FROST Webinar
on
“WATER BODY POLLUTION”
(October 8 and 9, 2021; 17:00 – 20:30 IST)

Tackling Water Pollution from Mining and Industrial Activity - in an Indian Context

- Prabhash Gokarn
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Disclaimer

This presentation consolidates my experiences and thoughts gathered over the years.

The company I work for does not necessarily subscribe to the views and thoughts expressed in this presentation, and nor is it necessarily the prevalent views within the company; and should not be construed as such.

Also, the information presented is from various published sources and contains no proprietary or confidential information. A list of references is given in the end for anyone needing more information.

Structure of my talk

A Brazilian Wake-up Call

The Espirito Santo Coast before the tragedy

Accident: Toxic Mud from a burst Tailings Dam

Toxic Mud is spreading across the Espirito Santo Coast

Ecological Impact on the Espirito Santo Coast

A Brazilian Wake-up Call

Sludge and Mud flows through Bento Rodrigues

Bento Rodrigues inundated with Toxic Waste

600 people evacuated by helicopter

A Brazilian Wake-up Call – the incident

- Vale S.A., Brazil, 3rd largest mining company in the world. Largest producer of iron ore (>350 Mn MT/yr.); produces >60% of iron ore produced in Brazil (15% of world production).

Fig-1a : Location of Bento Rodrigues

Fig-1b : Mariana mining site

- Samarco's mines, produces iron ore pellets (22 Mn MT/yr.) post gravity concentration & beneficiation.
- The tailings are stored in four tailing dams that surround the mines.
- Between late afternoon and evening of 5 Nov 2015, ***two tailing dams** in **Mariana*** collapsed. Tailing dams which stored tailings and water, suffered a **sudden break-out** – catastrophic flow side failures - leading to **release of over 60 million cubic meters of sludge water** and **mining waste** and flattening nearby towns in the state of Minas Gerais. This contaminated the **Doce River** and its **tributary, Rio Gualaxo do Norte**, and the toxic brown mudflows **reached the Atlantic Ocean** 17 days later

A Brazilian Wake-up Call – the impact

- **Immediate**:
  - River basin drainage area of 86,715 sq. km, covers 230 municipalities that use it for subsistence
  - Loss of life and livelihood of people along the river
  - Water Emergency in communities that depended on Rives Doce and its tributaries
  - Fine of USD 66 million on Vale; USD 265 million liability for the clean-up.
  - Cost Prime Minister Dilma Rousseff and her government the election

Were the lessons learnt?
- There was another tailing dam burst in 2019 ☹

- **Long term**
  - Stoppage of production in 8 mining sites
  - 25% drop in value of Vale stock price: Vale awarded as corporation with most "*contempt for the environment and human rights*" in the world! Vale to pay over $7bn in compensation.
  - Long term heavy metal contamination of the river
  - Lack of oxygen and high temperatures caused by pollutants killed much of the aquatic life along a 500km stretch of the river. Thousands of hectares of protected areas destroyed and total extinction biodiversity.
  - Beautiful beaches around Espírito Santo coast closed.

A Brazilian Wake-up Call – what went wrong

Multiple things:

1. State allowed Samarco to **increase the dam's height**, over-riding concerns

2. Recommended **monitoring of the dam was lax** - gave absolutely no advance warning of the impending disaster.

3. **No contingency plan** or a "dam break analysis": when the dam broke, no one knew what exactly to do. Thus, people in harm's way were not warned and evacuated in time.

4. Many **modern safety techniques** such as radar and laser-monitoring can give advance warning of structural problems: none of these were adopted

5. Five dam breaks in the last decade: **no learning from the repeated failures** and control measures or suggestions not implemented across all mines.

6. Officials in Minas Gerais rated the dam as Class III - its highest level for potential to cause environmental damage; warned of dangers of increasing mine height. Samarco provided own independent report which judged dam as safe. State officials visited the dam in October 2014 and considered it safe, but they were not engineers.

An Indian Perspective

- Fortunate to have a robust mining legislative system with active monitoring mechanisms in India Indian Bureau of Mines published a Manual for Mining Plan that details the steps needed for proper tailing dam management, like:

  - Complete details regarding physical and chemical characteristics of tailings, possible reuse, if any along with the design, size and capacity of tailing pond.

  - Details of process of water treatment and quality and quantity of final discharge and place of disposal (proximity to rivers, public well or any other public utility places) in Mining Plan

  - Tailings Dam Management: steps to be taken for protection and stability of tailing dam

  - Detailed Disaster Management Plan and Risk Assessment

  - Tailing Dam design and its management form an integral part of the EIA report for getting the Environmental Clearances

  - Central Pollution Control Board & State Pollution Control Boards stipulate conditions in Consent to Operate under Air & Water Act for Tailing Dam Management and ensure compliance by way of regular visits

Treating Mine Water – a local example

About Sukinda

- 92% of India's chrome deposits
- Source economic benefit to India – globally exported.
- Chrome used in stainless & alloy steels
- Mainly stable Cr_2O_3, < 1% Cr^{+6}
- Hexavalent di-chromate soluble, Sukinda water found to have Cr^{+6} of 0.2-4 mg/l
- Prolonged exposure may effect health

Water Management at Sukinda

- Heavy rainfall, 80% in monsoons
- Water runs off surface or pumped out of mine carries silt, picking up hexavalent chromium

- Joins water sources contaminating them

3 ETPs

- Tata Steel set up effluent treatment plants in early 2000s to treat this water

Treating Mine Water – a local example

Impetus to Upgrade

Tata Steel set up Effluent Treatment Plants in the early 2000s:

1. Afforestation program => higher rainfall.
2. Deepening Mine => increased quantity of water
3. Facilities now available : automation, online monitoring, better water treatment methods.

Choosing the Right Technology

Sl No	Technology	Suitability
1	**Physical Adsorption**	TSS & pH too high
2	**Electro chemical treatment**	High cost, low treatment in low concentration
3	**Osmosis/Membrane separation**	High cost, low treatment in low concentration
4	**Bio-remediation**	Intolerance & possible ill effects of bacteria
5	**Phyto-remediation**	Very low process kinetics/Large space Possible ill effects of plant bio-mass
6	**Chemical Precipitation**	Method chosen due to prior experience, fast reaction time, low space requirement. Tolerance to TSS, pH, temperature variations, very well understood process

Treating Mine Water – a local example

Unique features of the ETP

Highly efficient technology

- Rapid reduction of hexavalent chromium, rapid flocculation
- Reduced residence time
- Increased through-put

Future Ready Output current + stricter norms for treated effluent

* <0.01 mg/l of Cr+6 against norm of 0.05
* TSS < 10mg/l against a norm of < 100 mg/l
* Treat both surface run off & mine water in same way

State of art online monitoring & automation systems :

a. 24/7 real-time monitoring
b. Highly automated with feedback
c. Automated backwash

Zero Discharge

- Largest Single Location ETP in India: 108 MLD
- Treated output water better than water of local stream
- Cost saving – pumping from 3 km away; reduced chemicals needed for treatment
- Zero Discharge / Zero Intake: all water used internally in WTP, Dust Suppression, Concentration plant

Treating Mine Water – a local example

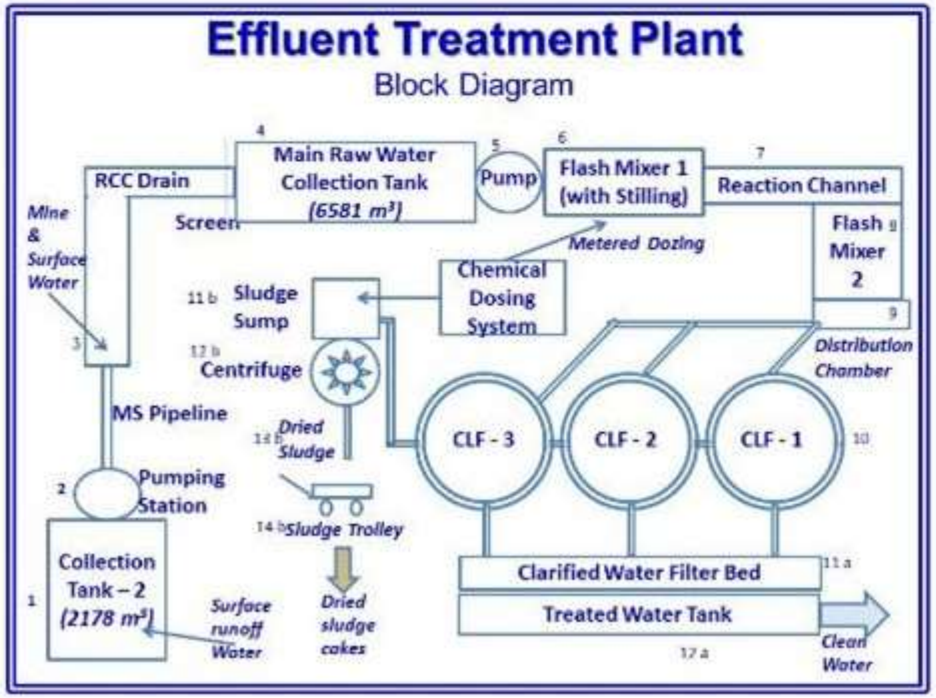
Effluent Treatment Plant

Peak Capacity : 108 million litres / day (raw effluent)
(3 modules of 1500 m^3/hr)

This plant will treat all water (mine water plus surface run-off) making it free from hexavalent chromium, remove suspended solids and neutralize pH.

Output Water Parameters :

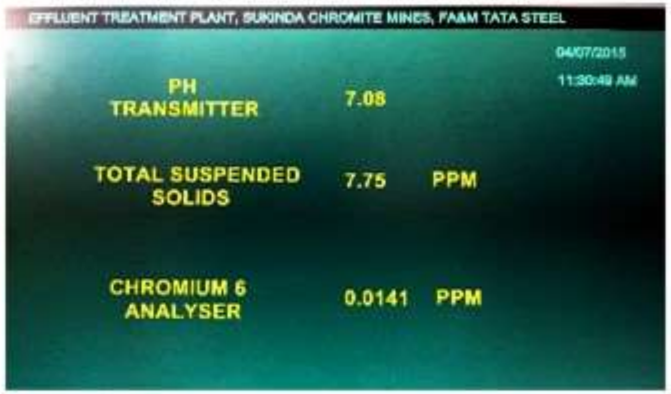
pH : 7.0-8.5 TSS : < 10 mg/l
Hex Cr : < 0.001 mg/l Total Cr < 0.2 mg/l



Raw Water Collection Tank and Gravity Sand Filters

Three Clariflocculators capable of independently treating water @1500 m^3/hr

Treated Water from Effluent Treatment Plant being collected in the inlet channel of the Water Treatment Plant for treatment



Online Monitoring System Output Screens

Industrial Water Pollution

Industrial water pollution can be of many types; and the pollutants are industry specific:

EXAMPLES OF HAZARDOUS WASTE GENERATED BY INDUSTRIES AND BUSINESSES:	
WASTE GENERATOR	**WASTE TYPES**
Chemical Manufacturers	Acids and Bases Spent Solvents Reactive Waste Wastewater Containing Organic Constituents
Printing Industry	Heavy Metal Solutions Waste Inks Solvents Ink Sludges Containing Heavy Metals
Petroleum Refining Industry	Wastewater Containing Benzene & other Hydrocarbons Sludge from Refining Process
Leather Products Manufacturing	Toluene and Benzene
Paper Industry	Paint Waste Containing Heavy Metals Ignitable Solvents
Construction Industry	Ignitable Paint Waste Spent Solvents Strong Acids and Bases
Metal Manufacturing	Sludges containing Heavy Metals Cyanide Waste Paint Waste

Source: Environmental Protection Agency, Solving the Hazardous Waste Problem: EPA's RCRA Program

Classification:

- Surface Water pollution – affects rivers, streams, lakes
- Underground water pollution – insidious with a possible large area and long term impact
- Marine Pollution – sea water: both due to marine activity (ships, deep sea oil extraction etc.) or from industries close to the coast

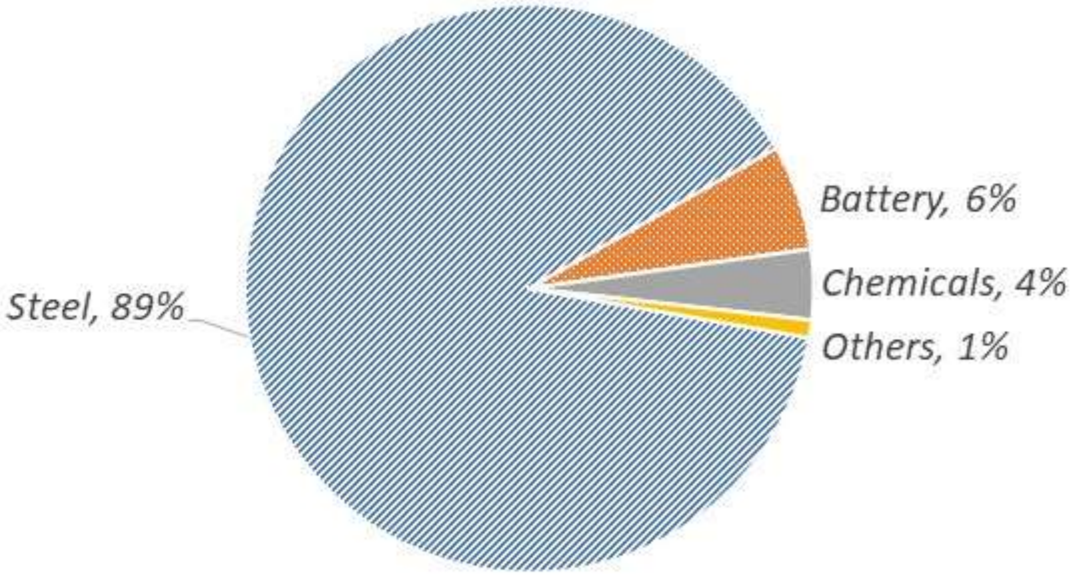
Limiting myself to the first two, possible methods of remediation:

- Reduce pollution (usually not possible)
- Post Treatment before letting out the water
- Treat and Recycle the water (to extent possible): aim for Zero Discharge

Treating Industrial Water –Solid Liquid Separation at Joda

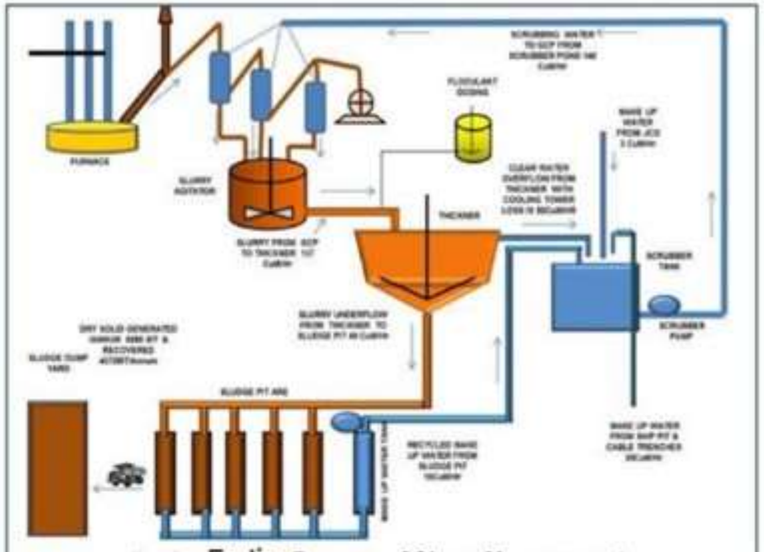
- FAP Joda was commissioned in 1958 and is in continuous operation since then.
- It currently produces 50,000 MTPA of HC Ferro Manganese using two submerged arc furnaces (SAF).
- The flue gases released during production contain manganese dust and other solid particles which need to be cleaned before being released to the environment.
- This is done by passing the flue gases through a GCP containing wet type venture scrubbers, which uses water to cool the flue gas and also to coalesce the dust particles.
- Gas Cleaning Plant (GCP) slurry generated in wet venture scrubbers used to be collected in slurry pits inside the plant for drying and subsequent disposal.
- With a view to recycle the water used in the wet venture scrubbers, we upgraded the slurry handling process by installing a unique slurry dewatering plant.

Announcing the Launch of the Ferro Alloy Plant at Joda, 1958

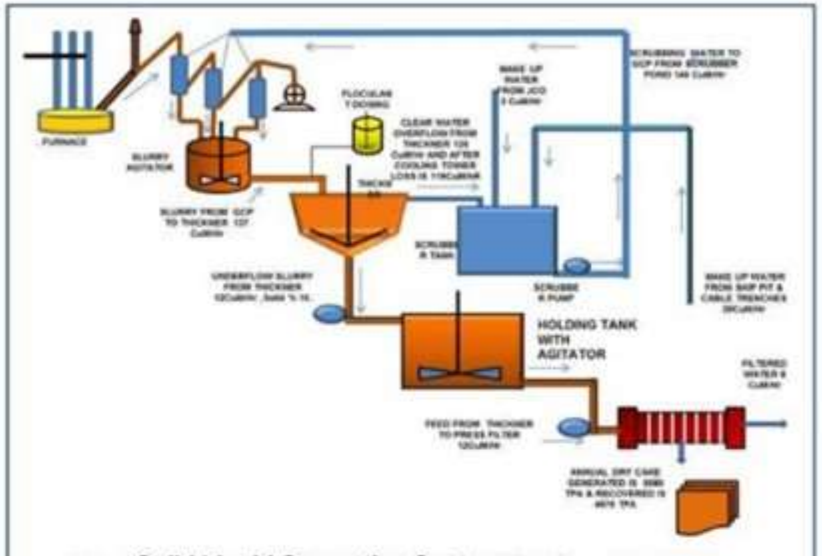


Applications of Manganese Alloys & Compounds

Treating Industrial Water –Solid Liquid Separation at Joda



Earlier Process of Slurry Management



Solid Liquid Separation System

Issues with earlier process of Slurry Management

- Space required for sludge drying pits
- Possible contamination of ground water if water from sludge percolates (despite impervious lining).
- Recycling of water is not possible: water from the sludge pit is lost by evaporation or percolation.

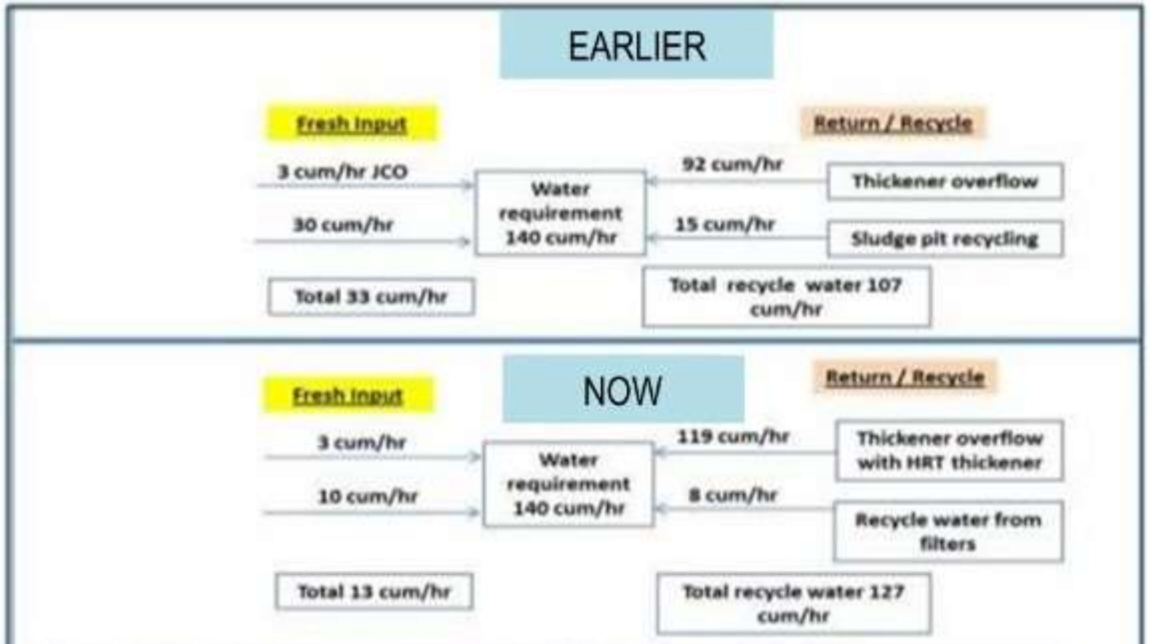
State of Art De-Watering (Solid Liquid Separation) Process Plant at FAP Joda:

- Filter press with accessories,
- High rate thickener with accessories
- Process Automation, including Chemical dosing system, Compressors and related electro-mechanical equipment

Advantages

- 100% Water Recycled: Zero Discharge or Ground Water Percolation
- Dry Sludge, easily stored inside plant

Treating Industrial Water –Solid Liquid Separation at Joda



- Fresh water consumption reduces from 33 cum/hr to 13 cum/hr.
- Recycling from thickener overflow by installing HRT increases by 27 cum/hr.
- Filters dewaterring recycle 8 cum/hr.

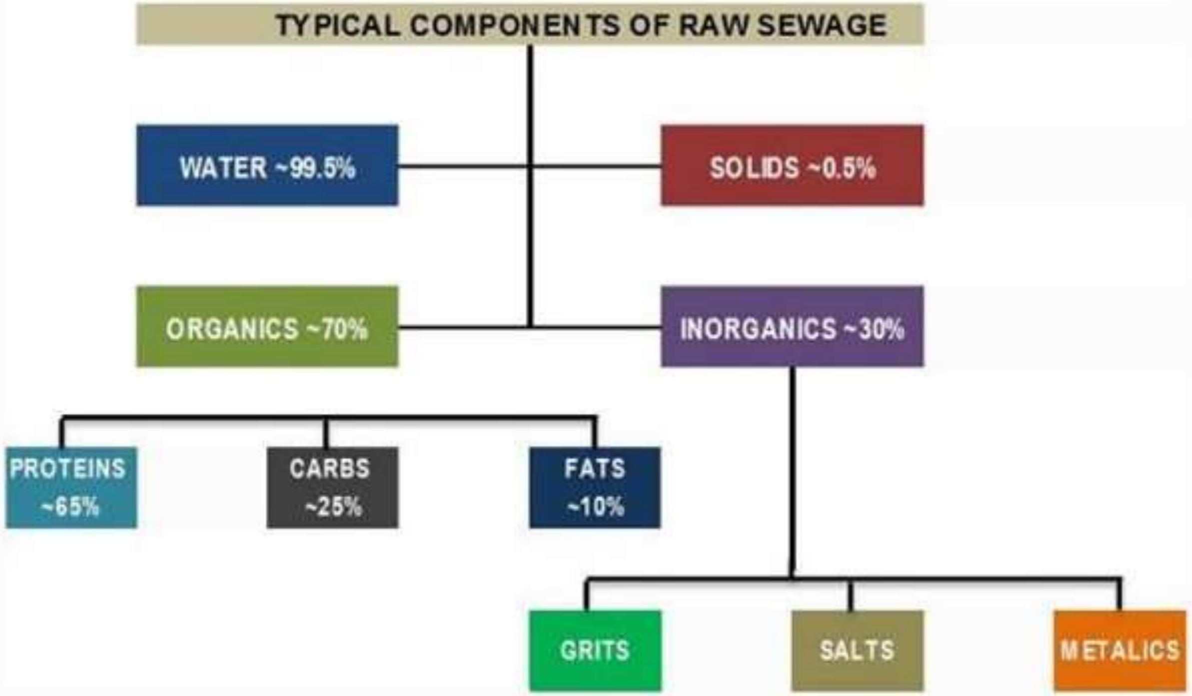
Water Conservation by Solid Liquid Separation System

Treating Mixed Sewage

- Any mining or industrial set-up requires people – and in an Indian context – a lot of people. Most industries are also located far away from cities and the larger set-ups have townships attached. Mines are, quite obviously, located in even more remote places, with attached accommodation.
- Larger Industrial houses provide schooling, hospitals or primary health care which serve the local communities as well.
- People use fresh, hopefully portable, water and generate sewage – both greywater (from sinks, bathtubs, showers, dishwashers, and clothes washers) and blackwater (the water used to flush toilets, combined with the human waste that it flushes away); and will also contain food waste (from kitchens and canteens).
- The sewage usually gets mixed with varying amounts of industrial waste water. This could contains various chemicals, heavy metal pollutants etc. Regulations today rightly prohibit the release of such water without some form of treatment.
- There are multiple options available depending on the quantity and quality of the water to be treated, the desired quality of the discharge (which depends on its re-use; operating philosophy of the unit) and the local circumstances.
- While I am no expert on sewage treatment, I have been fortunate to have set up various treatment plants across locations in Odisha and the following slides are a snapshot of my learning.

Treating Mixed Sewage – local examples

Components of Sewage



- ~ 80 to 120 litres of sewage/person/day, dry sludge component of 50 to 60 g
- Sewage mainly bio-degradable, contaminates environment in the interim
- Population & urbanization making sewage a major sanitary problem, only ~30% treated
- Disease, water contamination, overload of sewage in land causing overgrowth of weeds
- Heavy metal accumulation and re-circulation

The Science of Sewage Treatment

- Soak Pits : water soaks into soil. Danger of contamination – hence no longer acceptable.
- Aerobic Treatment : use natural microbes to break down sewage. Aeration done to increase speed of reaction.
- Three steps of most treatment technologies :
  - Primary Treatment (Screening): removal of insoluble debris
  - Secondary Treatment (De-composition): Aeration activates microbes to decompose organics into insoluble sludge, clarified water & sludge separated.
  - Tertiary Treatment (Treatment of Clarified Water): Clarified water filtered and disinfected
- Tertiary treated water can be used to flush toilets, wash roads and yards, and for gardening. Use as input to water treatment plant controversial.

Treating Mixed Sewage – local examples

Technologies for Sewage Treatment

Soak Pits

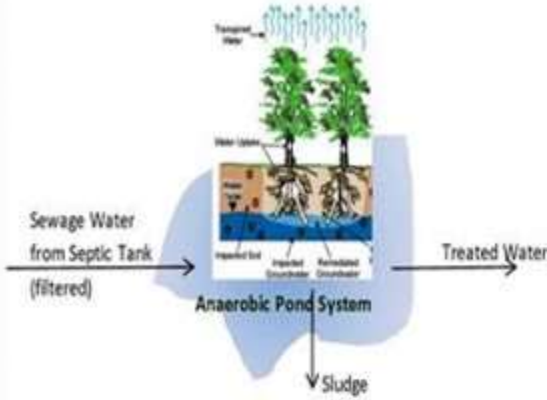
- Unconnected toilets in areas with low population
- Low rate of pathogen removal, risk of polluting ground water
- Inefficient soaking due to unfavourable soil conditions in lateritic soil areas
- Older technology, no longer acceptable

Overflowing Soak Pit due to impervious soil

Technologies for Sewage Treatment

Duckweed Pond System

- To tackle the problem of untreated sewage from settlements in a semi-rural setup.
- Shallow pond, retention of 7 to 14 days.
- BOD and SS removal of ~30 mg/l
- High mineral and nutrient removal rate due to the uptake by duckweeds
- Very low cost of construction
- Low sensitivity to varying flow rates
- Low pathogen removal, high land requirement
- Only suitable for rural areas
- Can be used for fish farming (heavy metals?)

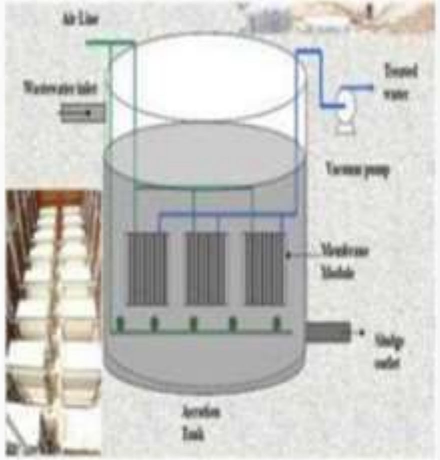


Treating Mixed Sewage – local examples

Technologies for Sewage Treatment

Membrane Based Bio-Reactor Systems – medium sized STPs

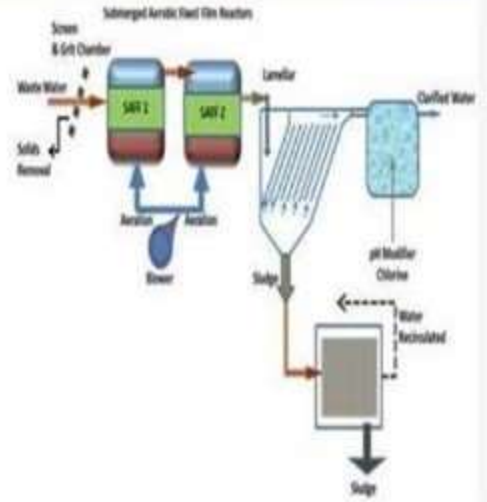
- Sewage decomposition in bio-reactors, i.e. MBR chambers with aeration grid
- Passing air as small bubbles - increases contact period and facilitates mixing
- Bacterial population grows on specially designed carrier media (MBR media)
- Rapid treatment
- Suitable for small to mid-sized plants with small variations in input sewage load
- Skilled manpower, recurring cost of media.



Technologies for Sewage Treatment

Submerged Aerobic Fixed Film Reactor – medium to large sized STPs

- Small footprint
- Effectively treats dilute domestic waste water
- Low and stabilized sludge produced eliminates the need for sludge digestion
- Need for primary settling to avoid clogging
- Can only accept relatively diluted sewage
- Proprietary Aerobic Fixed Film which needs proper maintenance and skilled manpower.

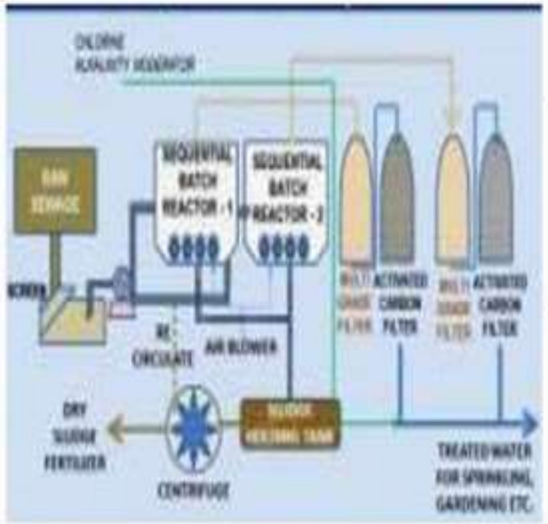


Treating Mixed Sewage – local examples

Technologies for Sewage Treatment

Sequencing Batch Reactor Technology
- Larger STPs

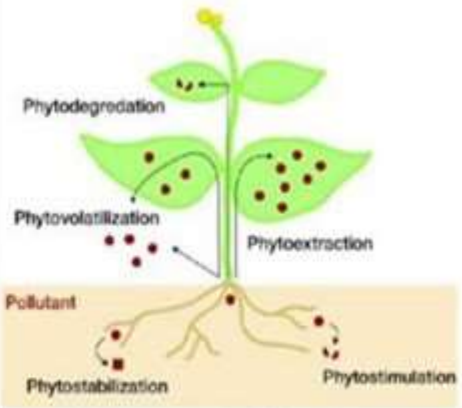
- Variation of the Activated Sludge process
- Process requires uninterrupted power supply for constant aeration and sludge recirculation
- Excess sludge needs to be withdrawn from the system periodically
- Highly efficient and can remove >90% of the pathogens with small footprint
- High level of automation
- Ideal for larger sewage treatment plants in congested and sensitive locations



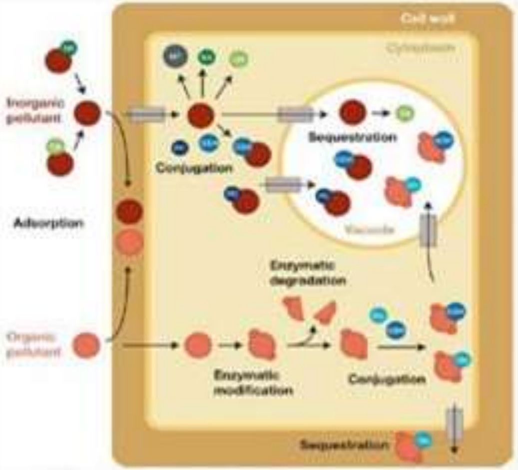
Technologies for Sewage Treatment

Phyto Remediation and Related Technologies

- Experimental method - better green remediation technology than others
- Plants like water hyacinth extremely efficient in absorbing nutrients : used for phyto remediation of waste water
- Large scale adoption hindered by risk of the uncontrolled growth of water hyacinth choking up all nearby water bodies
- Experimental work being done for treatment of heavy metal contaminated mixed effluent-sewage at Tata Steel.



Phytoremediation Mechanism



Pathway of Contaminants inside the plant cell wall

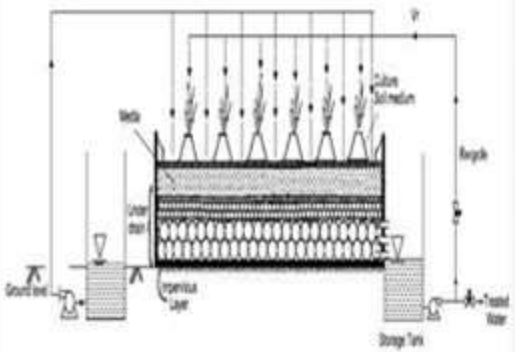
Treating Mixed Sewage – local examples

Technologies for Sewage Treatment

Soil Bio-Technology

- Developed at IIT Bombay, a recent technology used to treat sewage.
- VEC patented CAMUS-SBT system produces results of >95% COD reduction using a soil like media
- Presence of terrestrial ecology with plants as bio-indicators

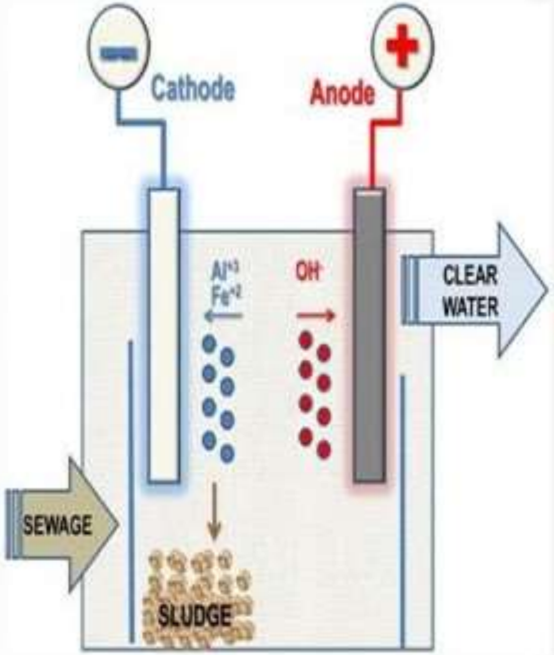
Soil Bio Technology (VEC patented CAMUS-SBT)



Technologies for Sewage Treatment

Electro-Flocculation

- Electrolysis to flocculate contaminants into a size which can be filtered, pressed and disposed of.
- Air agitation to prevent settling and for homogenization.
- Reactor contains Iron (Fe^{+2}) and Aluminium (Al^{+3}) electrodes connected to the cathode low voltage (9 to 11 volts) and high current.
- Anode converted to Fe_2O_3 and $Al_2(OH)_3$ which aid flocking.
- Dissolved contamination connected to flocks form large non-dissolved particles which are filtered out.
- Rapidly treatment
- Prohibitive cost of treatment – electrode cost



Conclusion

- Water is critical to the survival of all living organisms. Many organisms can thrive on salt water, but the great majority of higher plants and most insects, amphibians, reptiles, mammals and birds need fresh water to survive. However, pollution equally threatens life in both in the seas and on land.

- Fresh water is renewable but a finite natural resource. Fresh water can only be replenished through the process of the water cycle, in which water from seas, lakes, forests, land, rivers and reservoirs evaporates, forms clouds, and returns inland as precipitation.

- Less than 5% of total water on Earth is fresh water, including 2% frozen in glaciers, ice and snow, 0.5% as fresh groundwater and soil moisture, and less than 0.01% of it as surface water in lakes, swamps and rivers. Much of the surface water is rapidly getting polluted due to human activity – Mining and Industrial Pollution – amongst others.

- There are many technologies for treating waste water, what is lacking is the desire to implement appropriate technologies – even in the face of increasingly strict legislations. If we do not act soon, this desire to extract profit at any cost and cut corners will extract a penalty from man far higher than we can imagine.

Prabhash Gokarn
+91-7752004399
prabhashgokarn@hotmail.com

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