ENHANCING SUSTAINABILITY OF LOCAL RICE MILLS BY CLEANER PRODUCTION AND INDUSTRIAL ECOLOGICAL PRINCIPLES

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Abstract- Rice processing industry is the largest agro-based industry in the country turning more value of product than any other industry. Mainly two types of rice called raw and parboiled; famous among the local community. The rice milled from pre-treated paddy is known as parboiled rice. Parboiling is a hydro-thermal treatment followed by drying before milling for the production of parboiled grains. Nearly 70 percent of the paddy produced in Sri Lanka at present is parboiled. Two dominant wastages are released to environment in parboiled rice milling namely, soak water and paddy husks. For one metric ton of paddy, approximately 1.3 m^3 of soaked water and 0.2 tons of paddy husk are released to environment and soaked water is discharged to the environment without being treated. Due to this, bad odour is prevailed in the vicinities of the mills. In addition, paddy husk and ash dumps are washed away with rain to the waterways. To minimize bad smell, millers are advised to change socking every 10-12 hours. Even though socking water is changed every 12 hours time COD and BOD_5 levels of releasing water are higher than the values set by CEA. Therefore, sustainability of this industry relies addressing the waste streams in a productive manner. Therefore in this research cleaner production principle is adapted to minimize the waste generated by attacking the point of generation and using potion of treated wastewater for soaking process. Industrial Ecology concept is adapted by using by product (waste) of the process, paddy husk as a fuel initially to operate the boiler and later ash of the husk as filtering media of wastewater. In addition, steam generated by burning paddy husk will be partly used to rotate biological rotating disk which facilitate aerobic reaction. Treatment process consists of two stages and in the first stage, BOD value is reduced by aerobic digestion with the help of rotating biological contractors (RBC) and in the second stage pre-treated wastewater sent through a carbon filter in order to reduce COD. Result shows that treatment process gives promising results of the COD and BOD_5 concentrations of the treated water therefore treated water can be re-used for soaking purposes again.

Keywords: *Waste water, Cleaner Production, Industrial Ecology, Waste management, Sustainability*

1.0 Introduction

The Sri Lankan economy has traditionally been dominated by agriculture. The production of paddy has occupied an extremely important place in the agricultural sector. Rice processing industry is the largest agro-based industry in the country turning more value of product than any other industry. Sri Lanka currently produces average of 3.24 million tons of paddy annually. Large number of direct and indirect employment opportunities available in this industry. Unless this industry operates in a sustainable manner, those who are involved in this industry will get affected. Mainly two types of rice called raw and parboiled famous among the local community. The rice milled from pre-treated paddy is known as parboiled rice whereas the rice milled from untreated paddy is known as raw rice or white rice. Parboiling is a hydro-thermal treatment followed by drying before milling for the production of parboiled grains [1]. Nearly 70 percent of the paddy produced in Sri Lanka at present is parboiled. The parboiling process extensively used in Eastern, North Central, Uva, North-Western provinces. There are three major steps in parboiling process: soaking, steaming and drying. All these steps have a great influence of the final characteristics and quality of parboiled rice.

Two dominant wastages are released to environment in parboiled rice milling namely, soak water and paddy husks. For one metric ton of paddy, approximately 1.3 m^3 of soaked water and 0.2 tons of paddy husk are released to environment and mostly soaked water is discharged to the environment without treating. This leads to bad odour in the vicinities of the mills. In addition paddy husk also sometimes goes away with rain water to the waterways. As a rule of thumb, soaking time for short and long grains are twenty four (24h) and forty eight (48h) hours respectively [2]. Due to these extended hours of soaking effluent water contains bad odour. This problem aggravates sometimes millers re-use soaked water. In order to reduce this bad odour, currently Institute of Post Harvest Technology (IPHT) has been advocating millers to change soaking water at every twelve hours during soaking period. This leads to increase water consumption per tonnage of paddy and wastewater generated at two or three times. Even though socking water is changed every 12 hours time Chemical oxygen demand (COD) and five days biological oxygen demand (BOD_5) levels of releasing water are 1100 mg/l and 310 mg/l approximately and these values far higher than the values set by CEA (Central Environment Authority). According to CEA guidelines effluent has to be treated to reduce COD and BOD values and bad odour. Even there is no proper mechanism to manage ash generated out of husk burning.

There are few previous cases to reduce COD value in wastewater generated from paddy parboiling process. Ash generated from paddy husk was used as filtering media and tests were carried out in laboratory scale model to test the feasibility. However, this research managed to drop COD limits to 225mg/l [3]. Furthermore, that work did not attempted to reduce BOD and nothing was referred to reduce the bad odour. In addition, IPHT also tested similar kind of mechanism as above and that did not progress due to inherent operational difficulties as well as that method could not reduce the odour and BOD in substantial manner within considerable time frame [4].

Department of Chemical and Process engineering, University of Moratuwa and Environment and Management Lanka (Private) Ltd, have conducted several tests on that waste water treatment in parboiling. They understood that Anaerobic process (digestion) conducted could not be use totally satisfactory manner as digestion did not readily occur and cannot be applied to all rice mills. Physical chemical process was used them by adding alum and lime to reduce BOD and COD. The test results indicated that physical chemical treatment along is not sufficient to reduce BOD and COD. Also, they test Trickling filter and understand this method can applied when BOD level is remaining low. In next experiment they construct Oxidation Ditch and get down the BOD_5 from 1350 to 150mg/l. within the 16 hours [5].

There are number of drawbacks in the previously tested methods. Many tried to control one aspect only with the studies (such as COD reduction). None of them tried to eliminate bad odour generated from effluent water. Furthermore, some tried to treat chemically by adding chemicals. But, none of them succeed. Therefore, in this research a combined effluent treatment process to be developed. Though the main objective of this research is to develop a wastewater treatment method, there are number of additional benefits also available. By-product of the process: paddy husk is used as a fuel first for the boiler and then ash of it is used for wastewater filtering media. Furthermore, steam generated from boiler is partially used to fulfil power requirement for rotating of the drum of the treatment plant. By adapting above concepts total water consumption for the soaking and washing processes to be minimized.

2.0 Methodology

This research is adapted to minimize the waste generated by attacking the point of generation, what cleaner production (CP) principle mainly attempts. This is achieved by initially by developing the walk through assessment of the rice mill and later quantifying the material flow and energy requirements for the process. However, for this research main focus was to reduce water consumption for the soaking process and to treat and reuse wastewater generated from soaking process.

The process flow diagram of the rice milling process is given in Figure 01. The water consumption for soaking process has been reduced by reuse of soaked and treated water mixing with fresh water. In addition, the by product of the rice milling process, paddy husk has been used as fuel for steam generation to boil paddy under controlled burning and later used partly burned ash as filtering media in the wastewater treatment. Since this research adapted aerobic digestion to reduce high BOD strength of wastewater within shorter time line, a rotating biological contractor (RBC) is used. The advantage of RBC are simplysity of maintenance and operation, low power consumption, no pliers or objectionable odour, ability to withstand socks or toxic loads and desirable sludge setting properties [6]. In order to rotate this reactor, steam generated from the boiler is to be used for 75 % of the time it is being used. Thereby electrical energy used to rotate the disk can be minimized. The proposed methodology is shown in a schematic diagram in Figure 02.

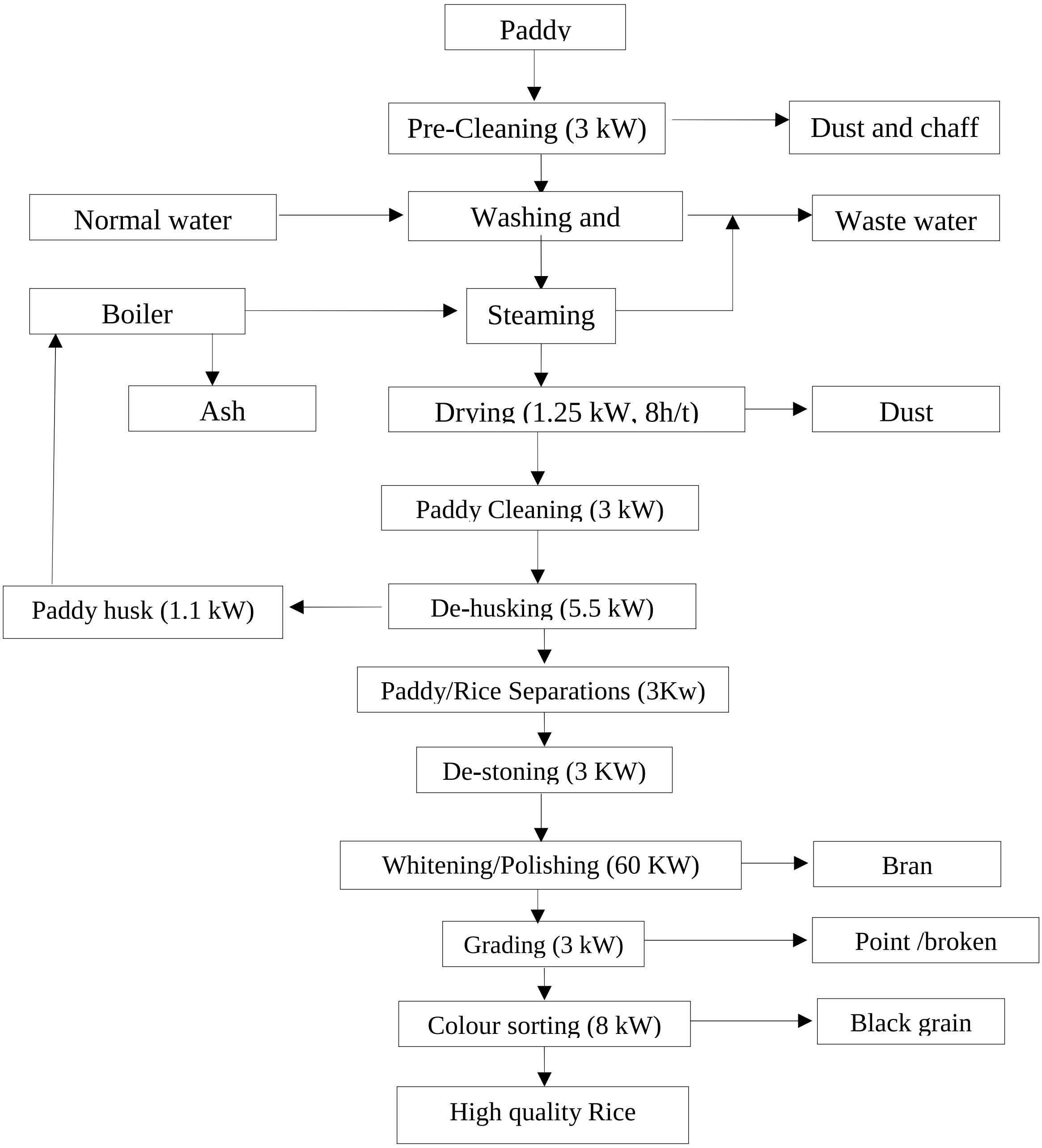

Figure 1: *Process Flow Diagram of rice production (Production Capacity: 1 t/h)*

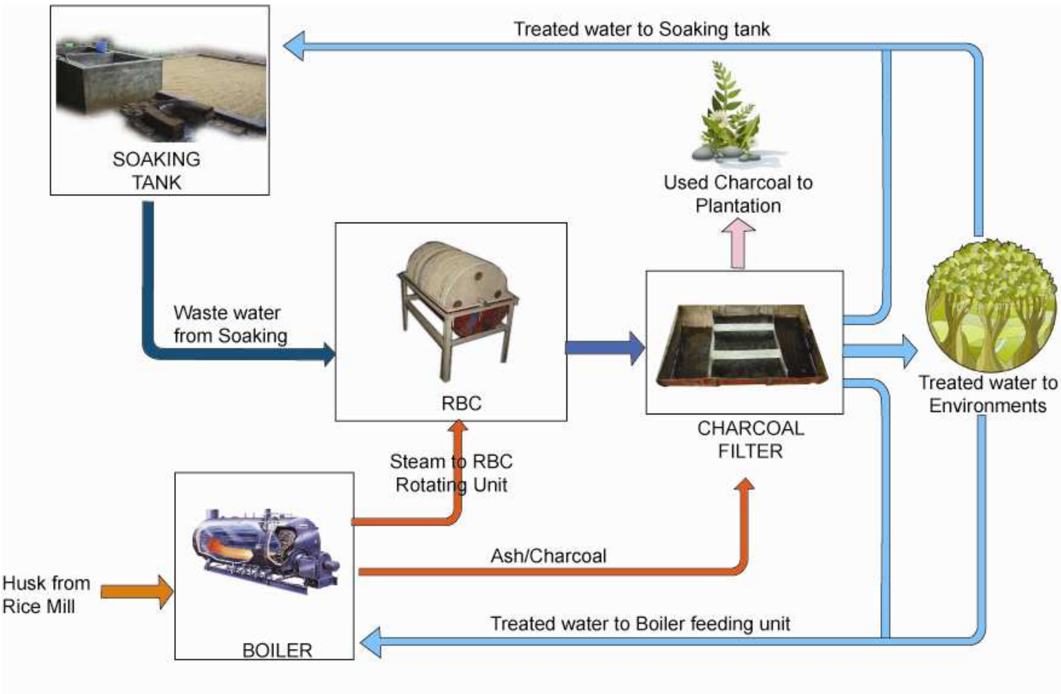

Figure 2: *Schematic diagram of the cycle proposed*

2.1 Experiments

In order to validate the model proposed in the paper, a laboratory scale treatment plant was design and developed. This plant mainly consisted of two sections: the rotating biological reactor and paddy husk ash based horizontal filtration bed. The photos of the lab scale model are given in Figure 3. The Rotating Biological Contactor (RBC) was fabricated in work shop of Institute of Post Harvest Technology. It consisted of a hemi cylindrical tank made of barrel by applying suitable paint coating to prevent from corrosion or rust. The rotating disk also corrosive resistant and made by BI sheet coated with suitable paint to prevent from rust and oxidization.

Two stages were used for the treatment. First stage used for RBC system and second stage contained with Paddy Husk Ash Filter (RHA). The first stage tank was 88cm long and 60 cm in radius with a volume of 100 litres. The system was developed for batch type treatment to match with soaking process of the rice mills. A central steel shaft ran through the whole length of the tank and was used to support the rotating disk. There were 39 discs. Each disk having a diameter of 56cm and attached together in each stage to allow maximum surface area for a given volume. The total surface area for 39 disks was 19.21m^2 providing a volume to surface area ratio of 5.2 litres/m^2. The disks were 40% submerged and rotated at a constant speed of 1.6 rpm [7]. The wastewater was subjected to ten hours treatment as a batch in the RBC system and then it was send to the RHA filter which has same dimension and capacity.

The tank which has same diameter as above, consist 40 inch long RHA filter in the middle part. The treated water came from RBC system was fed through the RHA filter in horizontal direction. At the end pipe was facilitate to drain out purified water.

Figure 3: *Lab scale model of the proposed batch type wastewater treatment plant*

3.0 Results & Discussion

Data were collected from plant period of two weeks. Five days biological oxygen demand (BOD_5), Chemical oxygen demand (COD) and PH were measured during this time period. The results of the six day readings are given in Table 01. The BOD_5 readings before treatment varied from 50 mg/l to 98 mg/l and that of the COD readings varied from 905mg/l to 1676mg/l. The BOD_5 values of the waste water samples were shown low when compared to values in literature. This was due to the water changing at correct time. Furthermore, the adding of dust, husk and bran to soaking water may have caused to increase pollutants of soaking water. Hence, by collecting above by products into fully closed rooms would results low BOD_5 and COD readings in this experiment.

The degree of pollution (i:e the quantity of substances suspend in it and their state of fermentation) depend on the processing systems and conditions specially , length of time the paddy is in water, the impurities contained in the rice and their characteristic, water temperature etc. as well as processing condition [8]

Table 1: *BOD_5, COD and PH concentrations before and after the treatment process*

	Before treatment			After treatment		
No	BOD_5/(mg/l)	COD/(mg/l)	pH	BOD_5/(mg/l)	COD/(mg/l)	pH
1	50	997	6.98	25	245	7.58
2	53	1442	7.04	26	391	7.59
3	85	1029	5.09	20	112	8.2
4	65	905	4.29	55	214	7.36
5	98	1676	5.78	24	241	8.01
6	95	1230	5.94	16	42	7.75

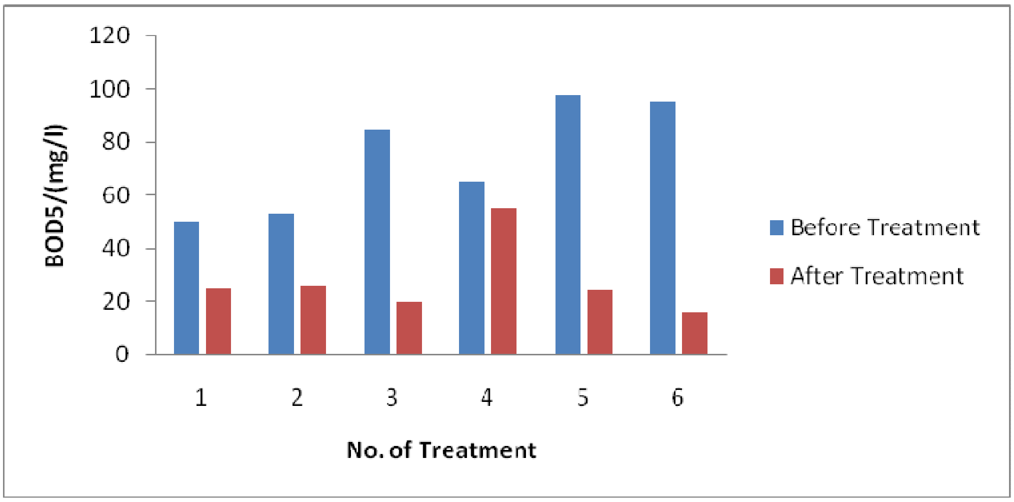

Figure 4: *The variation of BOD_5 change before and after the treatment process*

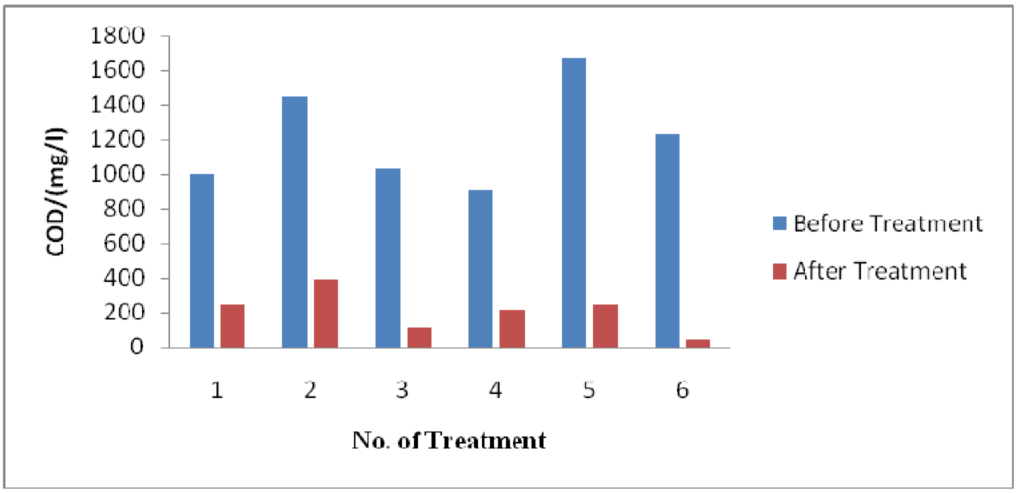

Figure 5: *The COD variation before and after the treatment process*

Based on the experiment, The BOD_5 values after treatment varied from 16 mg/l to 55 mg/l. Out of six trials, only one trial exceeds CEA standards in BOD_5 (CEA standard for BOD_5 is max. 30mg/l). This is at trial number 04. The COD values after treatment were from 42mg/l to 349 mg/l. In this treatments also, out of six trials, one trial exceeds CEA standards in COD (CEA standard for COD is max. 250 mg/l) at trial 02. This may be due to the collection errors of the treated wastewater sample or saturation of absorption characteristics of charcoal bed. However, when compared to percentage reduction of BOD_5 and COD; it is harder to see any pattern. In all these experiments the bad odour of the wastewater was eliminated after the respective batch of water was treated at two stages.

If the BOD and COD level of treated waste water is above the CEA standard, it is possible to reduce it by increasing the area in disk of existing RBC system or adding another RBC system. Further more, treated water could be diluted by adding little quantity of fresh water and could be used for boiler and soaking purpose.

4.0 Conclusion

This paper presented a sustainable mechanism to manage waste generated in local par-boiling rice milling industry. Main focus of the paper was to minimize the wastewater generated from the soaking process and to treat and reuse it in a sustainable manner. CP and IE based approach is presented in this research where, same industries waste and energy generated out of other processes are used for treatment process. Treatment process consists of two stages and in the first stage, BOD value is reduced by Anaerobic digestion with the help of rotating biological contractors (RBC) and in the second stage pre-treated wastewater sent through a carbon filter in order to reduce COD. Seventy five percent of energy used for RBC was supplied by stream generated for par-boiling purposes by burning paddy husk and carbon media for filtering purposes were used from the ash comes out from paddy husk burning. Result shows that treatment process gives promising results of the COD and BOD concentrations of the treated water therefore treated water can be re-used for soaking purposes again. The filtration media change frequency has not checked in this experiment. Currently this design is experimented with medium size par-boiling rice mil owners of North Central Province as a pilot project.

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