CURRENT TECHNIQUES, CHALLENGES & EMERGING OPPORTUNITIES FOR RICE MILL EFFLUENT TREATMENT

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Rice is a staple food for 65 % of the Indian population with India being the second-largest producer of rice in the world next to China. India is also the world's biggest rice exporter, with a turnover of more than Rs. 36,500 crores per annum. Indian Rice mills process about 85 million tonnes of paddy every year both from the conventional and modern rice milling processes. A total of 1,74,296 rice milling units were reported in India in the year 2009. The major rice-growing states include Tamil Nadu, West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Orrisa, Chhattisgarh, and Bihar. There are several rice mill clusters all over India, as listed in Table 1.

Table 1: Rice Mill Clusters in India, sources

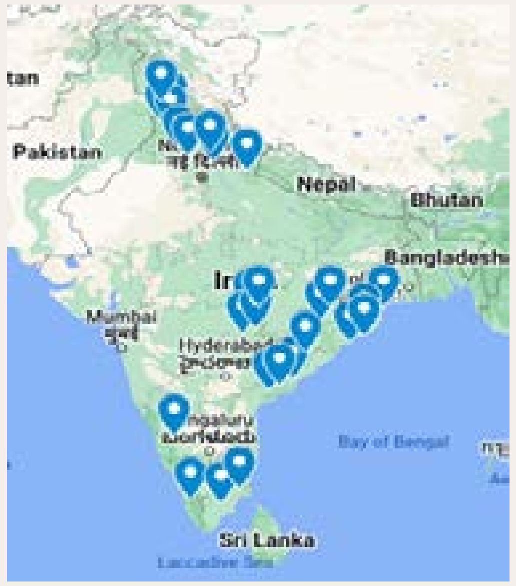
STATE	DISTRICTS
Andhra Pradesh	East Godavari, West Godavari, Krishna
Haryana	Karnal, Kurukshetra, Panipat
Jammu & Kashmir	Jammu/ Kathua
Karnataka	Shimoga
Maharashtra	Bhandara, Chandrapur, Gadchiroli, Gondia
Orissa	Balangir, Balasore, Cuttack, Ganjam, Koraput, Puri, Sambhalpur, Rayagada,
Punjab	Amritsar, Gurdaspur, Sangrur
Tamil Nadu	Madurai, Thanjavur, Kancheepuram, Tiruvannamalai, Thiruvallur, Sivagangai, Tenkasi, Tirunelveli
Uttar Pradesh	Muzaffarnagar, Saharanpur, Shahzahanpur, Kanpur Dehat, Raibareilly, Pilibhit
Uttaranchal	Udham Singh Nagar
Kerala	Ernakulam, Palakkad
West Bengal	Bardhaman, Purba Bardhaman, Dakshin Dinajpur

Rice Mill Clusters in India, sources

The wastewater generated from a rice mill contains a wide range of organic and inorganic contaminants. The effluent is typically dark coloured and foul smelling. 125 rice mills are registered with the Rice Millers Cluster, Kalady, Kerala, India with Industrial Cluster Development programme under MSE-CDP Scheme of Ministry of MSME (Micro Small & Medium Enterprises), Government of India. Approximately 2000 MT of paddy is processed in the mills in and around Kalady, Kerala and together they consume about 2 Million liters of water per day. Typical effluent quality of rice mill effluent of collected from a mill in the Angamaly - Kalady - Peerumbavur region, is given in Table 1 below. Variations of pH are encountered owing to different paddy characteristics, the parboiling process and the quality of water used. Suspended solids increase both biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

Numerous chemicals are added at various stages of processing such as pre-cleaning, dehusking, polishing etc. Rice mill effluent contains lignin, phenol and colour components that enhance the COD of the effluent along with the chemicals used in processing and pesticide residues.

The important step on the rice processing in India is parboiling. The production of parboiled rice products involve soaking, heating / steaming and drying of paddy. The parboiling process requires approximately 1,200 L per tonne of paddy for soaking. A medium scale parboiled rice mill generates 27.5 million litres of wastewater per year. The rice mill effluent contains soluble starches, sugars from the grain starch, polyphenolics, lignin, tannins and volatile fatty acids with COD ranging from 2000 to 5000 mg/l. It is reported that each rice mill industry all over India produces average wastewater for 200 days/ year during the parboiling process. For instance, in the state of West Bengal, India, 16,925 rice mill units are functional which discharges 3.4 × 1011 L of wastewater per year [Chandan et al 2016].

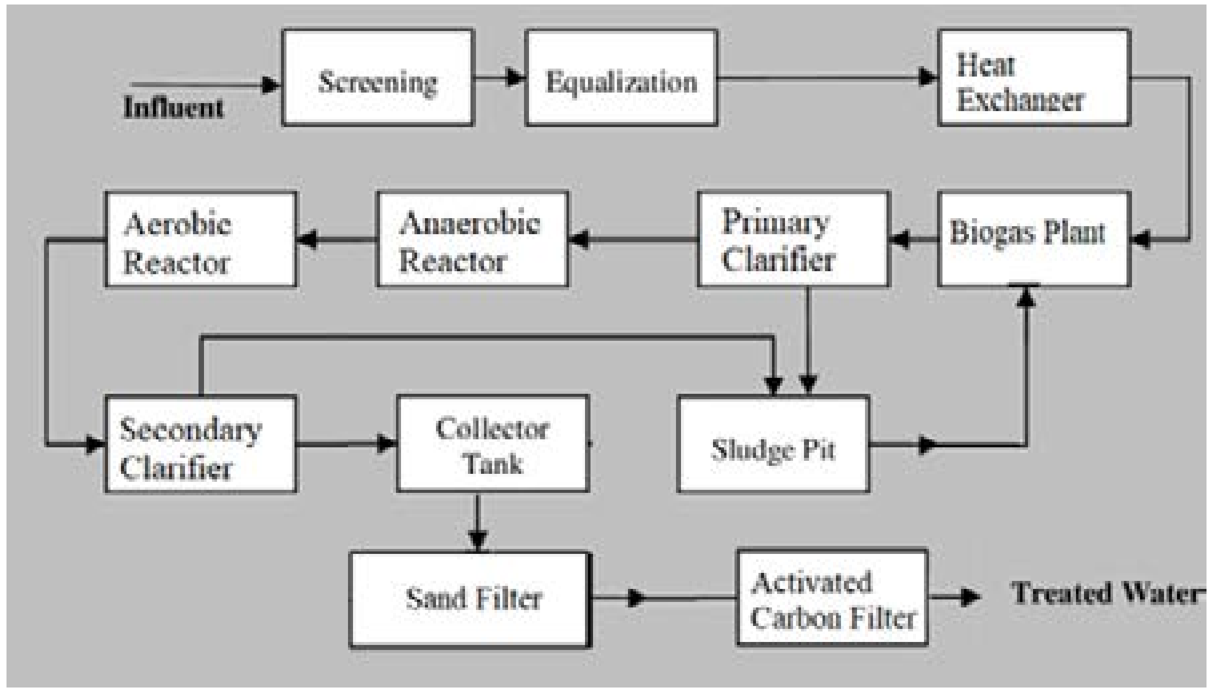


PARTICULARS	UNIT	VALUE
pH		4.7
BOD	mg/L	1115
COD	mg/L	4214
Total Sus.solids	mg/L	126
TDS	mg/L	3286
Chlorates	mg/L	383
Total organic carbon	mg/L	2436
Total Kjeldahl nitrogen	mg/L	212
Lignin	mg/L	52.86
Total Alkalinity	mg/L	788

Physicochemical Parameters of Rice Mill effluent

Treatment Options for Rice Mill Effluent

Conventional treatment plants for rice mill effluent comprises of physicochemical treatment, microbial treatment and filtration.



Flow Chart of Conventional treatment plant for rice mill water effluent involving Integrated Aerobic - anaerobic approach

Integrated aerobic - anaerobic approach along with conventional treatment methods brings down the contaminant load and treatment cost while simultaneously reducing the quantity of effluent discharged. The advantage of integrated approach is that the excess sludge produced in the aerobic reactor is recycled to the anaerobic unit there by reducing the organic loading rate, ensuring better waste stabilization and reducing the size and operating cost of downstream. effluent treatment units. Anaerobic digestion is an energy efficient and environment friendly technology to produce biogas . Up-Flow Anaerobic Sludge Blanket (UASB) reactor or Moving Bed Bio-Reactor (MBBR) or a combination of UASB and MBBR may be employed. Both systems are less expensive, require less energy, and produce lower amounts of secondary pollutants than conventional techniques.

In contrast with the conventional treatment, MBBR involves the combination of conventional Activated Sludge Process (ASP) and biofiltering mechanism. MBBR has been proven to stabilize waste water with good BOD and COD removal efficiencies. Besides the high removal efficiency for BOD and COD, it offers the additional advantage of lesser space requirement than conventional system and can be easily augmented to existing treatment plants. It is also proposed to integrate a biogas plant that can supply the necessary fuel required for the heating requirements of the rice processing plant and also reduce the organic load of the effluent treatment plant.

UASB (Upflow Anaerobic Sludge Blanket) reactors are recommended world over for the anaerobic treatment of wastewater [11, 12], e.g., from food processing plants, especially in tropical countries [13], such as India [9].

The UASB-type reactor is preferred over other anaerobic reactors since they can work on high organic loading rates, which is typical of rice mill effluents [3], [4]. It has also been recognized that India holds around 80% of the reactors out of the total UASBs installed worldwide in handling food processing wastewater [14].

For satisfactory performance, investigations have proven that UASB reactors should be configured based on optimizing significant operating parameters such as temperature, pH, solid retention time (SRT), Organic Loading Rate (OLR), food to microbe ratio (F/M), buffering capacity, etc.[17]. UASB reactors are best operated at values of organic volumetric load rate between 2-40 kgCOD/m3d and hence found to be a better choice for rice mill effluents.

The amount of biogas production from a UASB is based on the percentage of COD removed from the wastewater. It was found from stoichiometry that for every 1Kg of COD removed, 0.35 m3 of methane is produced.

However, conventional treatment methods for rice mill effluent are chemical based and/or capital intensive and not widely adopted and as a result rice mills are almost always in violation of statutory pollution control norms. The discharge of hot soak water repeatedly over a localised area stagnates, decomposes and raises the ire of the local population.

Adsorption

One of the methods employed for treating waste water is adsorption involving attaching of contaminant molecules on to the surface of adsorbents. Researchers have experimented with different adsorbents to treat rice mill effluent. Karichappan et al employed chitosan, a biopolymer, for treatment of waste water rice mill. Though chitosan is environmentally friendly, not poisonous, biologically degradable and regenerative giving high quality effluent, the high cost of chitosan, chemical modification required for performance improvement, sludge generation and performance dependence of factors like pH prevent its use in large scale treatment of rice mill effluent. Attempts have been made to utilize rice husk and rice husk ash, both of which are waste generated in rice mill, for treatment of rice mill effluent.

The COD removal efficiency was not more than 40%. It may be concluded that the treatment of rice mill effluent treated by adsorption requires further treatment for complete removal of contaminants and the adsorbants also require further treatment for regeneration.

Electrocoagulation

Electrochemical technologies have emerged as promising and efficient method for effluent treatment in many industries. Electrocoagulation utilizes electricity to destabilize suspended solids, oils and metal ions particles by changing their surface charge. The process is attractive as it does not generate secondary pollutants, remove more than 75% COD, does not involve addition of chemicals and the sludge formed is non - toxic and stable. However, electrocoagulation requires is energy intensive, regular replacement of electrodes and has high operating and maintenance costs.

Phytoremediation

Phytoremediation is a cost effective and eco-friendly effluent treatment method to remove, reduce, transport, stabilize and degrade the pollutant using plants. Several physical, chemical and biological reactions are involved in phytoremediation.

Phytoremediation is eco-friendly, sustainable and cost -effective technique for treatment of wastewater However, it a slow process that requires large area of land and often the raw effluent needs to be mixed with sewage prior to treatment. Hence, it is suitable for domestic and small-scale industrial units in localities where land is available. The treated effluent quality is not satisfactory for recycling to rice mill but can be used for irrigation purposes.

Case Study : Performance evaluation of ETP Facility at KRMC

Analysis of raw Effluent generated and its variations in various sections of ETP

The physicochemical analysis based on APHA of raw effluent and wastewater samples from various treatment stages were collected from KRMC's effluent treatment facility is presented below.

	PH	MLSS mg/L	MLSS mg/L	BOD Reduction	COD mg/L	COD Reduction
Raw Effluent	5.1	NA	3360		5520	
USAB Outlet	7.3	NA	2380	30%	3910	29%
Aeration Tank outlet	7.0	800*	2020	10%	3312	15%
After chlorination & Filtration	6.7	NA	1860	5%	2760	17%
			TOTAL	45%		45%

Physicochemical Analysis of Rice Mill Effluent

Key findings

1. Based on the analysis of the UASB outlet it has been observed that only 30% of BOD and COD load is removed in the UASB reactor. See Table 1. The reason for this could be the poor degradation kinetics of the UASB reactor.

2. BOD reduction in activated sludge process is also very low. Only around 10% of BOD is removed after activated sludge process. Typical MLSS concentrations for conventional activated sludge plants range from 2,000 to 4,000 mg/L. However, we found that only 800 mg/L is the MLSS concentration. This may not remove sufficient BOD from the wastewater.

3. The presence of inhibitory compounds (phenol and lignin) that interfere with, or hinder, the performance of, the activated sludge system in the oxidation (degradation) of the incoming organic load, again leading to high COD concentrations in the effluent.

4. Phenol causes complex COD and cannot be sufficiently oxidized in the UASB or ASP, leading to high COD concentrations in the effluent. Phenols can be degraded but only if the right microbes are present and functioning. The plant's microbial community determines whether you get full, partial or no degradation. Phenols are good and well controlled in aerobic biological purification as long as the compounds are fed in at a relatively constant rate and there are no coexisting inhibiting agents such as S2− in overly strong concentrations.

5. Even after post treatment such as chlorination and filtration the contaminants are seen to be still on the higher end. More specifically, the TDS value is still found to be 800 - 900 mg/L

6. It has also been observed from our visit that majority of the contaminants are removed mainly with the use of chemical coagulation unit rather than the UASB and ASP processes. This is because a coagulation unit is suitable to remove both Natural Organic Matter (NOM) and Dissolved Organic Carbon (DOC). Alternatively, these question the purpose of having a UASB and ASP reactor in the effluent treatment plant. This adds huge cost to the entire treatment unit and further generates unwanted sludges at undesirable points.

Proposed strategies for the existing treatment

- An extensive analysis of physical and chemical wastewater characterization is to be carried out to identify the appropriate treatment system for the removal of specific contaminants
- Cost analysis of the existing effluent treatment plant and identifying the scope for improvement and reducing unit cost
- Lab scale coagulation and flocculation studies and in-depth investigations of studies related to chemical dosing requirement in dosing tank and cutting down cost with respect to quantity and selection of coagulants.
- Studying the acclimatization process of activated sludge and UASB towards increasing BOD and COD in a Batch reactor and assessing the biodegradation kinetics
- Generating activated carbon from the ash produced from the industry and the same can be used in the activated carbon filter to reduce COD and TDS

Emerging Opportunities

Wastewater treatment systems have experienced a paradigm shift from removing pollutants to meet regulatory authority standards to wastewater recycling for zero discharge and wastewater valorization. Rice mill effluent are potential sources for recovery of value added resources and viable generation of energy. There is huge potential for generating viable energy sources from wastewater generated in these plants as well as bringing down water footprint in this sector.

Considering the impact of global warming due to toxic and hazardous emissions from various sources, and dependency of power sector on fossil based fuels, biomethane offers a clean and sustainable solution with high energy conversion.

The rice mill effluent contains soluble starches, sugars from the grain starch, polyphenolics, lignin, tannins, and volatile fatty acids with COD ranging from 2000 to 5000 mg/l and is an ideal candidate for industrial production of biomethane. The primary composition of biogas includes methane (CH_4) and carbon dioxide (CO_2), with trace amounts of hydrogen, water vapor, and other gases.

The biogas composition has a low heating coefficient because large volumes of carbon dioxide and water vapor interfere with the combustion process. Biogas can be upgraded to higher methane content (> 97% v/v), to resemble the quality of natural gas. Bio-methane (bioCH_4) is suitable for use as transportation fuel, and is economically more profitable than biogas combustion. Though many rice mills in India have integrated biogas production unit, upgradation to biomethane is not done in those plants.

Challenges

- Fluctuations in wastewater quality and quantity based on raw material quality and season
- Fluctuations in organic loading rate (OLR) and surface loading rate (SLR) affecting operation of biological reactors
- Design a robust system capable of handling feed variation.
- These rice mill plants are not fully efficient in terms of energy conservation, productivity and maintenance. The manpower employed by the units is neither fully professional and nor consistent.
- Effluent are chemical based and/or capital intensive. Many small scale units often violate statutory pollution control norms and discharge without proper treatment repeatedly over a localized area resulting in stagnation, accumulation and decomposition. This also leads to pollution of wells and nearby water bodies.
- Rigorous monitoring of microbial kinetics in the biological reactor
- Reluctance to adopt and invest in new technologies.

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