



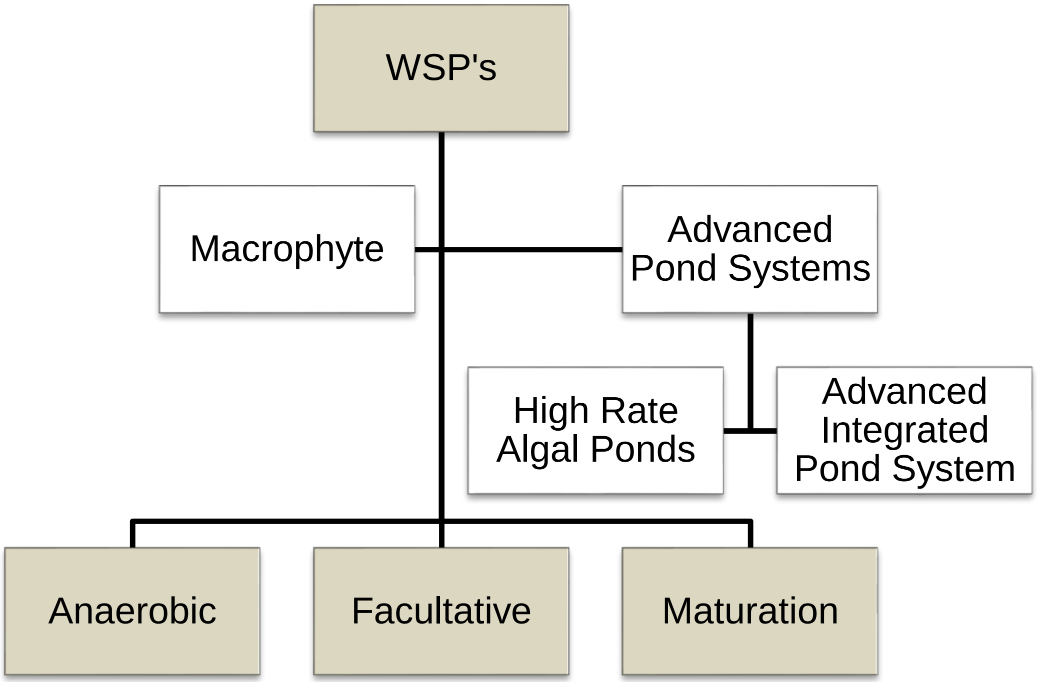


Combination of two NTS i.e., aquatic ponds (hydraulic aspects) along with constructed wetlands (rooted plants)

- **In-situ** treatment option for the revival of water bodies
- Hydroponically grown **emergent** wetland species
- Roots provide large **surface area for biofilm**
- Aquatic macrophytes - **'bio-indicators' of pollution**

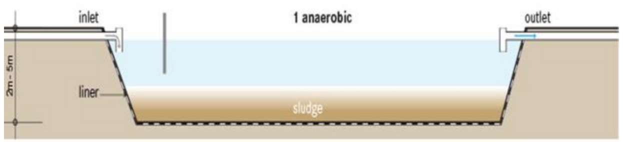
An artificial island of 200m^2 area (100 units of 2m^2 area each) was constructed in-situ on river Kshipra and tested for domestic wastewater

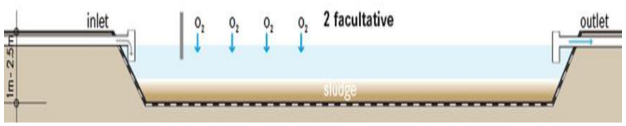
Waste Stabilization Ponds

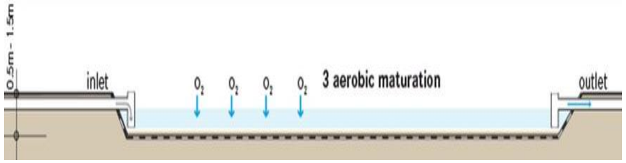


- Individual pond functions like a completely mix series reactor
- Series of ponds function as a series of completely mix reactors, thereby achieving the benefits of a plug flow reactor
- Capable of achieving 4-log removal of pathogens as against the 2-log removal for activated sludge process

Waste Stabilization Ponds







Classification:

1. Anaerobic ponds
   - Responsible for the primary treatment of wastewater
   - Reduce the area requirement of further ponds
   - Rate of sludge accumulation is higher in the beginning
2. Facultative ponds
   - Classified on the basis of their position in treatment chain
   - Micro-algae constituting the wastewater impart a green color
   - Pink/ red – overloading; purple colored anaerobic sulphide oxidizing photosynthetic bacteria
   - Sulphide and ammonia toxicity inhibit algal growth
3. Maturation ponds
   - Receive pre-treated wastewater from facultative pond or any STP
   - Aerobic throughout the depth
   - 5 to 7 days detention time refines the quality of final effluent
   - Natural bacterial die-off; presence of predators (like fish or crustaceans)

Advantages of NTS

Economical

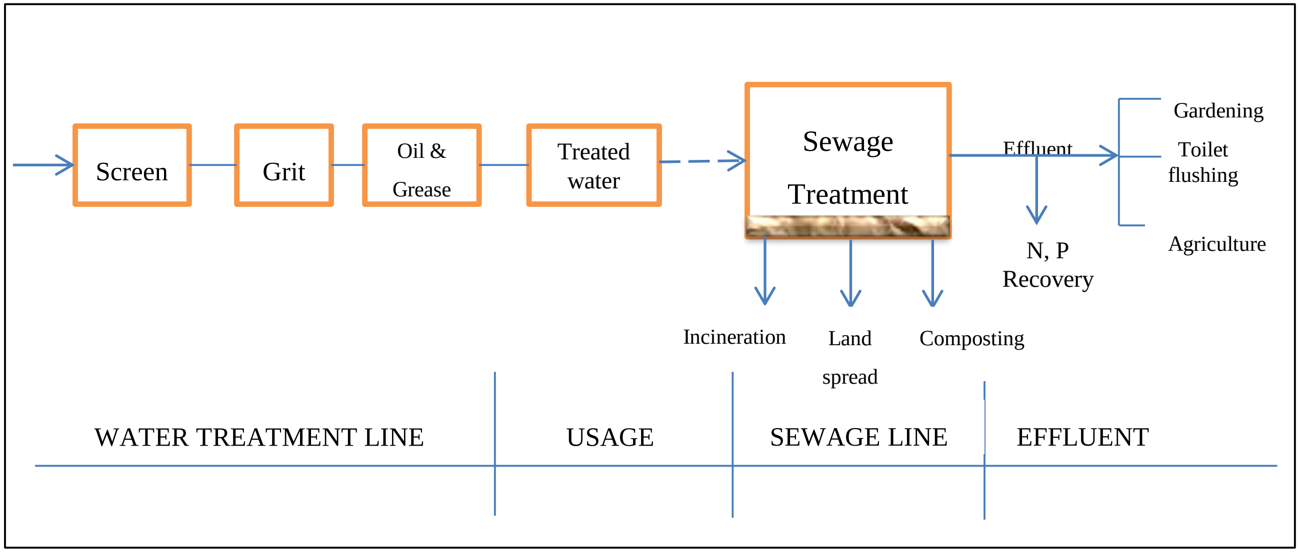
- Minimizes energy requirement
- Less expensive than the competitive mechanized treatment technologies
- Plants or flowers harvested might fetch revenue

Social

- Improve the aesthetics of the surroundings
- Recreation place where kids play and people can socialize
- Employment opportunities in rural and peri-urban areas

Recovery Aspects of NTS

- Significant resources getting lost to the environment
- Resource recovery from energy and nutrient streams can close the nutrient loops
- Wastewater and sludge – resource carriers
- Wastewater treatment facilities actually factories manufacturing resources in solid/ liquid/ gaseous forms



Water

Reuse for irrigation
Aquaculture/ fish farming

Materials

- Fertilisers
- Soil- conditioners
- Animal feeds
- Bio plastics

Energy

- Biofuels
- Biogas
- Methanol
- Ethanol
- Bio hydrogen

Thank You!

kalbar@iitb.ac.in

Questions!

FIT FOR PURPOSE TECHNOLOGIES FOR RECYCLE & REUSE OF WASTEWATER

Nature-Based or Mechanized Wastewater Treatment Technologies: Selection for 'Fit for Purpose' Application

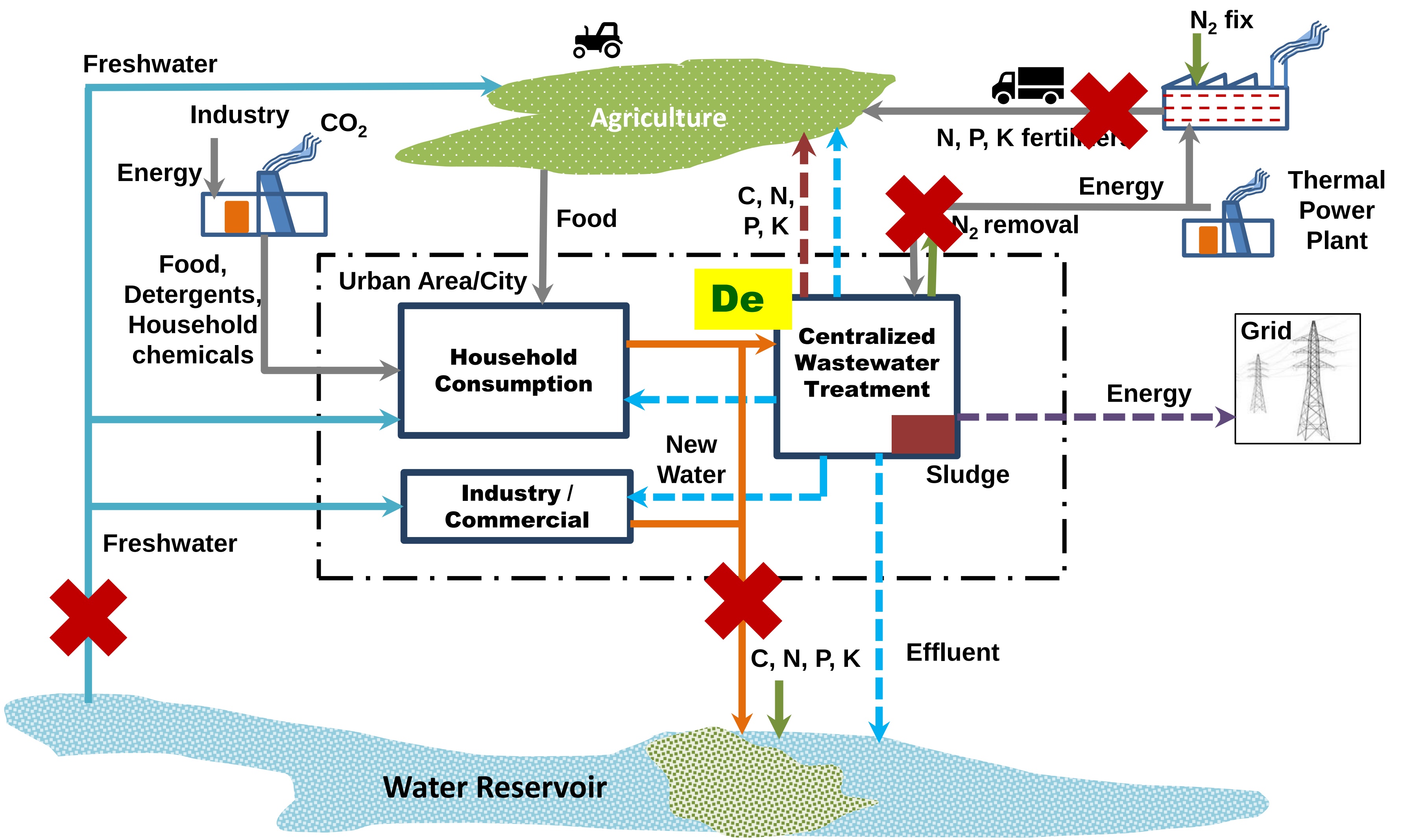
Dr. Pradip Kalbar
Associate Professor
Centre for Urban Science and Engineering (CUSE)
Indian Institute of Technology Bombay
Email: kalbar@iitb.ac.in
Tel. No. 022 2576 9330

11th Jan 2023

Centre for Urban Science and Engineering
Improving Quality of Urban Life
Indian Institute of Technology Bombay

Current Planning Approaches

What's wrong in current approach?



Current Planning Approach

The market for recycled water is ***ABSENT!***

- It is unknown who will consume the treated sewage unless there is a market for it!

Pricing issues

- Cost of recycled water is around Rs. 10 – 12 per m^3
- Freshwater tariff is meager Rs 3 to 6 per m^3 (with significant variations at a regional level)

Billing policies

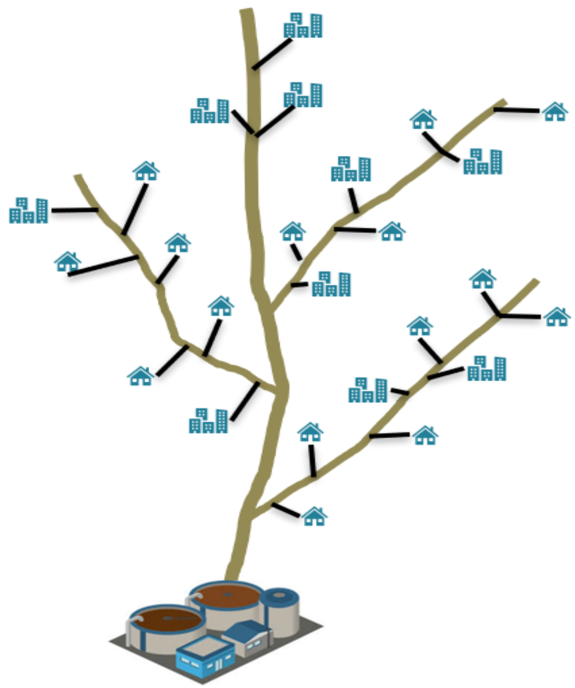
- Although the MCGM has a telescoping billing policy, many connections in island city are unmetered or most of the meters are dysfunctional
- Lack of appropriate guidelines for all stakeholders and bye-laws

Why recycling is not possible in the current context?

- Planners do not account land needed for wastewater treatment
- Infrastructure is planned with short-term benefits ex. Less capital cost
- Freshwater pricing is low to motivate people to adopt wastewater recycling

The Location!

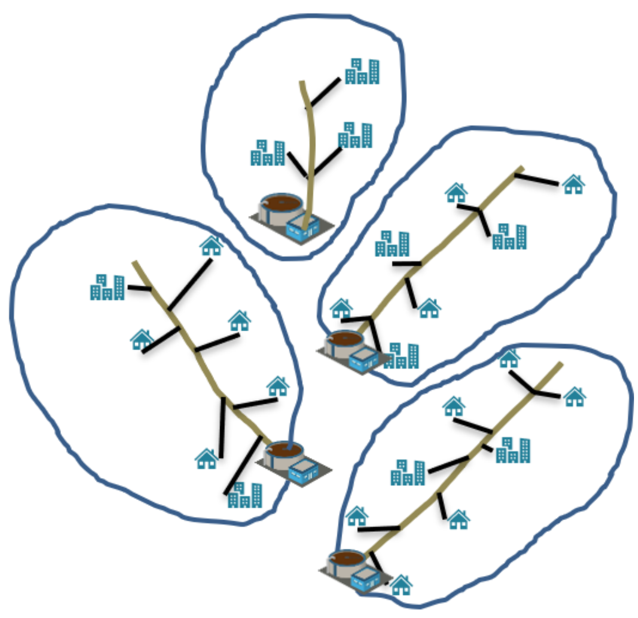
The problem:



- The planned recycling stations are highly centralized, at the fag end - which are currently planned around 400-500 MLD
- It will need a large secondary distribution network in mostly concreted roads already cramped with dozens of other utilities

The solution:

- Instead, decentralized recycling stations (about 50 MLD) may be more feasible in Mumbai's case, as these will create an opportunity for establishing a localized recycling network – about 40 satellite pumping stations
- Buildings can then have a second water connection from such localized recycled water networks.
- Modification in storage and internal distribution system in consumer premises



Technology Selection

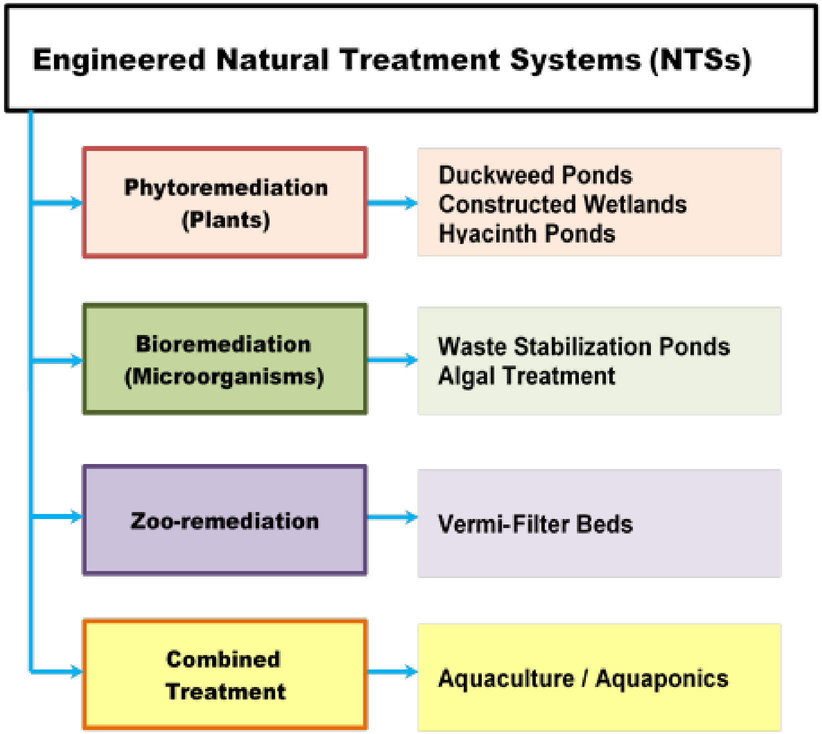
Challenges in Creating Sewage Infrastructure

- **Gap exists between sewage generation and wastewater treatment (WWT):** only around 44% of the wastewater generated is treated (ENVIS, 2021)

- **Mechanized Treatment Systems (MTSs)** have significant energy consumption resulting in high O&M costs.

- **Natural Treatment Systems (NTSs)** have potential of becoming sustainable infrastructure, but **not scaled up**.

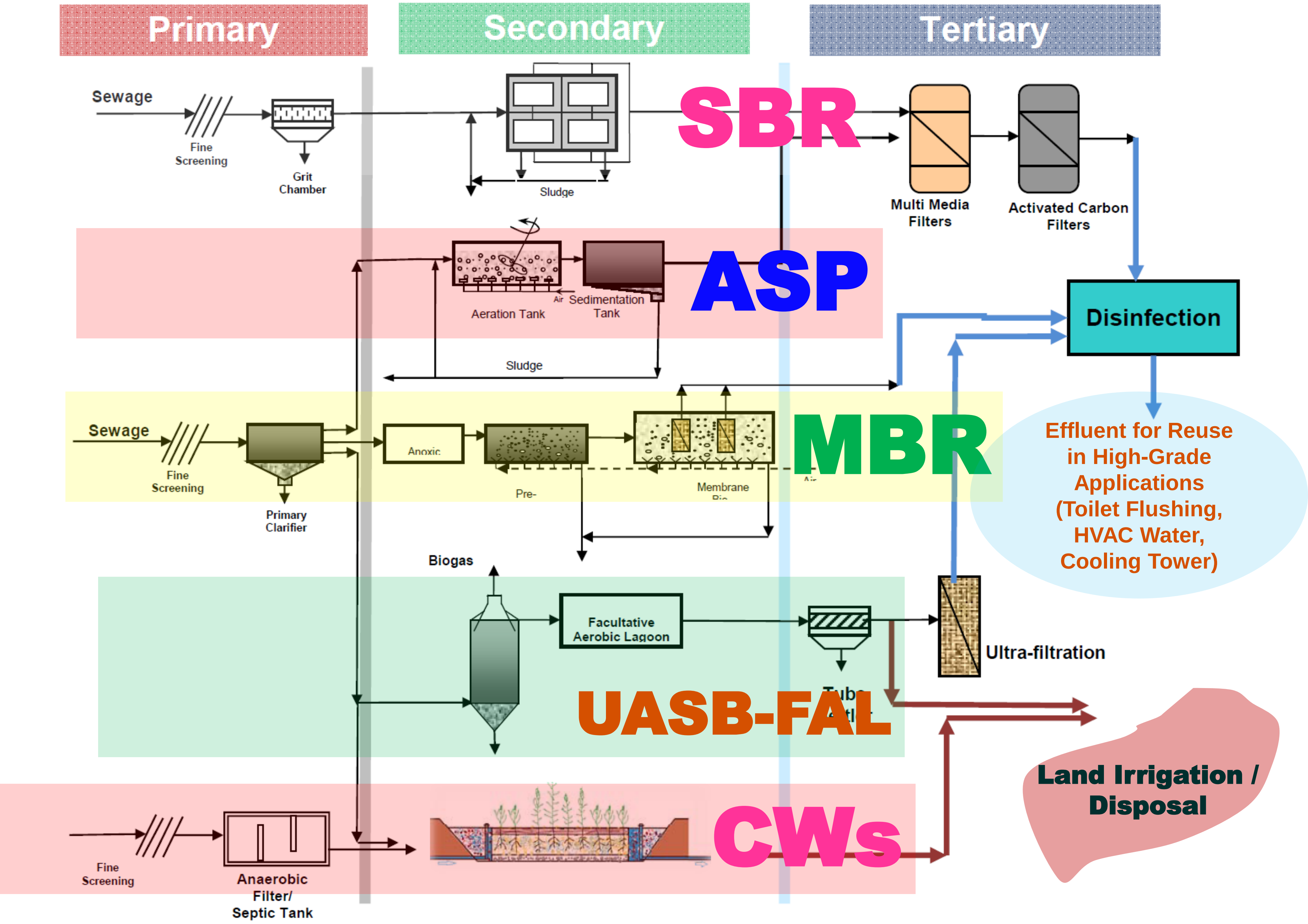
Classification of natural treatment systems



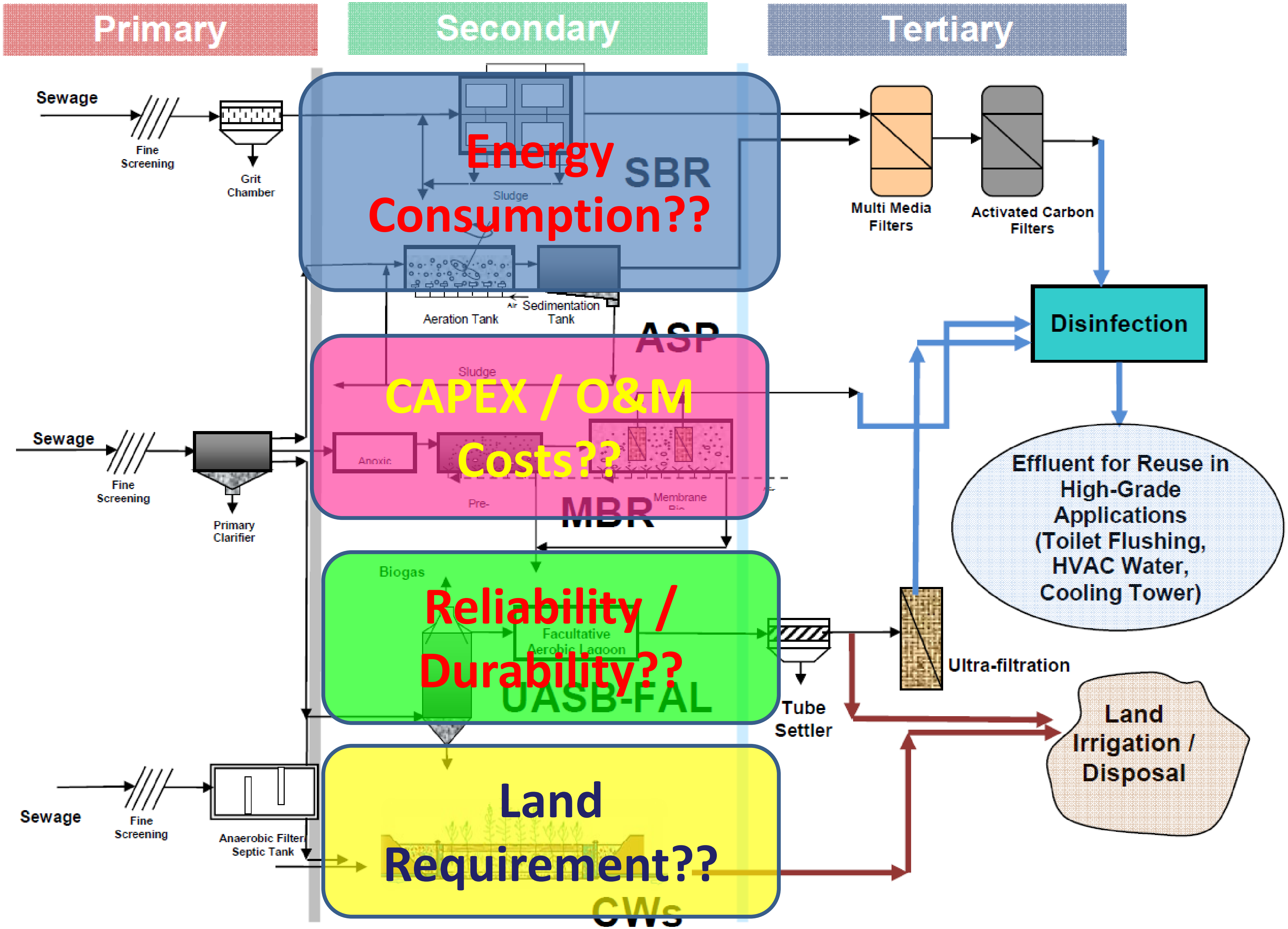
(Asolekar et al., 2014)

ENVIS (2021) Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology http://www.sulabhenvis.nic.in/database/stst_wastewater_2090.aspx. Accessed 15th July 2021

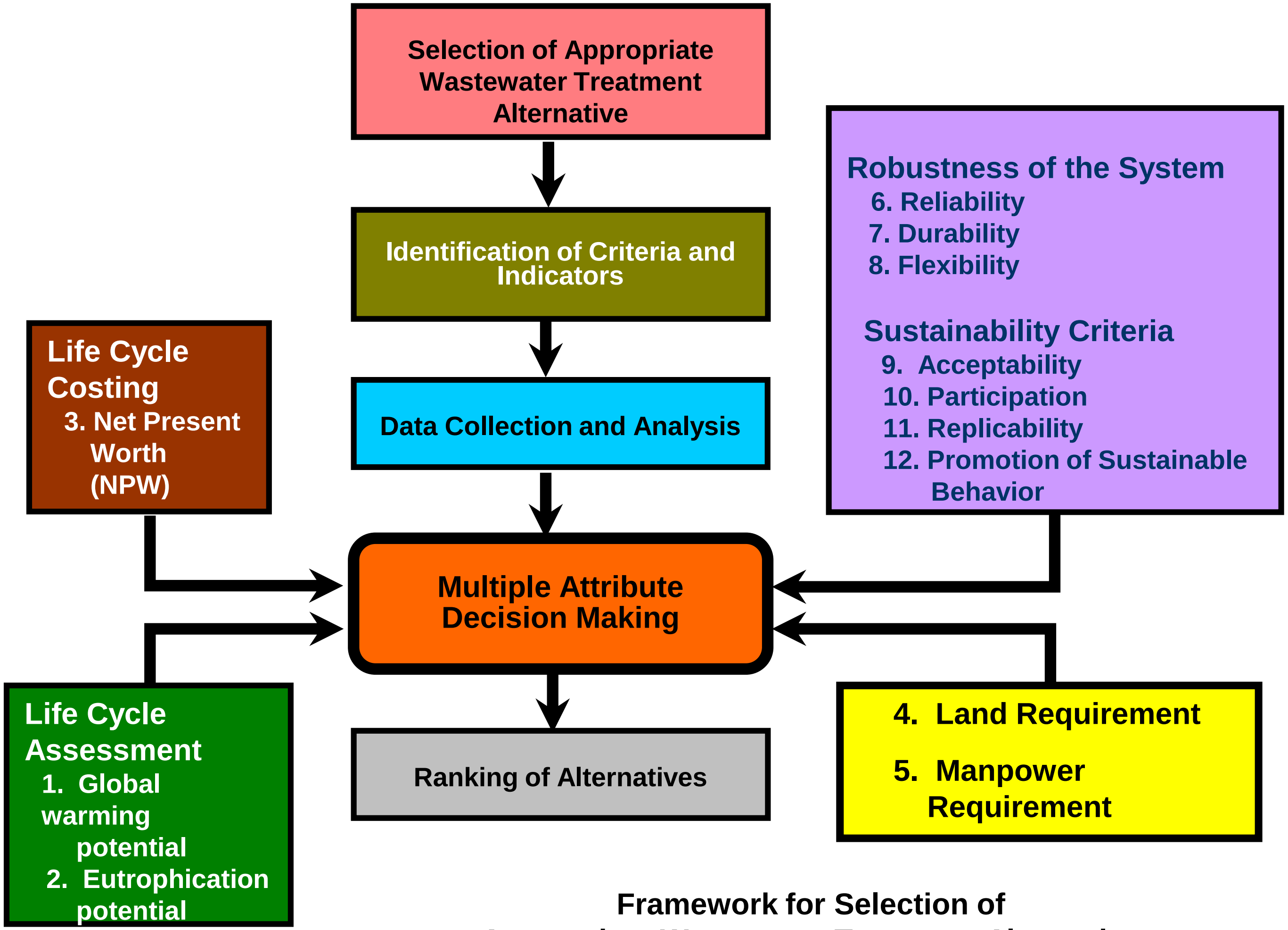
Asolekar SR, Kalbar PP, Chaturvedi MKM, Maillacheruvu KY (2014) Rejuvenation of Rivers and Lakes in India: Balancing Societal Priorities with Technological Possibilities. In: Comprehensive Water Quality and Purification. Elsevier, pp 181–229



Primary
Secondary
Tertiary
Sewage
Fine Screening
Grit Chamber
Sludge
SBR
Multi Media Filters
Activated Carbon Filters
Air
Aeration Tank
Sedimentation Tank
ASP
Disinfection
Sludge
Sewage
Fine Screening
Primary Clarifier
Anoxic
Pre-
Membrane
MBR
Effluent for Reuse in High-Grade Applications (Toilet Flushing, HVAC Water, Cooling Tower)
Biogas
Facultative Aerobic Lagoon
Ultra-filtration
UASB-FAL
Land Irrigation / Disposal
Fine Screening
Anaerobic Filter/ Septic Tank
CWs


Primary
Secondary
Tertiary
Sewage
Fine Screening
Grit Chamber
Energy Consumption??
SBR
Sludge
Aeration Tank
Sedimentation Tank
Multi Media Filters
Activated Carbon Filters
Disinfection
ASP
CAPEX / O&M Costs??
Sludge
Anoxic
Pre-
Membrane
MBR
Sewage
Fine Screening
Primary Clarifier
Effluent for Reuse in High-Grade Applications (Toilet Flushing, HVAC Water, Cooling Tower)
Biogas
Reliability / Durability??
Facultative Aerobic Lagoon
UASB-FAL
Tube Settler
Ultra-filtration
Land Irrigation / Disposal
Sewage
Fine Screening
Anaerobic Filter/ Septic Tank
Land Requirement??
CWs

Life Cycle Sustainability Assessment (LCSA)……..

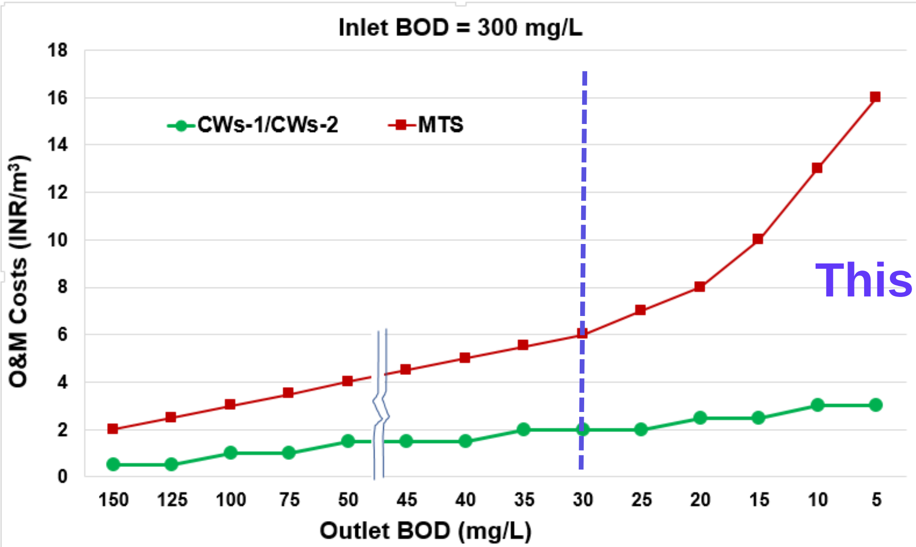


Framework for Selection of
Appropriate Wastewater Treatment Alternative

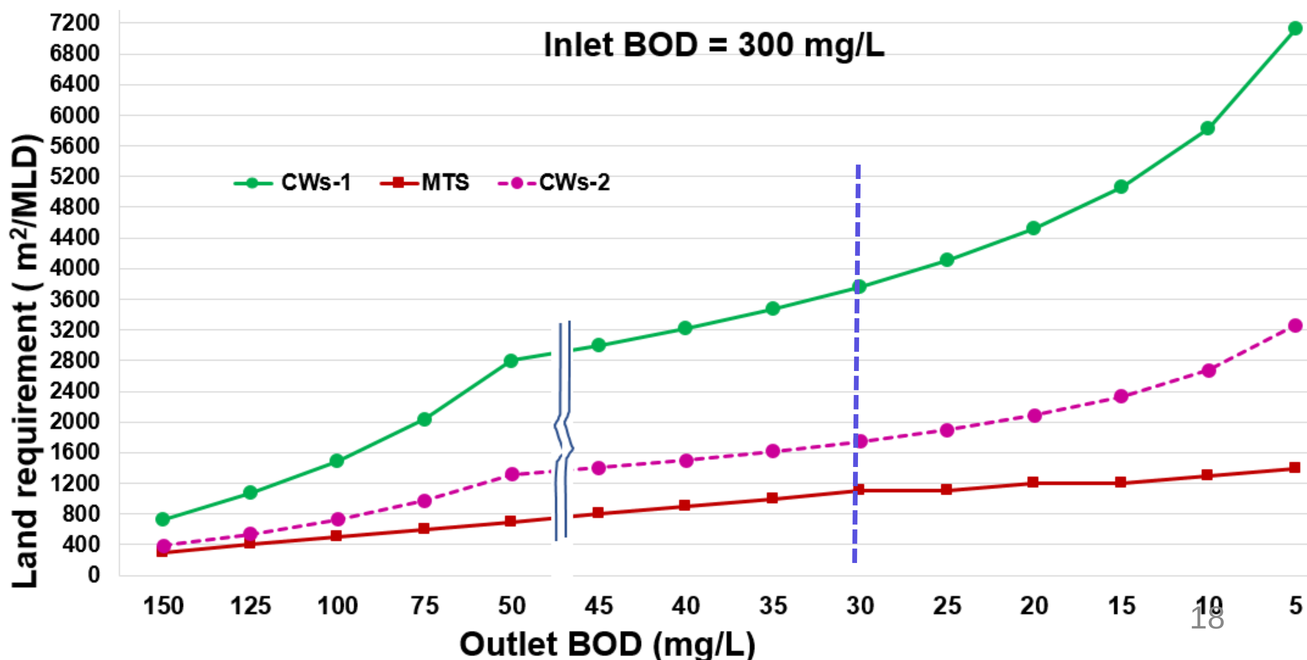
Kalbar, P. P., Karmakar, S., & Asolekar, S. R. (2012). Technology assessment for wastewater treatment using multiple-attribute decision-making. *Technology in Society*, *34*(4), 295-302.

Concept of Hybrid Treatment Systems and Scenario-Based Decision-Making

O&M Costs and Land Requirement Comparison



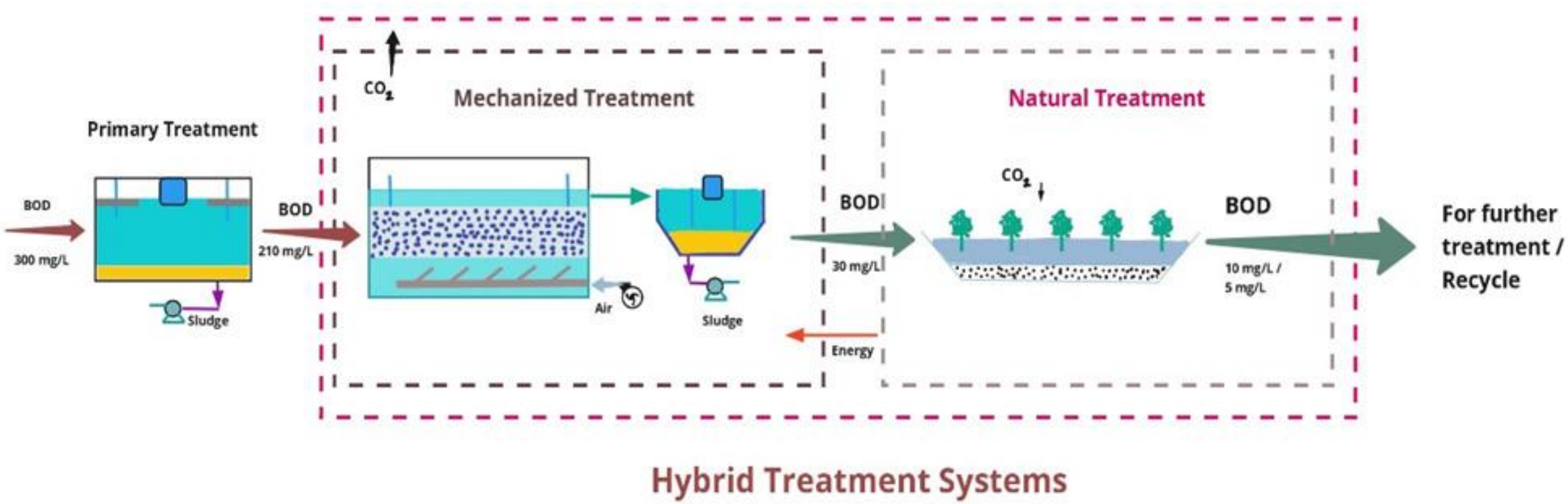
This shows at 30 mg/L we should shift to CWs!



Hybrid Treatment Systems (HTS)

HTSs is an appropriate combination of MTS and NTS to achieve **best performance at reduced overall cost**.

(Kalbar, 2021)



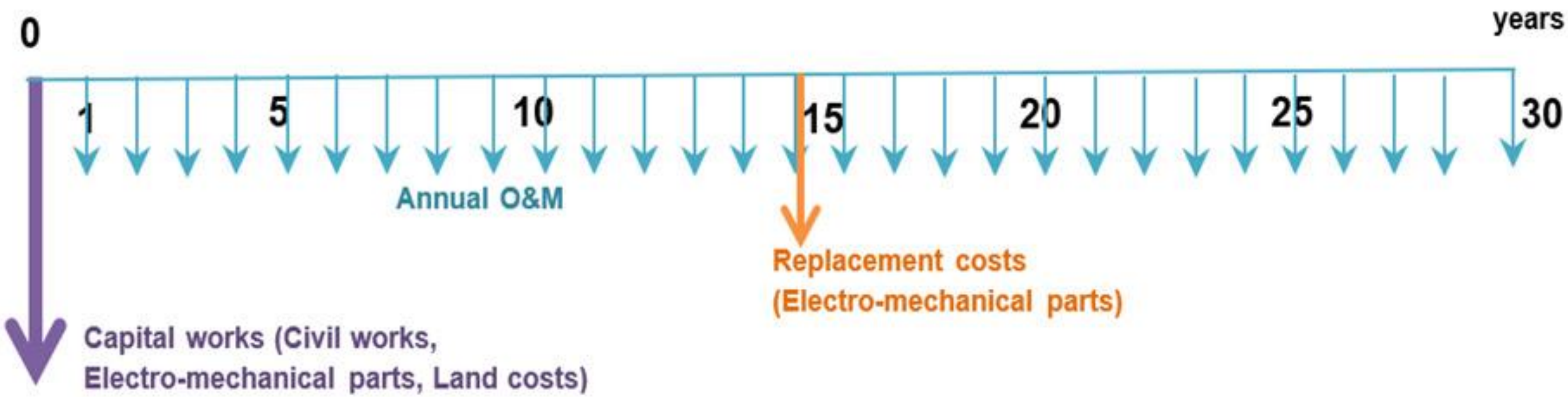
Hybrid Treatment System Approach

Kalbar, P.P. (2021) Hybrid treatment systems: a paradigm shift to achieve sustainable wastewater treatment and recycling in India. Clean Techn Environ Policy 23, 1365–1373. https://doi.org/10.1007/s10098-021-02034-x

Constructed Wetlands




Life Cycle Costing (LCC)



Cash flow diagram of WWTPs considered for LCC

Cost components

1. **Capital costs** (Civil works electro-mechanical works, Land requirement)
2. **Annual O&M costs** (labour, energy, chemicals, maintenance)
3. **Replacement costs**

Present worth method

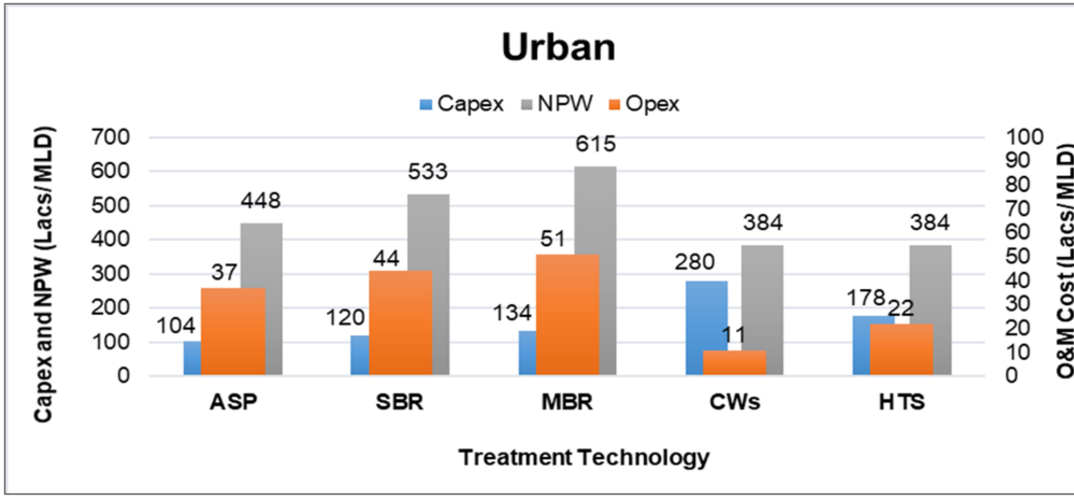
$$P = \frac{F}{(i+i)^n} = F\ (P/F,\ i,\ n)$$

$$P = \frac{A(1+i)^n - 1}{i(1+i)^n} = A(\ P/A,\ i,\ n)$$

Cost Effective Treatment Systems in Different Scenarios

Land cost used = INR 1.6 cr/ acre

Cost Comparision for BOD removal up to 10 mg/L		Capital Costs	Annual O&M Costs	Net Present Worth (30 yrs)
		Rs. Lacs/MLD	Rs. Lacs/MLD	Rs. Lacs/MLD
Urban	ASP	104	37	448
	SBR	120	44	533
	MBR	134	51	615
	CWs	280	11	384
	HTS	178	22	384
Peri-urban	ASP	91	37	435
	SBR	109	44	522
	MBR	126	51	607
	CWs	200	11	304
	HTS	136	22	342
Rural	ASP	84	37	428
	SBR	104	44	517
	MBR	122	51	603
	CWs	160	11	264
	HTS	115	22	321



- In the economic evaluation of the treatment technologies, **O&M costs play a significant role** and not the capital costs.

This analysis shows that in any setting it is wise to invest in land and adopt natural treatment systems rather than paying huge monthly energy bills--- ***which will help achieve both sustainability and resilience!***

Scenario Based Decision Making

Indicators	Scenario I		Scenario II		Scenario III		Scenario IV		Scenario V		Scenario VI	
	Urban Area / Land Constraint / Disposal to Surface Water Body		Urban Area / Land Constraint / Treated Water for Reuse		Sub-urban Area / No Land Constraint / Disposal to Surface Water Body		Sub-urban Area / No Land Constraint / Treated Water for Reuse		Rural Area / No Land Constraint / Disposal to Surface Water Body		Rural Area / No Land Constraint / Treated Water for Reuse	
	Weight[a]	Type of criteria	Weight[a]	Type of criteria	Weight[a]	Type of criteria	Weight[a]	Type of criteria	Weight[a]	Type of criteria	Weight[a]	Type of criteria
Global warming potential (kg)	**20**	cost	**20**	cost	**20**	cost	**20**	cost	**20**	cost	**20**	cost
Eutrophication potential (kg)	**20**	cost	**80**	cost	**30**	cost	**80**	cost	**30**	cost	**80**	cost
Net Present Worth (Rs. Lakh)	**20**	cost	**20**	cost	**60**	cost	**60**	cost	**90**	cost	**90**	cost
Land requirement (m^2)	**80**	cost	**80**	cost	**40**	benefit	**40**	benefit	**80**	benefit	**80**	benefit
Number	**10**	cost	**10**	cost	**40**	benefit	**40**	benefit	**80**	benefit	**80**	benefit
Reliability	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit
Durability	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit
Flexibility/Adaptability	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit	**40**	benefit
Acceptability/Simplicity	**10**	benefit	**10**	benefit	**30**	benefit	**30**	benefit	**80**	benefit	**80**	benefit
Participation/Responsibility	**10**	benefit	**10**	benefit	**30**	benefit	**30**	benefit	**80**	benefit	**80**	benefit
Replicability	**20**	benefit	**20**	benefit	**40**	benefit	**40**	benefit	**80**	benefit	**80**	benefit
Promotion of Sustainable behavior	**10**	benefit	**10**	benefit	**40**	benefit	**40**	benefit	**80**	benefit	**80**	benefit

Relative distance metric for each scenario and rank of each alternative in particular scenario

ALT	No Scenario		Scenario I		Scenario II		Scenario III		Scenario IV		Scenario V		Scenario VI	
	Equal Weights to Indicators		Urban Area / Land Constraint / Disposal to Surface Water Body		Urban Area / Land Constraint / Treated Water for Reuse		Sub-urban Area / No Land Constraint / Disposal to Surface Water Body		Sub-urban Area / No Land Constraint / Treated Water for Reuse		Rural Area / No Land Constraint / Disposal to Surface Water Body		Rural Area / No Land Constraint / Treated Water for Reuse	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
ASP	0.5066	4	0.7857	1	0.7081	2	0.4277	3	0.4355	3	0.3244	3	0.3359	4
SBR	0.5087	2	0.7789	2	0.8017	1	0.3715	4	0.4910	2	0.2686	4	0.3445	3
UASB-FAL	0.5083	3	0.7404	3	0.5816	3	0.4452	2	0.3754	4	0.4228	2	0.3982	2
CWs	0.5271	1	0.2127	4	0.2822	4	0.5506	1	0.5501	1	0.6262	1	0.6214	1

Fit for Purpose Applications

Correct Planning Approach

Criteria:

- Land availability?
  - Mechanized treatment comes with lower footprint at an energy cost
  - Natural treatment comes at a lower energy but at the cost of land
- Resource availability
  - Whether electricity is available 24x7 or not?
  - What is the level of skilled labour available for employment?
- Physical touch with treated effluent during recycling?
  - Irrigation and landscaping involves human touch with sewage hence has potential health risk associated with it
- Need for nutrient removal?
  - Stringent – if disposal in water bodies
  - Lenient – for agriculture or gardening or landscaping

Eutrophication

Powai lake

Eutrophic stretch of Upper Ganga Canal

Eutrophic stretch of river Yamuna

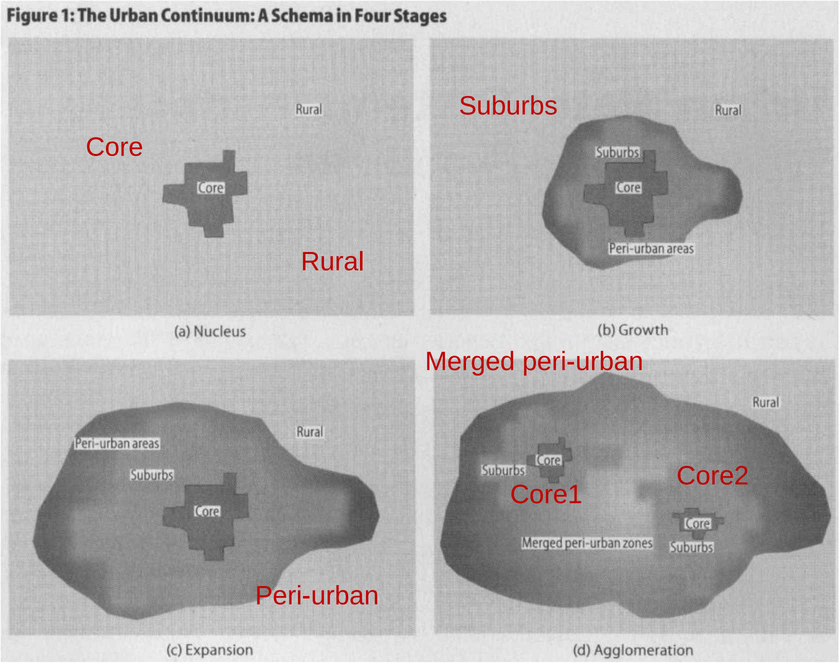
Plan for timely removal of nutrients to prevent eutrophication in water bodies!

The Upper Ganga Canal

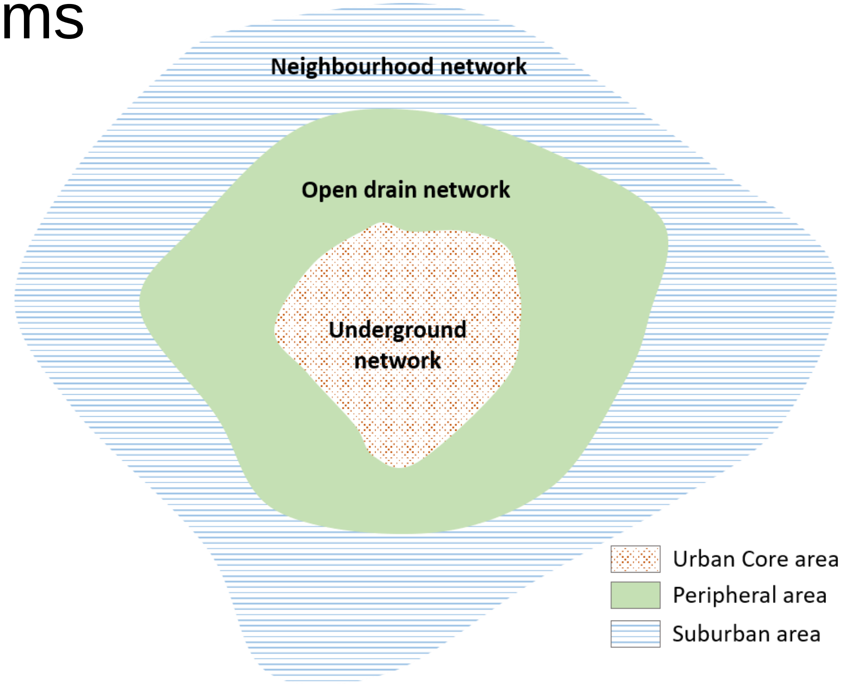
HTS Approach		Treatment System used For BOD removal up to 30 mg/L	Treatment System used For BOD removal up to 10 mg/L	Treatment System used For BOD removal up to 5 mg/L	Usefulness in Different Settings
HTS -1		MTS	MTS + Shallow Bed CWs	MTS + Shallow Bed CWs	This approach is more suitable for rural and peri-urban setting both in centralized and decentralized manner where sufficient land is available. This approach can be used in cities as well where STPs are located at the outskirts of the city.
	Land requirement (m^2) per MLD	1100	3166	4469	
	O&M costs (INR/m^3)	6	7	7	
HTS -2		MTS	MTS + Deep Bed CWs	MTS + Deep Bed CWs	This approach is more suitable in peri-urban and urban setting both in centralized and decentralized manner where there is a land constraint.
	Land requirement (m^2) per MLD	1100	2029	2616	
	O&M costs (INR/m^3)	6	7	7	

Context of Decision-Making

- In the city core or the dense urban areas, mechanized treatment systems such as MBR, SBR, ASP
- Peri-urban areas R-MBR/ ASP or NTS if land permits
- Rural areas with less dense population – decentralized or on-site treatment systems



Shah and Kulkarni, 2015



Sood et al., (2021, October) Economic assessment of centralized and decentralized sewerage network systems. 15th International Conference on Urban Drainage, Melbourne.

Thank You!

kalbar@iitb.ac.in

Questions!

Wastewater Technology Selection Parameters for Recycle and Reuse of Wastewater

Dr. Ajit Salvi,

Dy.Ch.Engineer,

BMC

Challenges in Wastewater Sector

Biggest problem in India??

All want visible development like roads, Metro, hospitals etc

- Wastewater receives low priority…
- From citizens, politicians, urban local bodies

Because *Sewerage Infrastructure* does not qualify as visible development!

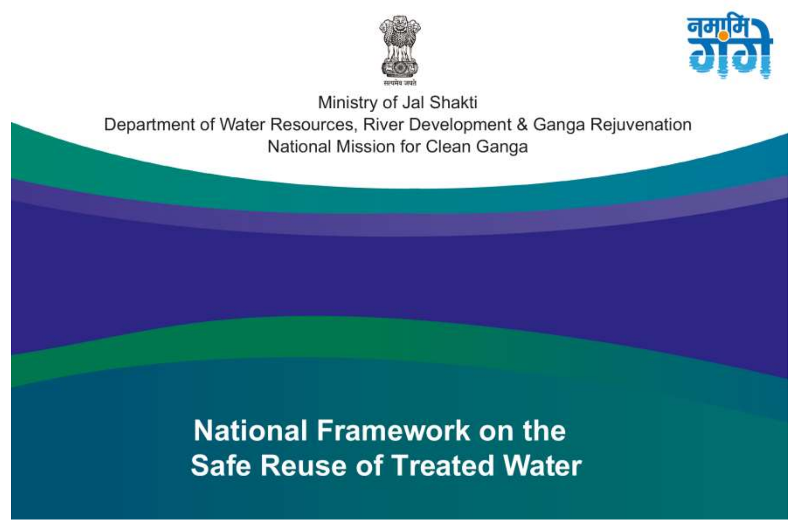
- People are less willing to pay for Sewage management.

Revenue generation by urban local bodies for sewerage infrastructure is a challenge.

Need for Wastewater Recycling

- Amidst freshwater scarcity, ***sewage*** is seen as a ***resource*** and STP's are factories manufacturing water and nutrients!
- Policies mandating wastewater recycling
- High-rise buildings and industries need to treat their own sewage and effluents

National Framework on the Safe Reuse of Treated Water encourages urban local bodies to plan for wastewater reuse and recycling….hence wastewater recycling is ***THE WAY AHEAD!***



Waste Water , Environment, Health

- **Contamination of Water**
- **Dirty Surrounding**
- **Breeding of Flies, Mosquitoes, Vectors etc.**

Thought Process of Public

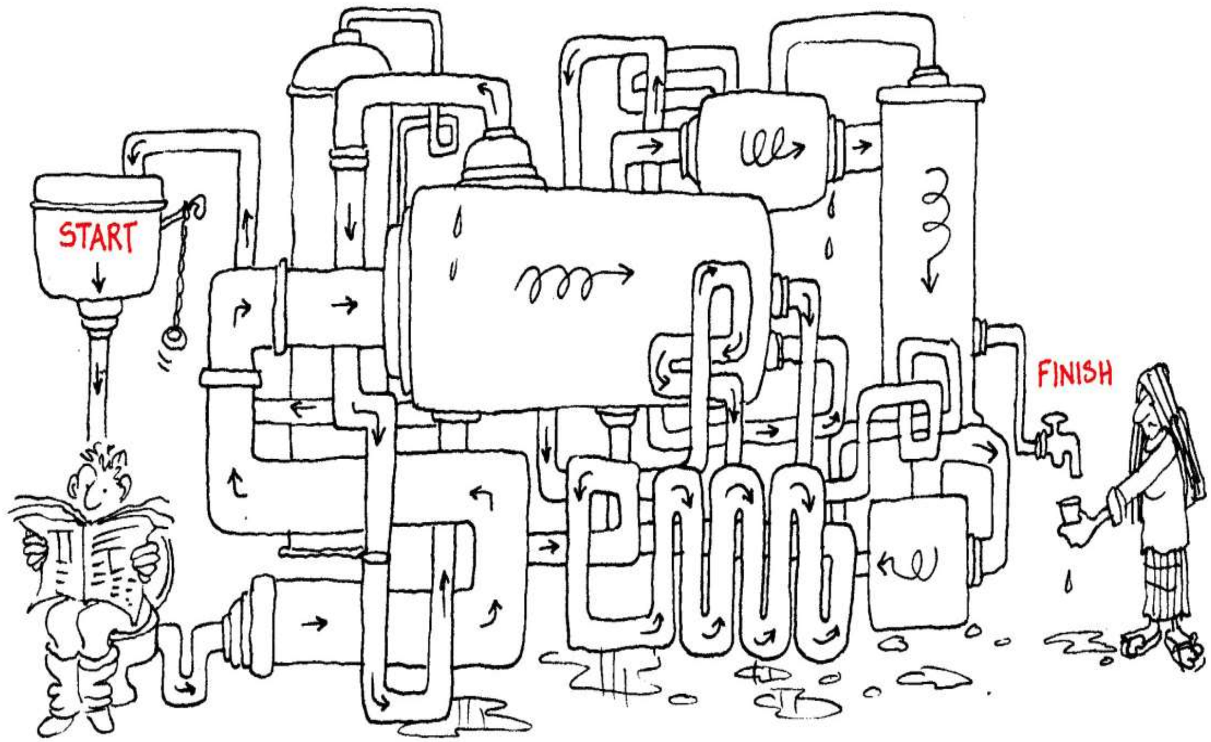
Urban Areas are new users of water

'Take, flush and forget'

A paradigm that must change, urgently

Cannot flush – and forget

Have to find new approaches : **Affordable and Sustainable**



REVOLUTION – CHANGE IN MINDSET

Ways to address: Paradigm shift

- From sewage treatment to Sewage Reuse and Recycling
- From Waste Management to Resource Recovery
- Emphasize that Waste Water is a Resource (in terms of Water, Nutrients for agricultural use and Energy) whose effective management is essential for Future Water Security.
- Decentralised Waste Water Treatment Option
- From Linear Economy to Cicular Economy

Plethora of Technologies

- Activated sludge process (ASP)
- Trickling filter (TF)
- Sequencing batch reactor (SBR)
- Rotating biological contractors (RBC)
- Aerated lagoons (AL)

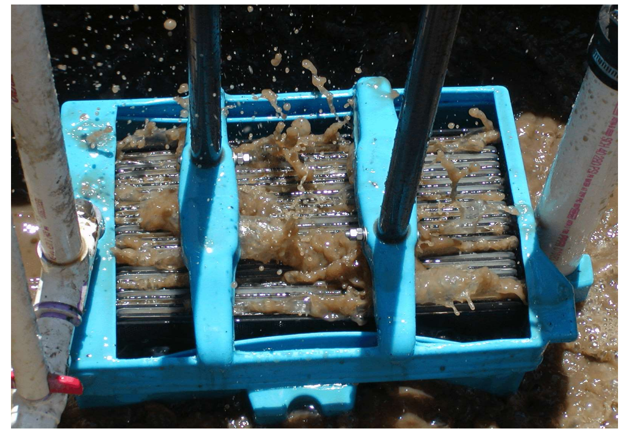
Mechanized treatment technologies (aeration/ energy needed)

- Constructed wetlands (CW)
- Waste Stabilization ponds (WSP)
- Duckweed ponds (DP)

Natural treatment technologies

Mechanized treatment technologies

Activated sludge process

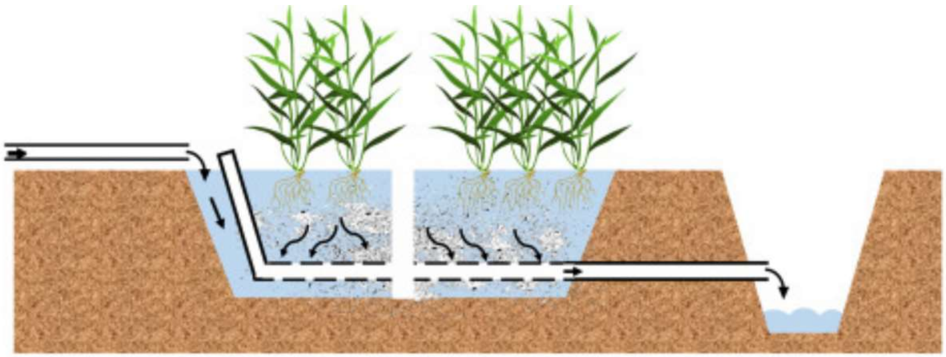


Membrane bioreactors

Extended aeration

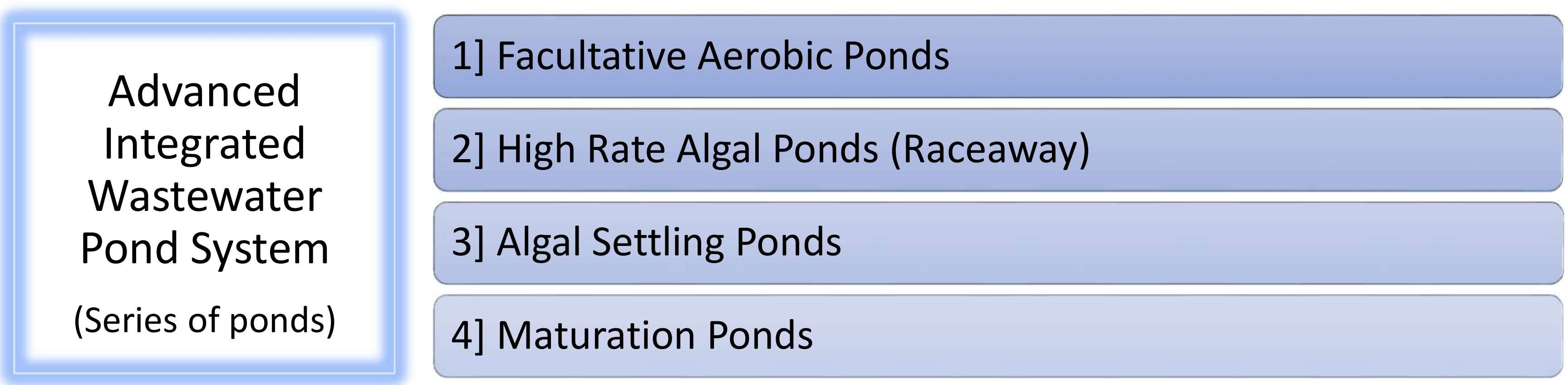
Trickling filters

Nature-based technologies



Constructed wetlands/ reed beds/ root zone technology

Duckweed ponds



Source: [a]Singh et al., 2022

Technology Selection

Before jumping to technology, '**approach**' of wastewater management is important

What is the end use of water?

Who is the client?

Are there any recycling opportunities?

Who will fund the sewage treatment?

Who will operate the system?

Will the effluent meet recycling norms?

Decision support:

Wastewater treatment classification needs to be understood by government officials and decision-makers

Water Reuse

- Agricultural Irrigation
- Landscape Irrigation
- Industrial Activities
- Ground Water aquifer recharge
- Other Non-potable urban use – Fire protection, Air Conditioning, Car Washing, Flushing, Construction.
- Potable use – Blending in water supply storage reservoir

Parameters of Concern for Reuse

Sr. No.	Reuse Applications	Parameters of Concern
1	Agricultural Irrigation	Fecal coliform
2	Reservoir Recharge	Nitrogen, Phosphorous, Drinking water standards
3	Groundwater Recharge	Nitrogen, Drinking water standards
4	Domestic non-potable	Turbidity, Fecal coliform, Total Residual chlorides

Performance Efficiencies of Wastewater Treatment Technologies

S. No	Technology	Source/Reference	Removal (%)				
			BOD	COD	TSS	TN	FC
Secondary treatment technologies							
1	ASP	(Tare and Bose 2009; CPCB 2013)	78.37	84.09	87.76	10.00	90.02
2	MBBR		66.86	56.57	71.43	10.00	99.12
3	SBR		95.50	90.00	95.67	75.00	99.99
4	WSP		35.14	46.43	30.00	34.43	99.99
5	DPS		66.86	56.57	71.43	37.80	30.00
6	A2O	(CPHEEO 2013)	98.83	91.06	98.92	76.91	99.87
7	UASB + EA	(CPCB 2013; Vashi et al. 2019)	82.19	90.00	85.15	10.00	90.00
8	MBR	(Tare and Bose 2009; Ajmi et al. 2018)	97.60	96.50	95.00	60.00	99.99
9	Anaerobic lagoon + SP	(CPCB 2013)	70.00	51.33	70.00	10.00	90.00
10	SAFF	(Tare and Bose 2009)	96.67	87.50	76.40	10.00	99.99
11	BIOFOR-F		97.00	95.40	92.00	70.00	99.99
12	FAB		47.95	74.4	88.79	10.00	90.00
13	BIOFOR	(Tare and Bose 2009; Sharma and Singh 2013)	95.20	93.40	90.00	70.00	99.99
14	Oxidation Pond	(CPCB 2013)	66.89	51.25	71.08	10.00	99.39
15	C.Tech		96.00	97.64	81.60	80.00	99.99
16	Trickling Filter		71.43	64.66	88.31	10.00	90.00
17	Constructed Wetlands (CW)	(Ramachandra et al. 2017; Thalla et al. 2019)	77.00	60.00	90.00	67.00	78.21
18	SBT	(Stefan et al. 2017)	80.99	83.13	71.92	70.00	99.99
Emerging technologies							
19	Modified Ludzack Ettinger (MLE)	(CPHEEO 2013)	0	0	0	75.5	90.00
20	Wuhrmann Process (WP)		0	0	0	81.25	90.00
21	Step-Feed BNR		0	0	0	62.50	90.00
22	Bardenpho Process		97.30	0	99.40	88.90	90.00
Tertiary treatment technologies							
23	Coagulation + Flocculation + Rapid Sand Filters (RSF)	(Hamoda et al. 2004; Üstün et al. 2011)	65.00	53.34	52.14	30.00	80.00
24	Ultrafiltration (UF) + Reverse Osmosis (RO)	(Pizzichini and Russo 2001)	72.79	60.97	85.00	94.00	99.99
25	Micro Filtration (MF) + Reverse Osmosis (RO)		41.27	24.19	85.06	92.24	99.99

Quality Criteria for Various Reuse Applications

S.No	Desired reuse	Source	pH	Turbidity (NTU)	COD (mg/l)	BOD (mg/l)	TDS (mg/l)	TSS (mg/l)	TN (mg/l)	FC (MPN/l)
1	Toilet flushing	(Asano et al. 1996; Lazarova et al. 2003; Lyu et al. 2016)	6–9	5	–	10	1500	10	10	200
2	Construction purposes	(Asano et al. 1996; Adewumi and Oguntuase 2016; Chen et al. 2017)	6–9	20	–	15	1500	10	20	200
3	Road cleaning	(Shuval 1977; Lyu et al. 2016; Chen et al. 2017)	6–9	10	–	15	1500	10	10	200
4	Landscape	(Coe and Laverty 1972; DeCook 1977; Smith et al. 1979; Adewumi and Oguntuase 2016)	6–9	5	–	20	1000	10	20	2000
5	Industrial cooling	(DeCook 1977; Asano et al. 1996; Lyu et al. 2016; Chen et al. 2017)	6.5–8.5	5	30	10	1000	10	10	2000
6	Irrigation	(Asano et al. 1996; Adewumi and Oguntuase 2016; Chen et al. 2017)	5.5–8.5	–	100	40	1000	10	–	20,000
7	Vehicle washing	(Zaneti et al. 2012; Pei et al. 2013; Lyu et al. 2016; Chen et al. 2017)	6–9	5	–	10	1000	20	10	2000
8	*Environmental flow*									
a	Inland surface water	(CPHEEO 2013)	6.5–9	–	250	30	–	100	100	10,000
b	Surface waters used as a source of drinking water		6.5–8.5	–	–	10	–	10	10	2300
9	Fire protection	(Shuval 1977; Okun 2002; Lyu et al. 2016)	6–9	10	–	15	1500	10	10	200
10	Laundry washing	(Japan Sewage Works 1993; Tamanna et al. 2011; Adewumi and Oguntuase 2016)	6–9	2	–	10	2000	10	–	250
11	Dust control	(California Guidelines 1994; Lyu et al. 2016)	6–9	20	–	15	1500	10	20	200
12	Snow making	(California Guidelines 1994; Asano et al. 1996)	6–9	10	–	15	1500	10	10	22
13	Outdoor bathing	(BIS 1992)	6.5–8.5	–	–	3	–	10	10	5000
14	Groundwater recharge	(Smith et al. 1979; Idelovitch et al. 1980; Adewumi and Oguntuase 2016)	6.5–8.5	2	10	5	50		1	1

Technology Selection Criteria

- Numerous criteria listed in literature for selecting a particular technology
- Criteria changes with respect to location and context of decision-making
- Not practically possible to account for all but few important criteria for consideration are:

Space requirement

Capital cost

Operation & Maintenance

Energy requirement

Sludge management

Sustainability

Space requirement

- Mechanized and natural treatment systems mainly differ in space requirement
- Mechanized treatment – less footprint hence most favourable option in urban areas or in places where land constraints (Ex. ASP, SBR, MBR)
- Natural treatment – more footprint so generally avoided due to increased land costs (Ex. CW, WSP)

Urban areas → Mechanized treatment

Rural areas → Natural treatment

Capital cost

- Capital cost includes land cost, construction cost, material purchase cost, electro-mechanical equipment, consultancy fees (STP design), contractor’s profit etc.
- Capital cost often becomes the governing criteria for decision-making
- In the case of wastewater recycling and reuse, ***‘redistribution network’*** for conveying treated effluent to the point-of-reuse will also need to be accounted

Operation and Maintenance

- O&M cost includes
  - Cost of spares, consumables, material
  - Manpower (skilled or unskilled technicians, lab staff, technical assistants for sampling etc.)
  - Chemicals needed for routine Operation
- O&M cost component is often excluded in planning and decision-making. However, if treated wastewater is to be recycled, then ***maintaining effluent quality is of utmost importance***
- O&M on a regular basis will ensure sustenance of the STP hence ***O&M cannot be neglected*** while recycling wastewater

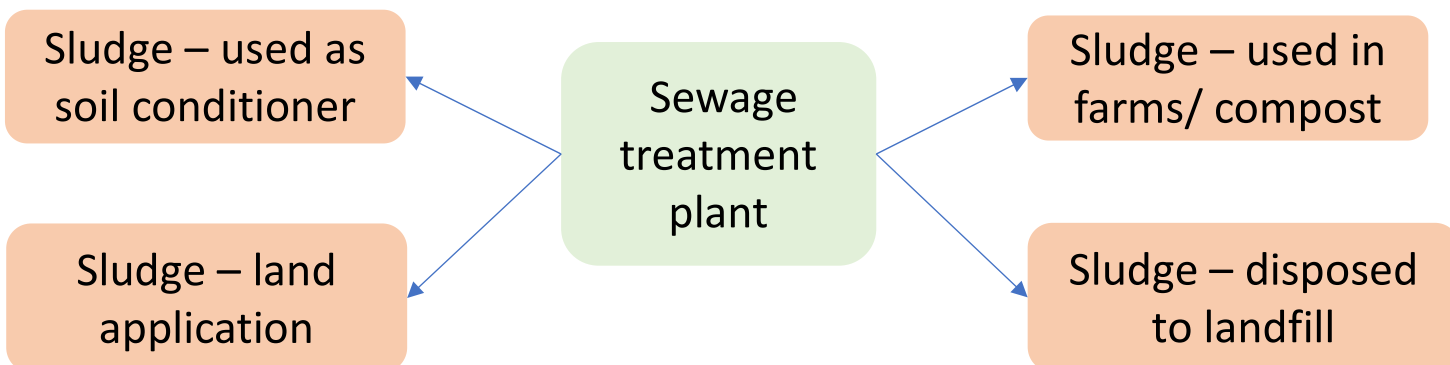
Energy requirement

- Mechanized treatment technologies such as ASP, SBR, MBR etc. are energy consuming
- 50-60% operational costs are associated with energy mainly for aeration and pumping
- Nature-based systems such as CWs, WSPs do not have aeration hence reduce energy requirement

- For wastewater recycling, if mechanized treatment is used, the revenue from recycled water should be ensured to keep the STP running in the future
- Availability of electricity should be ensured while opting for mechanized treatment systems
- CWs and WSPs or duckweed ponds are low-energy consuming technologies which should be prioritized for recycling

Sludge management

- Biological treatment such as activated sludge process involves secondary settling tanks hence sludge management (or biosolids handling) becomes significant
- Desludging on a regular basis is important
- Class A & Class B sludge
- Providing a market for sludge for ex. Reuse in agriculture or use as compost/ soil conditioner should be explored



Sustainability

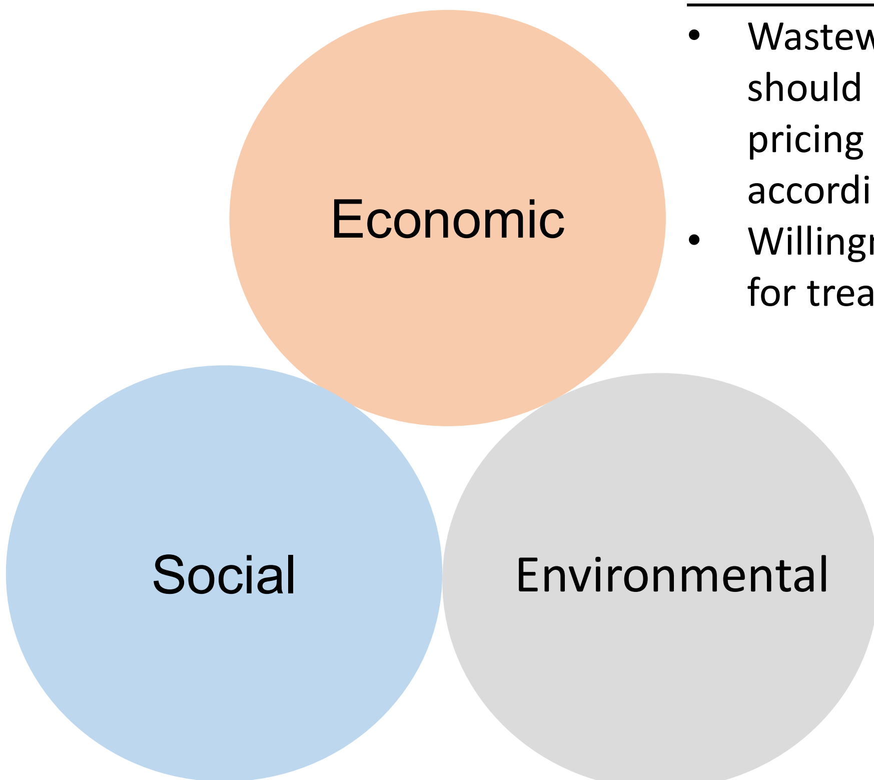
Pillars of sustainability:

Economic dimension:

- Wastewater treatment technologies should be financially viable – water pricing should be planned accordingly
- Willingness surveys of clients to pay for treated wastewater

Social dimension:

- Technologies should be accepted by the local community
- Local people should have opportunities to operate and manage the STPs
- There should not be any nuisance of odour or noise



Environmental dimension:

- Technologies should remove nutrients and pathogens to meet recycling norms
- Effluent disposed in rivers should not cause eutrophication

Techno Commercial Evaluation

A. Non Cost Factors.

1. Constructability –

- Ease of construction
- Depth of excavation / Total height of structure
- Number of units required

2. Operation & Maintenance -

- Sludge Quantity
- Skill Requirement / Ease of O &M
- Past Experience

3. Reliability of Plant Performance

- Past Experience in terms of size of operating Plant
- Reliability of performance

4. Environmental

- Odour & Noise pollution
- Explosion hazard
- Health & Safety

B. Cost Factors

1. Capital Cost
2. Operation & Maintenance Cost
3. Cost Recovery
4. Life Cycle Cost

Technology Comparison- Monetary terms for Core Technology-0.5 MLD

Sr. No.	Parameters	Tiger Bio Filter	Phytorid	Soil Imbolized Bio Filter	Soil Bio Technology	Stabilization pond	Activated Sludge Process	Moving Bed Bio Reactor	Membrane Bio Reactor	Extended Aeration	Submerged Aerobic Fixed Film Reactor	Sequential Batch Reactor
(I)	**Capital Cost**											
	Land Cost (Rs. Lac / Ha)						12.50					
1	Area requirement (Hactare)	**0.05**	**0.08**	**0.18**	**0.13**	**0.60**	**0.03**	**0.05**	**0.03**	**0.06**	**0.04**	**0.05**
2	Land Cost (Rs. Lac)	0.63	1.00	2.25	1.63	7.50	0.38	0.63	0.31	0.69	0.47	0.56
3	Unit capital cost (Secondary treatment)	53.69	58.16	86.00	58.91	46.43	85.00	122.54	143.18	127.68	134.13	118.79
4	Unit capital cost (Tertiary treatment)	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
5	Total capital cost (Secondary+Tertiary)	68.69	73.16	101.00	73.91	61.43	100.00	137.54	158.18	142.68	149.13	133.79
6	Total Land + Capital Cost (Rs.Lac)	69.32	74.16	103.25	75.54	68.93	100.38	138.16	158.49	143.36	149.59	134.35
	SUB TOTAL	**69.32**	**74.16**	**103.25**	**75.54**	**68.93**	**100.38**	**138.16**	**158.49**	**143.36**	**149.59**	**134.35**

Technology Comparison- Monetary terms

Sr. No.	Parameters	Tiger Bio Filter	Phytorid	Soil Imbolized Bio Filter	Soil Bio Technology	Stabilization pond	Activated Sludge Process	Moving Bed Bio Reactor	Membrane Bio Reactor	Extended Aeration	Submerged Aerobic Fixed Film Reactor	Sequencial Batch Reactor
(II)	**Operating Costs**											
a.	Gross Operating Costs											
1	Power cost (Rs./m3)	0.43	0.61	0.81	1.22	0.29	2.65	2.18	2.15	2.12	2.16	2.07
2	Chemical (Rs./m3)	0.20	1.00	0.70	0.70	0.10	0.10	0.20	0.20	0.20	0.20	0.20
3	Manpower (Rs./m3)	2.40	2.40	2.40	2.40	1.33	4.67	4.56	5.29	4.12	4.35	4.26
4	Residual Disposal (Rs./m3)	0.10	0.10	0.10	0.10	0.10	2.65	2.00	2.00	2.00	2.00	2.00
5	Maintenance Cost of Plant (% of Capex)											
a.	E & M Works	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%
	Maintenance Cost of E & M Works (Rs./m3)	0.23	0.18	0.25	0.12	0.35	0.90	1.20	1.72	1.29	1.42	1.21
b.	Civil Works	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
	Maintenance Cost of Civil Works (Rs./m3)	0.05	0.05	0.07	0.05	0.03	0.04	0.05	0.04	0.05	0.05	0.05
6	Total Operating Cost (Rs /m3)	3.41	4.35	4.34	4.59	2.21	11.01	10.19	11.40	9.78	10.18	9.79
7	**Total Operating Cost per annum (Rs.Lac)**	**6.23**	**7.93**	**7.91**	**8.38**	**4.03**	**20.10**	**18.59**	**20.80**	**17.85**	**18.58**	**17.87**

Technology Comparison- Non monetary terms

Sr. no	Description	Tiger Bio Filter	Phytorid	SIBF	SBT	Stabilization Pond	ASP	MBBR	MBR	EA	SAFFR	SBR
1	**Preliminary units**											
	Coarse Screening	√	√	√	√	√	√	√	√	√	√	√
	Fine Screening						√	√	√	√	√	√
	Grit Separation	√				√	√		√			
	O&G removal					√	√		√			
2	**Secondary units**											
	Aeration tank+ blowers					√	√	√	√	√	√	√
	Bio media Filtration tank	√	√	√	√							
	Sedimentation tank/Sludge separation tank						√	√		√	√	
	Intermediate Storage tank with recirculation system			√	√							
	Sludge Treatment/Management					√	√	√	√	√	√	√
	Pressure Sand Filter/ Activated Carbon Filter	√	√	√	√							
	Disinfection	√	√	√	√	√	√	√	√	√	√	√

Conclusion

- A selective approach for multiple wastewater recovery is desirable & technologically feasible, to provide water at specific standards for each reuse objective.

- "Fit-for-purpose" approach to water reuse could save water and would reduce production cost & energy demand by eliminating unnecessary treatment and long term conveyance, with typically aim at local reuse.

- The appropriate choice of technologies for such approaches is the most critical & hence need to be selected carefully.

Thank you

for your kind attention!